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# Energy Utilization from Various Fat Sources by Broiler Chickens at Different Ages

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**Abstract:** Two studies were conducted to estimate nitrogen-corrected apparent metabolizable energy ($AME_n$) of different fat sources for broilers from 1 to 7 and 28 to 35 d of age. Corn-soybean meal diets with inclusions of 2, 4 and 8% degummed soybean oil (DSO), acidulated soybean soapstock (ASS), or pork lard (PL) (experiment 1) and coconut oil (CCO), palm oil (PO), or palm kernel oil (PKO) (experiment 2). Fats were added to the feeds at the expense of corn starch. Experiments were conducted in battery cages (0.72 $m^2$) with 8 Ross × Ross 308 male broiler chicks each. Experimental diets were provided from 1 to 7 and 28 to 35 d and feed intake was recorded for each cage. Total excreta was collected from 3 to 7 and 33 to 35 d. Linear regressions at each age (Y = a + bx; Y = apparent available fat; x = level of fat added) allowed estimations of $AME_n$ for each fat source as the product of the coefficient of apparent availability of fat (slope of the equations) multiplied by the gross energy of fat. Estimated values of $AME_n$ (kcal/kg) from 1 to 7 vs. 28 to 35 d were, respectively, 8.348 vs. 9.283 (DSO); 7.706 vs. 8.533 (ASS); 8.219 vs. 8.781 (PL); 7.837 vs. 8.824 (CCO); 7.952 vs. 8.884 (PO) and 7.627 vs. 8.425 (PKO). Older chickens had average increases in fat $AME_n$ of 8.3 and 10.5% compared to the younger ones. These responses present useful values for poultry feed formulation.

**Key words:** Broiler, fat, metabolizable energy

## INTRODUCTION

Fat is routinely added to broiler feeds, in varying amounts in order to increase energy concentration. The cost of dietary energy has been increasing as a result of a consistent expansion in the demand for vegetable fat sources worldwide, a trend that has been exacerbated in recent years with the rise in use of vegetable fats for biodiesel production. Use of alternative sources of lower costs has been hindered by limitation in the knowledge of their effective energy utilization by poultry.

Several factors affect nitrogen-corrected apparent metabolizable energy ($AME_n$) values of fat for poultry, including type of fatty acid (chain length and degree of saturation) and rate of inclusion in feeds (Artman, 1964; Wiseman and Salvador, 1991). Fatty acid chain length is a chemical structural factor that has a direct impact on the $AME_n$ of supplemental fats with fatty acids having longer chain lengths usually have higher $AME_n$ values for poultry (NRC, 1994). On the other hand, unsaturated fatty acids are better utilized when compared to saturated ones in younger birds (Wiseman *et al*., 1986; Leeson and Atteh, 1995; Smits *et al*., 2000). However, significant effects of age on excreta fatty acids were found and the proportion of saturated fatty acids were greater in older than younger birds. Improvements in fat retention and metabolizable energy (ME) of fats with increasing age may be a reflection, in part, of an increase in absorption of the saturated fatty acids such as C16 and C18 (Sell *et al*., 1986).

Fat absorption and subsequent $AME_n$ value of saturated fats has been shown to increase when they are mixed with unsaturated fats (Renner and Hill, 1961; Wiseman and Lessire, 1987). In parallel, a higher efficiency of fat utilization has been related to the increase in dietary fat level (Carew and Hill, 1964; Wiseman and Salvador, 1989). Physiological functions necessary for the utilization of dietary fats are immature in birds during the first post-hatching days (Carew *et al*., 1972) and the limited availability of bile salts, lipase, colipase and phospholipids may reduce utilization of dietary lipids when birds were fed with higher dietary fat levels (Krogdahl, 1985; Escribano *et al*., 1988).

Fat utilization in young poultry is lower than that of more mature birds. This in parts appears to be partly due to a poorer reabsorption of bile salts by younger birds which can impair the formation of fat micelles (Noy and Sklan, 1998; Smits *et al*., 2000). Lower lipase secretion has also been shown as a cause for the reduced fat utilization by young chicks (Leeson and Atteh, 1995) and the improvements in fat utilization noted with increasing

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age of chicks and turkeys may be the result of increased bile salt secretion or increased pancreatic lipase activity (Escribano *et al.*, 1988).

While soybean oil, as degummed soybean oil, has been used extensively as a fat source in poultry feeds, other vegetable sources such as palm and coconut oil are available in tropical regions. Other fat by-products are still underutilized around the world, such as acidulated soybean soapstock, pork lard and palm kernel oil.

The objectives of these studies were to evaluate the utilization of fats of varying degree of saturation, fatty acid chain length and free fatty acid percentage when used at different inclusion levels in broiler feeds in the first and fifth weeks of age. The goal of this work is to provide the poultry industry with $AME_n$ values for these different fat sources with consideration for broiler age.

Table 1: Ingredient and nutrient composition of the basal diets (as-is basis)

| Ingredient, (%) | 1 to 7 d | 28 to 35 d |
|---|---|---|
| Corn | 47.68 | 54.64 |
| Soybean meal (44% CP) | 33.86 | 27.00 |
| Corn gluten meal | 6.00 | 6.00 |
| Corn starch | 8.00 | 8.00 |
| Dicalcium phosphate | 2.02 | 2.02 |
| Limestone | 1.01 | 1.01 |
| Salt | 0.54 | 0.46 |
| DL-Methionine 99% | 0.25 | 0.23 |
| L-Lysine HCl 78% | 0.24 | 0.32 |
| Choline chloride 60% | 0.07 | 1.00 |
| Vitamin and mineral mix[1] | 0.12 | 0.15 |
| L-Threonine 98.5% | 0.01 | 0.04 |
| **Calculated nutrient composition, (%) unless noted** | | |
| $AME_n$, kcal/kg | 2.900 | 3.000 |
| CP | 23.00 | 20.50 |
| Ca | 1.00 | 0.95 |
| Av. P | 0.50 | 0.47 |
| Na | 0.23 | 0.20 |
| Dig. Lys | 1.24 | 1.12 |
| Dig. TSAA | 0.90 | 0.83 |
| Dig. Thr | 0.78 | 0.72 |

[1] Added per kg of feed: vitamin A, 8,000 UI; vitamin $D_3$, 2,000 UI; vitamin E, 30 UI; vitamin $K_3$, 2 mg; thiamine, 2 mg; riboflavin, 6 mg; pyridoxine, 2.5 mg; cyanocobalamin, 0.012 mg, pantothenic acid, 15 mg; niacin, 35 mg; folic acid, 1 mg; biotin, 0.08 mg; iron, 40 mg; zinc, 80 mg; manganese, 80 mg; copper, 10 mg; iodine, 0.7 mg; selenium, 0.3 mg; monensin sodium, 275 mg (Elanco Animal Health, Greenfield, IN)

## MATERIALS AND METHODS

All procedures used in the present study were approved by the Ethics and Research Committee of the Universidade Federal do Rio Grande do Sul, Porto Alegre, Brazil. Two experiments (Exp) were conducted with one-day-old Ross x Ross 308 male broilers that were placed in steel battery cages (0.90 x 0.80 m) each cage with 8 birds. Batteries were located in a temperature-controlled room and managed to maintain bird comfort. Feed and water were provided *ad libitum*.

A basal corn-soybean meal diet without fat supplementation was formulated (Table 1). Fat sources were added to the feeds at the ratios of 2, 4 and 8% at the expense of corn starch in an entire basal diet. The experimental diets were provided from 1 to 7 and 28 to 35 d. The chicks used from 28 to 35 d were housed on day 1 on floor pens, where they remained until 27 d. On day 28, birds were randomly allocated into 36 steel battery cages.

Fat sources evaluated were degummed soybean oil (DSO), acidulated soybean soapstock (ASS) and pork lard (PL) in Exp 1 and coconut oil (CCO), palm oil (PO) and palm kernel oil (PKO) in Exp. 2. Birds were allocated to 9 treatments (Trt) each period of age, with 4 replications of 8 birds each in a completely randomized design. The same design was used in Exp. 1 and 2. Feed intake was recorded each age period.

Total excreta was collected twice daily on wax paper at 4, 5 and 6 d in the first age period and at 32, 33 and 34 d in the second age period. Excreta samples were immediately mixed and pooled by cage and stored at -20°C until analysis. Feed and excreta were analyzed for fat, nitrogen and gross energy. Previous to calorimetry, excreta was dried in a forced air oven at 55°C and ground to pass through a 0.5-mm screen in a grinder.

All fat sources were analyzed prior to the beginning of the study according to the methods: fat source moisture was determined using the Karl Fischer method (AOCS, 1995); unsaponifiable content was determined according AOAC (2006) and gross energy was determined using a Parr 1261 adiabatic calorimeter (AOAC, 2000). For diets and excreta fat extraction was performed using a racemic mixture of ethylic and petroleum ether after acid hydrolysis (AOAC, 2006). Nitrogen analysis was done using the Kjeldahl procedure, method 984.13 (AOAC, 1990). The energy content of fat sources was estimated by regression equation, where $AME_n$ intake was regressed against feed intake with the slope representing the $AME_n$ content of each fat source per period of age. $AME_n$ was calculated using the following equation adapted by Wiseman *et al.* (1986) and Dozier *et al.* (2008):

$$AME_n = Ge_i - [Eo_t - (1 - X)\ Eo_r] / X$$

where, $GE_i$ represents the gross energy of the test ingredient; $EO_t$ represents the energy output of test diet; $EO_r$ represents the energy output of reference diet and X represents the percentage of inclusion of each test ingredient (fat sources).

Data were analyzed using the ANOVA procedure of SAS (SAS, 2009). The Tukey's HSD test (Tukey, 1991) was applied to determine differences among means, considering a significance level at 5%. The PROC REG procedure of SAS was used for regression analysis, which was conducted for each age separately and each energy source, considering the basal diet without supplemental fat and the three levels of each added fat source.

## RESULTS AND DISCUSSION

Chemical characteristics as well as gross energy and predominant fatty acids for the fat sources utilized in the present research are shown in Table 2. These data were regarded as within acceptable commercial standards for feed use.

Resulting data for $AME_n$ from the two experiments along with the linear equations obtained from the regressions and utilized in their determination are presented in Table 3 and 4. In the Exp. 1, linear regression slopes were higher for DSO and PL when compared to ASS from 1 to 7 d; however, the slope of the DSO regression was higher than those for PLL and ASS in the period from 28 to 35 d. In the Exp. 2, linear regression slopes were higher for CCO and PO when compared to PKO regardless of age. Corresponding $AME_n$ (kcal/kg) values for DSO, ASS, PL, CCF, PO, PKO at 7 d were: 8.348; 7.706; 8.219; 7.837; 7.952 and 7.627, respectively whereas values determined for the same fat sources at 35 d were: 9.283; 8.533; 8.781; 8.824, 8.884 and 8.425. Differences in $AME_n$ values of each fat sources were observed in two ages in the present study. Younger birds had lower $AME_n$ values when compared to older ones in both experiments. It has been reported that birds improve their ability to digest and absorb lipids as they age (Katongole and March, 1980), then the fat utilization may be higher in older birds. Utilization of fat by post-hatching chicks has frequently been the object of specific investigations because of the overall impact on broiler meat production due to the limitation in its utilization at early ages (Noy and Sklan, 1998). The origin of the limited ability to utilize fat by chicks may be partially related to a poorly developed bile salt recirculation, which may lead to a reduction in fat emulsification (Jeanson and Kellog, 1992). Pancreatic lipase secretion is also lower with young chickens when compared to older ones (Krogdahl, 1985; Nir and Levanon, 1993). In the present study, the increased utilization of fat by older birds were, in average, of 8.3 and 10.5% in the Exp. 1 and 2, respectively, when all fats were considered altogether. One could expect an interaction between fat and age due to the type of triglyceride, especially because, during fat hydrolysis, the 2-monogliceride plays a role in emulsifying total fat in the gut. Therefore, it can stimulate bile secretion that is required for micelle formation in small intestine (Wiseman and Salvador, 1991).

Considering that, the main quality characteristics of the different fats utilized in the present study were satisfactory; differences in their utilization were expected to express variation in their chemical structure and their resulting impact in animal metabolism. Therefore, differences in fat utilization and in the resulting $AME_n$ observed in the present study can be compared to data published in the literature (NRC, 1994; Rostagno *et al*., 2011). Numeric differences could be observed as references for $AME_n$ between those, which may be related to the methods of determination of $AME_n$. Regardless of the reference, however, it is possible to state that fats having longer and more unsaturated fatty acids present higher $AME_n$ values. Fat sources having longer and more unsaturated fatty acids in the present study were DSO and ASS with intermediate values observed for PL, CCO and PO and the most saturated profile being observed for PKO.

The similarity in fatty acid composition between DSO and ASS were related to the fact that both were exclusively soybean-derived products. Thus, their differences in fat utilization by broilers at both ages could have been only related to variations in chemical composition than the fatty acids, especially to the presence of glycerol as well as the greater amount of proportional carbon bonds in DSO when compared to ASS. A significant difference was found between $AME_n$ from DSO and ASS with a higher value for DSO at both ages. Acidulated soapstocks are expected to have similar fatty acid profiles when compared to their original triglycerides. This was the case in the present study

Table 2: Chemical characterization and prevalent fatty acids of fat sources tested (% or as noted)

| Item | Soybean oil | Acidulated soybean soapstock | Pork lard | Coconut oil | Palm oil | Palm kernel oil |
|---|---|---|---|---|---|---|
| Moisture | <1.0 | <1.0 | <1.0 | <1.0 | <1.0 | <1.0 |
| Unsaponifiable content | <1.0 | <1.0 | 2.4 | <1.0 | <1.0 | <1.0 |
| GE, kcal/kg | 9.443 | 9.228 | 9.264 | 9.094 | 9.359 | 8.786 |
| Prevalent fatty acids | | | | | | |
| C12 | - | 1.2 | - | 4.6 | 0.2 | 44.8 |
| C14 | 0.1 | 0.6 | 1.3 | 16.6 | 0.9 | 17.3 |
| C16 | 11.7 | 14.7 | 24.5 | 9.5 | 39.3 | 10.0 |
| C16:1 | 0.1 | 0.5 | 2.3 | - | 0.1 | - |
| C17 | - | - | 0.4 | - | 0.1 | - |
| C17:1 | - | - | 0.7 | - | - | - |
| C18 | 4.3 | 4.6 | 13.4 | 2.8 | 5.7 | 2.6 |
| C18:1 | 27.2 | 27.3 | 42.4 | 17.5 | 43.0 | 17.9 |
| C18:2 | 49.8 | 45.8 | 13.1 | 3.1 | 10.0 | 2.6 |
| C18:3 | 5.7 | 4.1 | 0.5 | - | 0.2 | - |

Table 3: Linear regression equations used to estimate AME$_n$ of different fat sources (Exp. 1)[1]

| Treatments | a | b[2] | AME$_n$, kcal/kg[3] | r[2] | SD |
|---|---|---|---|---|---|
| **1 to 7 d** | | | | | |
| DSO[4] | 25.75 | $0.8784\pm0.0218^{a}$ | 8.348 | 0.988 | 2.83 |
| ASS[5] | 25.75 | $0.7796\pm0.0187^{b}$ | 7.706 | 0.982 | 2.80 |
| PL[6] | 25.75 | $0.9066\pm0.0218^{a}$ | 8.219 | 0.985 | 2.84 |
| **28 to 35 d** | | | | | |
| DSO | 24.36 | $1.0016\pm0.0291^{a}$ | 9.283 | 0.976 | 4.41 |
| ASS | 24.36 | $0.8789\pm0.0340^{b}$ | 8.533 | 0.971 | 4.37 |
| PL | 24.36 | $0.9199\pm0.0340^{b}$ | 8.781 | 0.978 | 4.39 |

[1] Y = a+bx; apparent available fat = Y, g/kg as fed; level of inclusion of fat = x, g/kg as fed.

[2] Slopes (b) within the same age with different letters superscript letter differ based on Tukey separation at $p<0.05$.

[3] Calculated as the product of apparent availability of fat (slope of the equations) and gross energy of fat.

[4] DSO: degummed soybean oil. [5] ASS: acidulated soybean soapstock. [6] PL: pork lard

Table 4: Linear regression equations used to estimate AME$_n$ of different fat sources (Exp. 2)[1]

| Treatments | a | b[2] | AME$_n$, kcal/kg[3] | r[2] | SD |
|---|---|---|---|---|---|
| **1 to 7 d** | | | | | |
| CCO[4] | 33.12 | $0.7401\pm0.0195^{a}$ | 7,837 | 0.982 | 2.96 |
| PO[5] | 33.12 | $0.7536\pm0.0228^{a}$ | 7,952 | 0.984 | 2.92 |
| PKO[6] | 33.12 | $0.6885\pm0.0231^{b}$ | 7,627 | 0.980 | 2.95 |
| **28 to 35 d** | | | | | |
| CCO | 21.01 | $0.8899\pm0.0184^{a}$ | 8,824 | 0.988 | 2.79 |
| PO | 21.01 | $0.8011\pm0.0216^{a}$ | 8,884 | 0.987 | 2.81 |
| PKO | 21.01 | $0.8196\pm0.0216^{b}$ | 8,425 | 0.989 | 2.78 |

[1] Y = a + bx; apparent available fat = Y, g/kg as fed; level of inclusion of fat = x, g/kg as fed.

[2] Slopes within the same age with different letters differ significantly using Tukey at $p<0.05$.

[3] Calculated as the product of apparent availability of fat (slope of the equations) and gross energy of fat.

[4] CCO coconut fat. [5] PO: palm oil. [6] PKO: palm kernel oil

when ASS was compared to DSO. However, ASS produced lower AME$_n$ values at both ages. It has been demonstrated that an increase in free fatty acid proportions reduces fat energy availability (Wiseman and Salvador, 1991). Still, those are fat sources of reduced market price and, therefore, worth of being included in poultry feeding.

In the present study, CCO and DSO produced intermediate AME$_n$ if related to ASS. The study by Gaiotto *et al.* (2001) reported AME$_n$ values of 8.200 kcal/kg and 6.715 kcal/kg for DSO and ASS, respectively, which were lower than those obtained in this study. Pena *et al.* (2014) reported an AME$_n$ value of 9.232 kcal/kg for 28-d old chickens using ASS as fat source. Freitas *et al.* (2005) also estimated AME$_n$ values for ASS of 7.488 kcal/kg and 8.610 kcal/kg for 20-d old chickens and roosters, respectively. On the other hand, CCO had an increased AME$_n$ value when compared to PO and PKO. Possibly, this was due to a greater proportion of mid chain fatty acids in the CCO. These are efficiently absorbed and readily enter into the enterohepatic circulation when compared with long chain fatty acids (Cera, 1989).

Differences in the utilization of fats by 1 and 5 weeks old broiler chickens were shown in the present study with older birds proportionally gathering more energy from the same amount of fat source. Energy utilization obtained from the different fat sources was related to their chemical composition with higher energy derived from fat with a higher degree of unsaturation and longer chain length. Determined AME$_n$ (kcal/kg) for DSO, ASS, PL, CCF, PO, PKO at 7 d were: 8.348; 7.706; 8.219; 7.837; 7.952 and 7.627, respectively. Values determined for the same fat sources at 35 d were 9.283; 8.533; 8.781; 8.824, 8.884 and 8.425.

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