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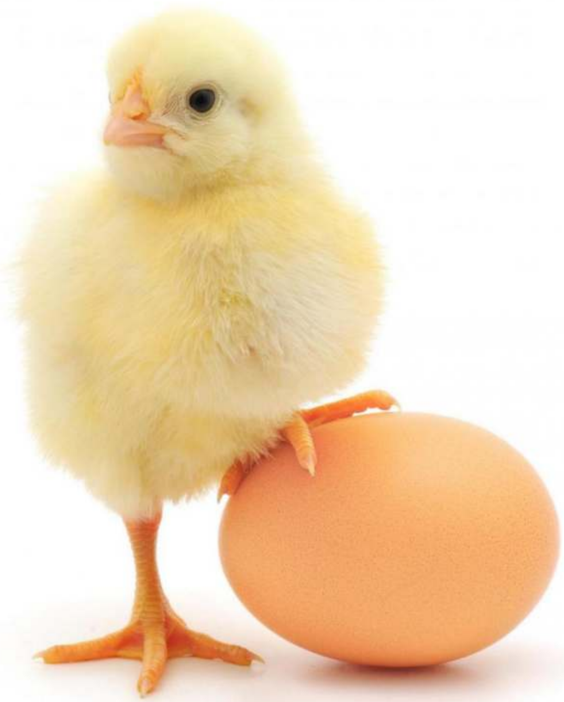

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Energy Requirement for Maintenance and Egg Production for Broiler Breeder Hens

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Abstract: Mathematical modeling is an accounting tool that can be used for predicting the nutritional requirements for poultry with different genetic strains, environments and stages of meat gain or egg production. Models are also useful for describing or predicting the animal's production process. Modeling the daily ME requirement of broiler breeder hens requires partitioning Metabolizable Energy (ME) requirements into maintenance, egg mass and body weight gain. Determining the daily energy requirement for maintenance and egg production in breeders requires separating the daily energy needs for egg production from energy needs of maintenance. The objective of the research reported herein was: 1.) to obtain information about body tissue changes and egg composition for breeders being fed specific intakes of ME in a set environment and 2.) to evaluate a technique for partitioning the Metabolizable Energy (ME) requirement into maintenance and production for each individual breeder. An estrogen antagonist, TAMOXIFEN ([Z]-1-1[p-Dimethylaminoethoxyphenyl]-1,2-diphenyhl-1butene) (TAM), was used to separate the ME needs into two periods: laying and non-laying. Broiler breeder hens were provided TAM to stop egg production and their individual ME requirement for maintenance determined. Each broiler breeder resumed egg production when TAM was withdrawn and the ME requirement for egg production and BW gain determined. The estimated ME required for maintenance for breeders (ME_m) housed in a constant 21C was 98.3 kcal/kgBW$^{0.75}$, ME_g for gain was 5.6 kcal/g and ME_e for egg mass was 2.4 kcal/g. The energy efficiencies for protein gain (kp), fat gain (kf) and egg calories (ke) were 34%, 79% and 65.7%, respectively. The use of TAM provided an opportunity to estimate breeder maintenance requirements and reduce the interdependence in estimating factorial coefficients while partitioning production energy.

Key words: Metabolizable energy, broiler breeders, tamoxifen, energy efficiency, modeling

INTRODUCTION

Feed costs represent around 70% of the poultry production costs. Nutritional requirements for any nutrient needs to be fully understood in order to know the potential risk in production when trying to reduce feed costs and develop appropriate margins of safety. Research in the area of the energy requirements has been focused on estimating the energy requirements for laying hens while for broiler breeder hens the information is slowly being developed. Metabolizable Energy (ME) requirements for broiler breeder hens are higher than for commercial layers primarily because of their larger body size. Nevertheless, in many cases the maintenance energy requirement of metabolizable energy (ME_m) has been extrapolated from studies conducted mainly with Leghorn type hens (Leeson, 2003).

The accurate determination of energy utilization coefficients needed for modeling the ME requirement for broiler breeder hens is complex due to the interdependency among factors involved. Sakomura *et al.* (2011) reported on the current estimation methods for nutritional requirements (dose-response or factorial methods) and elaborated on the need to define nutrient partitioning, intake and the animal's growth potential in these models. Nutrient assignment for maintenance, growth and production determines the nutrient partitioning, where maintenance is a priority and the remaining available nutrient is used for growth and production.

In order to develop factorial breeder ME requirements, estimates of ME for maintenance, egg synthesis and tissue gain are needed. An estimate of ME needed for egg formation requires obtaining specific breeder information on the amount of energy contained in eggs and also the amount of energy in breeder BW gain. The use of non-laying breeder hens should reduce the errors in accurately calculating the maintenance requirements for broiler breeder hens by eliminating the interfering factors involved in production. An estrogen antagonist, TAMOXIFEN® ([Z]-1-1[p-Dimethylaminoethoxyphenyl]-1,2-diphenyhl-1butene) (TAM) has been shown to stop

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egg production for White Leghorn layers (Jaccoby *et al.*, 1992). Zhang and Coon (1997) previously utilized TAM to model ME requirements for commercial layers by injecting TAM intramuscularly to stop egg production and then separate the ME needs into laying and non-laying periods. TAM is a trans-isomer of triphenylethylene that blocks estrogen when administrated in high doses to laying hens. TAM acts as an absolute estrogen antagonist in the avian oviduct that competes for estrogen receptors; as a result, egg production is suppressed.

The objectives of the present study were 1) to determine if TAM can serve as a tool for reducing the interdependence in estimating factorial coefficients for breeders and 2) to determine the energy requirement for breeders for maintenance, body weight gain and egg mass output.

MATERIALS AND METHODS

Birds and management: A total of 60 Cobb 500 broiler breeder hens, 53 weeks old were individually housed in an environmentally controlled room in individual broiler breeder female cages. Cages (47 cm high, 30.5 cm wide, 47 cm deep) were each equipped with an individual feeder and nipple drinker. Birds were fed individually and provided with free access to water at all times. Temperature was kept constant at 21°C throughout the trial. The lighting regimen was 16 h light and 8 h darkness per day. Initially, ten birds were randomly selected and sacrificed (by using CO_2) and frozen at -4°C until they were processed for comparative carcass analysis. The broiler breeder hens that continued in the feeding experiment were injected intramuscularly with doses of Tamoxifen (TAM, 5 mg/kg body weight) in corn oil at days 1 and 4 in order to stop egg production. All the data collected during the period that birds did not lay any eggs was considered the non-laying period. Data from the last 3 days of the non-laying period were not used in calculating MEm to avoid erroneous estimations due to physiological processes involving egg production. The laying period was considered from the moments the birds resumed egg production and until the end of the 9 week trial period.

A diet containing 2798 kcal AME_n/kg and 14.6% of Crude Protein (CP) was fed to breeders at a level of 110 g/bird/d during the non-laying period and a level of 136 g/bird/d during the laying period (Table 1). Individual body weight was recorded daily starting on day 5 of the trial for a period of 9 weeks (Table 2 and 5). Feed residuals for each breeder were recorded weekly.

The first ten hens that resumed egg production after TAM was withdrawn were sacrificed by using CO_2 and kept frozen at -4°C until carcass analysis was conducted. All eggs were collected and weighed daily and refrigerated for further analysis. Shell-less eggs were counted and their weight was estimated from the average weight of all eggs laid by that breeder hen during the total laying period. Three eggs from each broiler breeder hen, collected at the beginning, middle and end of the 9 wk laying period, were used to determine fat and nitrogen content. Using an egg separator, yolk and albumen were separated, weighed and refrigerated for proximate analysis. Yolks were first rolled on a paper towel (to eliminate the remaining albumen), poured in a plastic cup and weighed. Shells were washed, wiped and put in individual plastic cups overnight to dry. Wet albumen weight was calculated by the following formula:

Table 1: Composition and analysis of diet

Ingredients	Composition (g/kg)
Corn grain 7.25% protein	66.47
Soybean meal solvent ext. 47.5% protein	22.26
Choline Chloride 60%	0.07
Alimet 88	0.11
Dicalcium PO_4	1.62
Ethoxyquin 66%	0.02
Poultry fat	1.43
Limestone	7.36
Kemin Mold Curb 50% propionic acid	0.05
Salt	0.39
Trace mineral CVI Breeders[A]	0.06
CVI Breeder premix 2960[B]	0.15
Calculated crude protein (%)	15.50
Calculated AME_N (kcal/kg)	2816.00
Analyzed AME_N (kcal/kg)	2798.00
Analyzed crude protein (%)	14.60

[A]Provided per kg of diet: Mn 120 mg; Zn 120 mg; Fe 60; Cu 12 mg; I 1.2 mg; Mg 31.8 mg and Ca 855.

[B]Provided per kg of diet: vitamin D_3 4.95 KICU; vitamin A 14.7 KIU; vitamin E 80.7 IU; niacin 94.7 mg; D-Pantothenic acid 39.2 mg; riboflavin 21.1 mg; pyridoxine 12.4 mg; thiamine 6.3 mg; folic acid 3.9 mg; biotin 0.44 mg; 29.7 MCG

Wet albumen weight = Egg weight - (wet yolk weight + dried shell weight)

Pooled wet yolk and pooled wet albumen samples were freeze-dried for 7 and 9 days, respectively. Egg shells also were freeze dried for four days. Dried yolks and albumen samples from the same individual breeders were weighed and finely ground in a mortar and pestle in order to obtain homogeneous sub-samples for fat and protein content analyses.

At the end of the trial, all birds were sacrificed and frozen at -4°C for future carcass composition analysis. Individual carcasses of all the sampling periods were autoclaved and homogenized in a blender to obtain homogeneous whole-body samples. Homogenized samples were frozen at -4°C and then freeze-dried for 7 days for further analysis.

Apparent Metabolizable Energy (AME_n) was determined for ten randomly selected birds. Two percent acid insoluble ash (Celite) was added to the diets and used as a marker. Breeder hens were fed the diet containing the insoluble marker for ten days. Excreta were collected on trays at days 5 and 10, frozen and freeze-dried prior to analysis. Diets and excreta were analyzed for acid insoluble ash and nitrogen by standard AOAC procedures (AOAC, 1990). The gross energy of diets and excreta were measured using a Parr adiabatic bomb calorimeter. The metabolizability of nitrogen and energy (AME) were determined using the measured acid insoluble ash marker along with the determined nutrients in both the feed and excreta and using the equation of Scott and Balnave (1991).

Energy retention calculations: Pooled freeze-dried yolks and albumen and whole-body samples were analyzed for Dry Matter (DM), nitrogen and ether extract. Nitrogen was analyzed on freeze-dried samples by Method 990.03-Combustion Method of the AOAC (AOAC, 1995) and fat was analyzed by Method 920.39 C (AOAC, 1990). Carcass energy and egg energy was estimated by multiplying fat and protein content on a dry matter basis by 9.3 and 5.4 kcal, respectively and then adding up those two values (Mayes, 2000).

Energy Retained (ER) during the non-egg production period was measured by subtracting carcass energy from non-laying breeder hens at the Beginning of the Maintenance feeding study (BMP) from carcass energy from breeders at the End of the Maintenance Period (EMP). ER as protein (ER_p) was calculated as the difference of initial protein content (DM basis) of BMP and final protein content (DM basis) of EMP and was multiplied by 5.4 (Mayes, 2000). ER in body as fat (ER_f) was calculated as the difference of initial fat content of BMP and final fat content of EMP, on dry matter basis and was multiplied by 9.3 (Mayes, 2000). Total ER was obtained by the sum of ER_p and ER_f. ER was later used to calculate the efficiency of energy utilization for body weight gain (kg) with the following formula:

kg = ER (kcal)/ME consumed above maintenance (kcal) x 100

Partial efficiencies for fat retention (kf) and for protein retention (kp) were calculated from simultaneous equations using the known values of: ERp, ERf (measured in carcass); kg; ME_g and the constant values of 9.3 and 5.4 (gross energy available from 1 g of fat and protein), respectively (Mayes, 2000). Efficiency of energy utilization for egg mass synthesis (ke) was calculated by dividing energy used for egg synthesis: (ME_e) = [MEintake- (ME_m + ME_g)] by the energy output in egg: (EOE) = GE concentration in the hen's egg x egg mass output. Energy for body weight change (ME_g) was calculated as: ME_g = (MEintake - ME_m)/BWΔ, where BWΔ = body weight change (g/d).

Statistical analysis: Standard statistical procedures were used to obtain linear regression equations for predicting ME_m (Mendenhall and Sincich, 2003). Regression analyses and polynomial equations were fitted using the least squares procedure of JMP IN® Software (SAS Institute, 1999-2000a). Data were subjected to a one-way ANOVA using the General Linear Models procedure of SAS® (1999-2000b). When a significant F statistic was detected, means were separated using Tukey's test at 5% of probability (Freund and Wilson, 1997).

RESULTS AND DISCUSSION

Egg Production (EP) dropped to zero five days after the first TAM administration. Eighty percent of the hens resumed egg production three weeks after TAM injections. The first egg production resumed 15 days after the second TAM injection and the last breeder began egg production 21 days after the TAM injection. The breeders were in egg production an average of 18 days during the laying period. Only 5% of broiler breeder hens did not resume egg production before the 9 wk experiment was terminated.

ME for maintenance: The energy requirement for maintenance was calculated using the individual data collected during the non-laying period in order to reduce interdependence among factors involved in egg production. The linear relationship between body weight change (BWΔ) (g/hen/d) and ME intake (kcal/kgBW$^{0.75}$) provided the ME_m at the intercept, with the *x*-axis being ME intake at 0 body weight change (Fig. 1). Data from the last 3 days of the non-laying period were not used in calculating ME_m and ME_g to avoid erroneous estimations due to physiological processes involving egg production. The estimated ME_m of broiler breeder hens housed at thermo neutral temperatures (21°C) was 98.3 kcal/kgBW$^{0.75}$.

Reported ME_m requirements for broiler breeders reared in individual cages at thermo neutral temperatures (21-23°C) are lower than that found in the present study. Johnson and Farrell (1983) suggested a daily allotment of 87.2 kcal/kgBW$^{0.75}$ for group-caged broiler breeder hens 42 to 49 weeks of age. A similar ME_m requirement (87.7 kcal/kgBW$^{0.75}$) was reported by Spratt *et al.* (1990) for caged Hubbard broiler breeder hens, 28 to 36 weeks of age. Sakomura (2001) reported a requirement of 91 kcal/kgBW$^{0.75}$ of ME for maintenance for Hubbard Hy-Yield broiler breeders housed in individual cages. Rabello *et al.* (2004) found a maintenance requirement of 91.5 kcal/kgBW$^{0.75}$ for broiler breeders in cages kept at 21°C. Rabello *et al.* (2006) determined the ME_m of broiler breeders in floor pens was 112.8 kcal/kgBW$^{0.75}$. Romero *et al.* (2009a, 2009b) reported higher ME_m for broiler breeder hens in cages (104.4 to 115.6 kcal/kgBW$^{0.75}$) compared to the estimate for ME_m (98.3 kcal/kgBW$^{0.75}$) for Cobb 500 breeders in the present study. The differences in ME_m reported by previous research may be attributed to the breeder strain utilized, differences in the

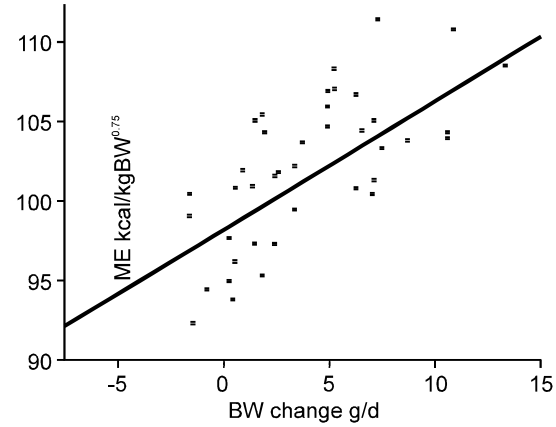

Fig. 1: ME intake as a function of body weight change. $ME = 98.25 + 0.81BW\Delta$ R^2 0.61

methodology, type of diet, environment and duration of the studies. For instance, Johnson and Farrell (1983) and Spratt *et al.* (1990) measured Heat Production (HP) using indirect calorimetry, whereas Sakomura (2001) and Rabello *et al.* (2006) used the comparative slaughter technique. The difference in ME_m (112.8 kcal/$kgBW^{0.75}$) reported by Rabello *et al.* (2006) compared to the Me_m (98.3 kcal/$kgBW^{0.75}$) shown in Fig. 1 can be attributed to the differences in housing systems; birds in floor pens expend more energy for activity than birds kept in cages or respiratory calorimeters.

The ME_m requirements estimated for laying hens by indirect calorimetry have been lower than ME_m estimated by energy balance and comparative slaughter (Fuller *et al.*, 1983; Chwalibog and Baldwin, 1995). Jadhao *et al.* (1999) reported the same ME_m for layers when using indirect calorimetry and the slaughter technique, although the efficiency of utilization of ME for maintenance was lower when the comparative slaughter technique was used.

Zhang and Coon (1997) found a higher ME_m when studying TAM treated laying hens than ME_m established using indirect calorimetry. The researchers conducted a trial using 120 Dekalb TAM treated hens, 62 wk of age, housed in 6 different environmentally controlled rooms in order to determine the effect of environmental temperature on ME_m. The prediction equations developed by Zhang and Coon (1997) were later evaluated in another trial using a total of 480 White Leghorn hens from four different strains. The estimates for ME_m reported by Zhang and Coon were 19.2% higher than that calculated by studies conducted by using indirect calorimetry and 13.3% lower that ME_m proposed by the NRC (1994). The higher estimates for ME_m for laying hens utilized in the study by Zhang and Coon (1997) study were housed in cages and in practical environmental conditions compared to layers confined in respiratory calorimeters.

The reduced physical activity of breeders used in the present study can be compared to that of birds used in calorimetric studies. Measurements of Heat Production (HP) from birds in respiratory chambers cannot be distinguishing from the actual heat produced from feed or mobilized body tissue heat (Grimbergen, 1974) and errors in estimating the actual ME_m may occur. Besides the choice of method used to determine HP, respiration calorimetry or comparative slaughter technique, HP may differ because of other factors such as age, genetic strain, environmental temperature and energy concentration of diets (Sakomura *et al.*, 2003).

Physical activity is an energy-demanding process that is considered part of the ME for maintenance (Chwalibog, 1991). Activity of poultry may comprise 4.3-35% of the total heat production (Chwalibog, 1991; Balnave, 1974; Luiting, 1990) depending on feeding system, housing, lighting, space allowance, age, strain of birds and environmental conditions. McDonald (1978) reported that caged pullets needed between 5.6 and 11% less energy for maintenance than floor pen housed pullets and caged hens spent 4.1% less energy than hens reared on the floor. Sakomura (2001) reported a larger ME_m difference of 20% for 26-33 wk old broiler breeders housed in cages compared to floor pens. Leeson and Summers (2000) suggested an allotment of 17% and 11% of the total energy for activity for broiler breeder hens 32 and 55 weeks of age, respectively. These values corresponded to requirements at thermo neutral temperatures. Wenk (1997) stated that in growing farm animals reared under practical conditions, physical activity might represent around 20% of the total maintenance requirements.

Assuming that physical activity can account for around 20% of the total ME_m, the estimate of 98.3 kcal/$kgBW^{0.75}$ for ME_m for breeders in cages with less physical activity may potentially increase to 118 kcal/$kgBW^{0.75}$ for broiler breeder hens on the floor at 21C.

The genetic strain of breeders may influence the reported ME_m by different researchers. Spratt *et al.* (1990) and Johnson and Farrell (1983) used older genetic lines of broiler breeder hens that probably had a different body composition and performance characteristics compared to the broiler breeder hens (Cobb 500) utilized in the present study.

Grimbergen (1974) hypothesized that the use of non laying hens would allow the estimation of ME_m by the regression of energy retained in body on ME intake. In the present study, the energy expended for maintenance was calculated by plotting energy intake (kcal/$kgBW^{0.75}$) of each individual broiler breeder hen against individual weight change (g/d) and the intercept of such a plot provided the estimate of ME_m. Thus, the use of non-laying (TAM treated hens) in the present study should have reduced the errors involved in calculating the actual ME_m coefficient. After birds stop laying, ME intake should have been partitioned only into ME for maintenance and

ME for body weight change since ME was no longer needed for yolk follicle synthesis on the ovary and for eggs being produced.

ME for weight gain: The calculated ME_g for the present experiment was 5.6 kcal per gram of body weight gain and kg was 57%. The ME_g value determined for breeders in present study is close to the value estimated by NRC (1994) (5.5 kcal/g) and by Emmans (1974) (5 kcal/g) for laying hens. The 5.6 kcal per gram BW gain estimated for ME_g in the present study is larger than the estimates of 2.76 kcal/g (Byerly *et al.*, 1980), 3.13 kcal/g (Waldroup *et al.*, 1976) and 3.84 kcal/g (Sakomura *et al.*, 1993) and smaller than ME_g estimates of 7.62 kcal/g (Rabello *et al.*, 2000) and 7.48 kcal/g (Spratt *et al.*, 1990) for broiler breeder hens. The variation in these data might have been caused by the method used to determine protein and fat accretion rates (respiration calorimetry or comparative slaughter) (Webster, 1989).
Energy retained as protein observed in the present study was 35% and ER_f was 65%. The partial efficiencies for fat and protein retention were 0.79 and 0.34, respectively (Table 2). These results can be compared with the partial efficiencies of 0.96 and 0.51 for fat and protein, respectively, reported by Spratt *et al.* (1990).
Based on the carcass composition of broiler breeder hens in the present study, actual energy deposited as BW gain above maintenance was stored primarily as fat. The variation in the composition of hens was mainly due to the variation in fat content of individual hens (Table 4). Emmans (1974) concluded that the energy content of weight gain and the efficiency for utilization of energy deposited in carcass would determine the energy needs for growth or BW gain. The variation in ME for weight gain previously reported may have been caused by the different methods used for estimating energy balance and because body composition depends on age, genetics, nutrition, productive stage and environment. Modern strains of broiler breeders producing high yield progeny may deposit a larger amount of protein into breast meat during the production period compared to older genetic lines. The percentage of protein and fat gain for high yield producing breeders in production may be dependent upon stage of egg production and the amount of dietary energy being fed. Salas *et al.* (2010) reported a large increase in lean mass with a reduction in fat mass for breeders in production from 30-65 wk of age. The researchers showed the relative body composition changes were independent of dietary energy being fed. The ME_m of breeders would also change dependent upon the body composition because of the differences in maintaining daily energy needs of lean tissue compared to maintaining fat tissue.
In the present trial, body weight gain was related to an increase in fat retention which is agreement with the findings of Pearson and Herron (1981), Spratt and Leeson (1987) and Spratt *et al.* (1990). Recent experiments conducted by Sun and Coon (2005) and Sun *et al.* (2006) during the complete laying period with Cobb 500 broiler breeder hens housed in individual cages showed that the retained energy for breeder hens was 75% fat and 25% protein. Heavy broiler breeders retained more energy as fat than as protein, whereas lighter body weight breeders retained more protein during the productive cycle (20-65 weeks). Boekholt *et al.* (1997) concluded that daily retention of protein and fat was linearly related to energy retention. The authors found that more fat than protein was retained when growing broilers were fed at increasing energy intakes, but when energy intakes were lower, a constant daily protein retention and a variable fat retention occurred.

ME for egg production: Broiler breeder performance and egg composition parameters are presented in Table 3

Table 2: Body weight, daily body weight change and retained energy of broiler breeder hens during the non-laying period

Variable	Mean and SEM
Initial body weight (kg)	4.39±0.04
Final body weight (kg)	4.43±0.04
Body weight change (g)	41.62±12.06
Body weight change (g/d)	2.60±0.74
kg (%)	57
ER (kcal/d)	7.40±1.79
ER_p (%)	35
ER_f (%)	65
kf	0.79
kp	0.34

Table 3: Egg composition

Variable	Mean and SEM
Albumen (%)	31.67±0.28
Yolk (%)	59.30±0.25
Shell (%)	9.03±0.14
Albumen DM (%)	51.93±0.15
Yolk DM (%)	12.88±0.26
Albumen fat (% as DM)	0.003±0.000007
Albumen protein (% as DM)	81.53±0.24
Yolk fat (%)	57.83±0.0003
Yolk protein (%)	29.45±0.36
Egg gross energy (kcal/g)	1.62±0.0016

Table 4: Body composition of broiler breeder hens

Measurement	Initial[1]	First egg[2]	Final[3]
Fat (%)	18.78[ab]	19.66[a]	17.29[b]
Protein (%)	15.38	16.73	16.17
DM (%)	42.49	41.80	40.26
Fat (% as DM)	44.90	46.23	42.48
Protein (% as DM)	45.10[b]	47.70[a]	47.85[a]

[1]Carcass composition of breeders slaughtered at the beginning of the non-laying period.
[2]Carcass composition of breeders slaughtered at the end of the non-laying period.
[3]Carcass composition of breeders slaughtered at end of the trial.
[a,b]Means within a variable with no common superscript differ significantly ($p<0.05$)

Table 5: Performance characteristics of broiler breeders during the laying period

Characteristics	Mean and SEM
Egg weight (g)	68.27±0.81
Egg mass (g/hen/d)	48.44±0.92
Egg production (%)	71.05±0.25
Initial body weight (kg)	4.51±0.38
Final body weight (kg)	4.46±0.43
Body weight change (g)	-53.75±12.53
AME_n consumption above maintenance (kcal/d)	78.94±2.92

and Table 5, respectively. After broiler breeder hens resumed egg production after TAM injections in present study, the breeders egg production reached 71% and was at a higher rate than suggested (<57%) by the Cobb 500 Breeder Management Guide(Cobb-Vantress, 2008) for 53-62 wk breeders. The increase in egg production at this age is similar to what should be expected after a forced molt. The daily AME_n needed (energy intake) for each breeder during the laying period was underestimated because the breeders lost an average of 58 g BW during the 18 day egg production period (Table 5). Previous research by Sun and Coon (2005) indicated that breeders in cages only needed approximately 390 kcal per day at peak for maximum egg production. The diet used in present study was calculated to contain 2816 kcal AME_n/kg but the diet was analyzed to contain 2798 kcal AME_n and the 136 g intake provided approximately 380 kcal per day for each breeder. The breeders were producing at a 71% rate instead of 86% that would be expected at peak. The small loss in BW during the egg production period indicates energy was mobilized from tissues in order to sustain egg production. The mobilized energy from tissue and dietary ME intake were utilized in estimating ME energy for egg production (ME_e). Eight broiler breeder hens were excluded from the study for calculating the conversion of dietary ME into egg energy (ke) because the breeders did not resume adequate egg production after the TAM was withdrawn during the laying period. The average gross energy content of an egg was determined to be 1.62 kcal/g (including egg content and eggshell plus membrane). ME_e was estimated to be 2.4 kcal per gram of egg mass from the production study by subtracting the ME_m and ME_g from ME required for production. The average ke was determined to be 65.7%. The ME_e value is in the range of 2.04 and 3.13 reported in the literature for broiler breeder hens (Waldroup *et al.*, 1976; Sakomura *et al.*, 1993; Rabello *et al.*, 2000).

Estimated values of ke reported in the literature are variable and range between 60 and 86% (Grimbergen, 1974) depending on strain, age, egg composition and egg size, lighting pattern and nutritional and environmental factors (Pearson and Herron, 1982). High efficiencies for egg production have been observed when broiler breeder hens use body energy to compensate for a dietary energy shortage (Spratt *et al.*, 1990; Pearson and Herron, 1982; Attia *et al.*, 1995; Neuman *et al.*, 1998).

The ke found in this trial is similar to other estimated values for broiler breeder hens (Byerly *et al.*, 1980; Rabello *et al.*, 2000). Spratt *et al.* (1990) reported ke between 0.81 and 1.72 for broiler breeder hens receiving different energy levels. Energy balance was negative in those hens that had the highest efficiency for egg synthesis. Johnson and Farrell (1983) concluded that a non-linear relationship "between retained energy and total ME intake from maintenance to production" in broiler breeder hens might explain the ke above 70%.

The present study shows the use of TAM provides an opportunity to accurately determine ME_m during the non-laying period without interdependence of egg production for each breeder. The coefficients for predicting MEI for broiler breeder hens housed in a 21C environment were determined to be 98.3 kcal/kgBW$^{0.75}$ for ME_m, 5.6 kcal/g for ME_g and 2.4 kcal/g for ME_e. The energy efficiencies for protein gain (kp), fat gain (kf) and egg calories (ke) were 34%, 79% and 65.7%, respectively.

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