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ENERGY REQUIREMENT FOR MAINTENANCE AND EGG PRODUCTION FOR BROILER BREEDER HENS
REQUERIMIENTO DE ENERGÍA METABOLIZABLE PARA MANTENIMIENTO, PRODUCCIÓN DE HUEVOS,
EN REPRODUCTORAS PESADAS.

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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 ((2)-1-[p-Dimethylaminocarbonylphenyl]-1,2-diphenyl-3butene) (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 Each broiler breeder resumed egg production when TAM was withdrawn and the ME requirement for egg production and BW gain determined.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 (MEm) housed in a constant 21°C was 96.3 kcal/kgBW0.55, ME for gain was 5.6 kcal/g and ME for egg mass was 2.4 kcal/g. The energy efficiencies for protein gain (xp), fat gain (xf) and egg calories (xe) 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 needs.

Keywords: metabolizable energy, broiler breeders, tamoxifen, energy efficiency, modeling

RESUMEN
El modelaje matemático es una herramienta de contabilidad que puede ser usada para predecir los requerimientos nutricionales de las aves de diferente línea genética, ambientes, etapas de ganancia de peso o de producción de huevos. Los modelos también son útiles para describir o predecir el proceso productivo del animal. El modelaje de los requerimientos diarios de energía metabolizable (EM) para reproductoras pesadas necesita particularizarse en requerimientos para mantenimiento, masa de huevos y ganancia de peso.
corporal. Determinar el requerimiento diario para mantenimiento y producción de huevos en reproductoras requiere separar las necesidades energéticas diarias para producción de huevos del requerimiento para mantenimiento. Los objetivos de esta investigación fueron: 1) obtener información sobre el cambio en los tejidos corporales y la composición de los huevos en reproductoras alimentadas con cantidades específicas de EM en un ambiente determinado y 2) evaluar una técnica para particionar el requerimiento de EM en mantenimiento y producción para cada ave. Se utilizó un antagonista del estrógeno, TAMOXIFEN ([2]-1-1-1-[p-Dimethylaminoethoxyphenyl]-1,2 diphenyl-1butene) (TAM), para separar las necesidades de EM en dos periodos: producción y fuera de producción. Las gallinas recibieron TAM para que detengan la producción de huevos y su requerimiento de EM para mantenimiento pudo ser determinado. Cada reproductora reinició la producción cuando TAM fue retirado, así se pudo determinar los requerimientos de EM para producción. El requerimiento estimado de mantenimiento para reproductoras (EMm) encasetadas a una temperatura constante de 21°C fue de 98.3 kcal/kgPV0.75. EM para ganancia de peso fue de 2.6 kcal/g y EM para masa de huevos, de 2.4 kcal/g. La eficiencia energética para ganancia de proteína (GProt), ganancia de grasa (Ggr) y calorías de los huevos (CH) fueron 34%, 79% y 65.7%, respectivamente. El uso de TAM brindó la oportunidad de estimar los requerimientos para mantenimiento y reducir la interdependencia en la estimación de los coeficientes factoriales mientras se particiona la necesidad energética para producción.

1. 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 (MEm) 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. Sakamura 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 breeder breeder hens by eliminating the interfering factors involved in production. An estrogen antagonist, TAMOXIFEN ([2]-1-1-1-[p-Dimethylaminoethoxyphenyl]-1,2-diphenyl-1butene) (TAM) has been shown to stop egg production for White Leghorn layers (Jacoby, 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 may 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.

2. MATERIALS AND METHODS

Birds and management

A total of 50 Cobb 500 broiler breeder hens, 53 weeks old were individually housed in an environmentally controlled room in individual broiler breeder female cages. 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 slaughtered (by using CO₂) 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 TAM (5 mg/kg body weight) in corn oil at days 1 and 4 in order to stop egg production.

A diet containing 2798 kcal AME/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). Feed residuals for each breeder were recorded weekly.

<table>
<thead>
<tr>
<th>Ingredients</th>
<th>Composition (g/kg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Corn grain</td>
<td>66.47</td>
</tr>
<tr>
<td>Soybean meal solvent ext 47.7 % protein</td>
<td>22.26</td>
</tr>
<tr>
<td>Choline Chloride 60%</td>
<td>0.070</td>
</tr>
<tr>
<td>Allmet 88</td>
<td>0.11</td>
</tr>
<tr>
<td>Dicalcium PO₄</td>
<td>1.02</td>
</tr>
<tr>
<td>Ethoxyquin 65%</td>
<td>0.02</td>
</tr>
<tr>
<td>Poultry fat</td>
<td>1.43</td>
</tr>
<tr>
<td>Limestone</td>
<td>7.35</td>
</tr>
<tr>
<td>Kemin Molds Curb 50% propionic acid</td>
<td>0.05</td>
</tr>
<tr>
<td>Salt</td>
<td>0.39</td>
</tr>
<tr>
<td>Trace mineral CVI Breeders a</td>
<td>0.06</td>
</tr>
<tr>
<td>CVI Breeder premix 2960 b</td>
<td>0.15</td>
</tr>
<tr>
<td>Crude protein PCT</td>
<td>15.5</td>
</tr>
<tr>
<td>Calculated metabolizable energy (kcal/kg)</td>
<td>2836</td>
</tr>
<tr>
<td>Analyzed AME c</td>
<td>2768</td>
</tr>
<tr>
<td>Calculated crude protein d</td>
<td>15.5</td>
</tr>
<tr>
<td>Analyzed crude protein</td>
<td>14.6</td>
</tr>
</tbody>
</table>

a Provided per kg of diet; Mn 170 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; 4.95 KIU; vitamin A 34.7 KIU; vitamin E 80.7 IU; niacin 54.7 mg; D-Pantothenic acid 35.2 mg; riboflavin 21.1 mg; pyridoxine 12.4 mg; thiamine 6.3 mg; folie acid 3.9 mg; biotin 0.44 mg; 29.7 MCG.

c AME = kcal/kg.

d Crude protein = %

The first ten hens that resumed egg production after TAM was withdrawn were slaughtered by using CO₂ 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:

\[ \text{Wet albumen weight} = \text{Egg weight} - (\text{wet yolk weight} + \text{dried shell weight}) \]

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 slaughtered and froze 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 (AMEₐ) was determined for ten randomly selected birds. Two percent acid insoluble ash (Celite) was added to the diets and used as a marker. Brooder 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 Balmave (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 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 (ERₚ) 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 (ERₕ) 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 ERₚ and ERₕ. ER was later used to calculate the efficiency of energy utilization for body weight gain (xg) with the following formula:

\[ xg = \frac{ER \text{ (kcal)}}{\text{ME consumed above maintenance (kcal})} \times 100 \]

Partial efficiencies for fat retention (xp) and for protein retention (xp) were calculated from simultaneous equations using the known values of: ERp, ERf (measured in carcass); xg, MEₚ, 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 (xₑ) was calculated by dividing energy used for egg synthesis: (MEₑ) = (ME intake - (MEₚ + MEₚ))
by the energy output in egg: \( E_{GE} = GE \) concentration in the hen's egg x egg mass output. Energy for body weight change (\( ME_b \)) was calculated as: \( ME_b = (ME_{intake} - ME_{ne}) / BW\Delta \), where \( BW\Delta \) = 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).

**3. 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. 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 (\( BW\Delta \) g/week) 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 (Figure 1). Data from the last 3 days of the non-laying period were not used in calculating ME\(_m\) and ME\(_b\) 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 to 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. (2001) 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 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 Figure 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\textsubscript{m} requirements estimated for laying hens by indirect calorimetry have been lower than ME\textsubscript{m} estimated by energy balance and comparative slaughter (Fuller et al., 1983; Chwalibog and Baldwin, 1995). Jedhao et al. (1999) reported the same ME\textsubscript{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\textsubscript{m} when studying TAM treated laying hens than ME\textsubscript{m} established using 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\textsubscript{m}. The prediction equations developed by the 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\textsubscript{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\textsubscript{m} proposed by the NRC (1994). The higher estimates for ME 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\textsubscript{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 to 35% of the total heat production (Chwalibog, 1991; Balmave, 1974; and 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. Sekomura (2001) reported a larger ME<sub>m</sub> difference of 20% for 26-33 wk old broiler breeders housed in cages compared to floor pens. Leeson and Summersb (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<sub>m</sub>, the results of the present study would yield a ME<sub>m</sub> of 118 kcal/kgBW<sup>0.75</sup> for broiler breeder hens housed on the floor at 21°C.

The genetic strain of breeders may influence the reported ME<sub>m</sub> 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<sub>m</sub> 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<sup>0.75</sup>) of each individual broiler breeder hen against individual weight change (g/d), and the intercept of such a plot provided the estimate of ME<sub>m</sub>. Thus, the use of non-laying (TAM treated hens) in the present study should have reduced the errors involved in calculating the actual ME<sub>m</sub> coefficient. After birds stoplaying, 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<sub>y</sub> for the present experiment was 5.6 kcal per gram of body weight gain and kg was 57%. This ME<sub>y</sub> value is close to the value estimated by the NRC (1994) (5.5 kcal/g) and by Emmens (1974) (5 kcal/g) for laying hens. However, estimated ME<sub>y</sub> in the present study is larger than other estimates (Waldrup et al., 1976; Byerly et al., 1980; Sekomura et al., 1993), and smaller than those estimated by Spratt et al. (1990) and Rabello et al. (2000) 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<sub>p</sub> 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. There was variation in the individual composition of hens mainly due to the variation in fat content of individual hens (Table 4). Emmens (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. (2011) reported a large increase in lean mass with a reduction in fat mass for breeders in production from 45–65 wk of age. The researchers showed the relative body composition changes were independent of dietary energy being fed. The ME\textsubscript{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 high 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 breeder hens retained energy at 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.

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

<table>
<thead>
<tr>
<th>Variable</th>
<th>Mean and SEM</th>
</tr>
</thead>
<tbody>
<tr>
<td>Initial body weight, g</td>
<td>4.39 ± 0.04</td>
</tr>
<tr>
<td>Final body weight, g</td>
<td>4.43 ± 0.04</td>
</tr>
<tr>
<td>Body weight change, g</td>
<td>41.62 ± 12.05</td>
</tr>
<tr>
<td>Body weight change, g/d</td>
<td>2.60 ± 0.74</td>
</tr>
<tr>
<td>kg</td>
<td>57</td>
</tr>
<tr>
<td>ER, kcal/d</td>
<td>7.40 ± 1.79</td>
</tr>
<tr>
<td>ER\textsubscript{p}, %</td>
<td>35</td>
</tr>
<tr>
<td>ER\textsubscript{i}, %</td>
<td>65</td>
</tr>
<tr>
<td>kcf</td>
<td>0.79</td>
</tr>
<tr>
<td>kpi</td>
<td>0.34</td>
</tr>
</tbody>
</table>

### Table 3. Egg composition

<table>
<thead>
<tr>
<th>Variable</th>
<th>Mean and SEM</th>
</tr>
</thead>
<tbody>
<tr>
<td>Albumen, %</td>
<td>31.67 ± 0.28</td>
</tr>
<tr>
<td>Yolk, %</td>
<td>55.30 ± 0.25</td>
</tr>
<tr>
<td>Shell, %</td>
<td>9.03 ± 0.14</td>
</tr>
<tr>
<td>Albumen DM, %</td>
<td>51.53 ± 0.15</td>
</tr>
<tr>
<td>Yolk DM, %</td>
<td>12.88 ± 0.26</td>
</tr>
<tr>
<td>Albumen fat, % as DM</td>
<td>0.003 ± 0.000007</td>
</tr>
<tr>
<td>Albumen protein, % as DM</td>
<td>81.53 ± 0.24</td>
</tr>
<tr>
<td>Yolk fat, %</td>
<td>57.83 ± 0.0003</td>
</tr>
<tr>
<td>Yolk protein, %</td>
<td>29.45 ± 0.36</td>
</tr>
<tr>
<td>Egg gross energy, kcal/g</td>
<td>1.62 ± 0.0016</td>
</tr>
</tbody>
</table>
Table 4. Body composition of broiler breeder hens

<table>
<thead>
<tr>
<th>Measurement</th>
<th>Initial</th>
<th>First egg</th>
<th>Final</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fat, %</td>
<td>18.78a</td>
<td>19.66b</td>
<td>17.29c</td>
</tr>
<tr>
<td>Protein, %</td>
<td>15.38</td>
<td>16.73</td>
<td>16.17</td>
</tr>
<tr>
<td>DM, %</td>
<td>42.49</td>
<td>41.80</td>
<td>40.26</td>
</tr>
<tr>
<td>Fat, % as DM</td>
<td>44.90</td>
<td>46.25</td>
<td>42.48</td>
</tr>
<tr>
<td>Protein, % as DM</td>
<td>45.10b</td>
<td>47.70c</td>
<td>47.85c</td>
</tr>
</tbody>
</table>

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<.05)

**ME for egg production**

Broiler breeder performance and egg composition parameters are presented in Table 3 and Table 5, respectively. After broiler breeder hens resumed egg production after TAM was withdrawn in present study, the breeder egg production reached 71% and was at a higher rate than suggested (<57%) by the Cobb 500 Breeder Management Guide (2002) for that age. The increase in egg production is similar to what should be expected after a forced molt. The daily feed needed (energy intake) for each breeder during the laying period was underestimated (135 g/bird/d) because the breeders lost BW during the last week of the 9 wk trial (Table 5).

Previous research by Sun and Coon (2005) indicated that breeders in cages only needed approximately 350 kcal per day at peak for maximum egg production. The diet used in present study contained 2816 kcal/kg and 136 g intake provided approximately 383 kcal per day for each breeder.

The breeders were only producing at a 71% rate instead of 86% that would be expected at peak. The loss in BW during the 8-9th week 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 (MEe). 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). MEe was estimated to be 2.4 kcal per gram of egg mass from the production study by subtracting the MEi and MEa from ME required for production. The average KE was determined to be 65.7%. The MEE value is in the range of 2.04 and 3.13 reported in the literature for breeder breeder hens (Waldroup et al., 1976; Sakomura et al., 1993; Rabello et al., 2000).
Table 5. Performance characteristics of broiler breeder during the laying period.

<table>
<thead>
<tr>
<th>Characteristics</th>
<th>Mean and SEM</th>
</tr>
</thead>
<tbody>
<tr>
<td>Egg weight, g</td>
<td>68.27± 0.81</td>
</tr>
<tr>
<td>Egg mass, g/hen/d</td>
<td>48.44± 0.92</td>
</tr>
<tr>
<td>Egg production, %</td>
<td>71.05 ± 0.25</td>
</tr>
<tr>
<td>Initial body weight, kg</td>
<td>4.51 ± 0.38</td>
</tr>
<tr>
<td>Final body weight, kg</td>
<td>4.46 ± 0.43</td>
</tr>
<tr>
<td>Body weight change, g</td>
<td>-5.675 ± 12.59</td>
</tr>
<tr>
<td>Feed consumption above maintenance, kcal/d</td>
<td>78.94 ± 2.92</td>
</tr>
</tbody>
</table>

Estimated values of ke reported in the literature are variable and range between 50 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; and 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 MEₜ 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 21 C environment were determined to be 98.3 kcal/kgBW₀ for MEₜ₁, 5.6 kcal/g for MEₜ₂, and 2.4 kcal/g for MEₜ₃. The energy efficiencies for protein gain (xp), fat gain (xv) and egg calories (ke) were 34%, 75% and 65.7%, respectively.

4. ACKNOWLEDGEMENTS

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7. LITERATURE CITED


