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Technical Note

# Net Energy Prediction Equations Used in Chinese Yellow Chickens for Energy Evaluation

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## ABSTRACT

This study assessed whether the net energy (NE) system is beneficial for determining the efficiency of feed utilization in Chinese Yellow Chickens. A total of 5,600 male Chinese Yellow Chickens were assigned to eight dietary treatments (ten replicate pens per treatment and 70 chickens per pen) of differing apparent metabolizable energy (AME) and NE values. A highly significant linear correlation between dietary energy and feed conversion ratios (FCR) was observed ($p<0.01$). The linear regression equation between metabolizable energy (ME) and FCR was: AME=−1435.5×F/G+6278.2, where $R^2=0.8272$. The linear regression equation between NE and FCR was NE=−1350.1×F/G+5340.9, and $R^2=0.9551$. The $R^2$ of FCR (0.9551) for diets formulated using NE values was higher than the $R^2$ of FCR (0.8272) for diets prepared on the basis of the ME system. We conclude that the NE system is more accurate than the AME system for determining the energy requirements of Chinese Yellow Chickens.

## INTRODUCTION

Broilers ingest nutrients, including carbohydrates, proteins and lipids. Chemical energy is released and converted into usable energy for tissues and cells to maintain their vital functions. Accurate evaluation of the effective energy value of feed ingredients plays a vital role in broiler production. The metabolizable energy (ME) system is widely used in feed formulation for broilers around the world. Although the ME system has been used as the default system in the broiler industry, it has numerous limitations. Some studies found that the ME system overestimated the energy utilization rate of crude protein and crude fibre, and underestimated the utilization rate of fat and starch. Net energy (NE), which refers to the residual energy in the diet, is equivalent to ME minus total heat production (HP) during *in-vivo* metabolism, and has also been used in animal production. Heat increment (HI) values from different nutrients differ. Thus, the HI values of protein and carbohydrate were found to be similar, but both were significantly higher than the HI of fat.

The NE system is attracting increasing attention in both academia and industry. Noblet (1994) used respiration calorimetry to study the NE system in pigs, and established regression equations between NE values of feed ingredients and their chemical components. The National Research Council used these regression equations to calculate the NE values of feed ingredients in their database. In recent years, the NE system has been applied to broilers. In a thorough and detailed study, Wu *et al.* (2019) established regression equations between the NE values of broiler feed ingredients and their chemical components. However, no subsequent study has been carried out to compare NE and ME systems in broilers, particularly under practical conditions. This study aimed to estimate the NE values of commonly used feed ingredients for the Chinese Yellow Chicken. The correlation between FCR and feed energy gradient was used to evaluate the accuracy of the NE system compared with the ME system for Chinese Yellow Chickens.

# MATERIALS AND METHODS

## Animals, diets, and treatments

This study was conducted at Wens Foodstuffs Group Co., Ltd. (Guangzhou, China) and was approved by the Animal Care and Handling Procedures of the Institute of Animal Science, Chinese Academy of Agricultural Sciences, Beijing, China. A total of 5,600 Chinese Yellow Chickens (body weight ~35 g) used in this study were selected from the same farm on the basis of their genetic background and health status. The chickens were divided among eight dietary treatments. Each treatment had ten replicate pens and each pen (2.5 × 4 m) housed 70 chickens. Mash diets were fed in a three-phase feeding program as follows: starter (days 1 to 21), grower (days 22 to 42), and finisher (days 43 to 58). The eight diets were formulated to provide a similar nutrient profile but with different energy levels (Table 1). All treatment groups were fed with the same diet in

**Table 1 –** Ingredients and calculated nutrient composition of experimental diets.

| Phase Treatment | Starter | Grower | | | | | | | | Finisher | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Ingredients, g/kg | T1-T8 | T1 | T2 | T3 | T4 | T5 | T6 | T7 | T8 | T1 | T2 | T3 | T4 | T5 | T6 | T7 | T8 |
| Corn | 634.5 | 260.0 | 654.1 | 675.1 | 270.0 | 260.0 | 680.8 | 702.1 | 509.0 | 204.0 | 637.0 | 567.2 | 216.0 | 339.1 | 583.0 | 444.7 | 317.7 |
| Soybean meal | 240.1 | 60.0 | 98.1 | 124.5 | 60.0 | 60.0 | 132.0 | 144.0 | 60.0 | 60.0 | 101.6 | 96.6 | 52.0 | 60.0 | 104.6 | 88.9 | 60.0 |
| Cottonseed meal | 40.0 | 21.0 | | | | | | | 23.0 | 10.0 | 25.0 | 15.0 | | | 11.0 | 21.0 | |
| Corn gluten meal | 40.0 | 26.2 | 80.0 | 80.0 | 15.9 | 15.9 | 80.0 | 80.0 | 14.7 | 14.7 | 80.0 | 80.0 | 23.2 | 29.3 | 80.0 | 80.0 | 36.5 |
| Wheat | | | | | | | | | | 50.0 | 50.0 | 50.0 | 50.0 | 50.0 | 50.0 | 50.0 | 50.0 |
| Soybean oil | 4.0 | 40.0 | 4.2 | 9.9 | 40.0 | 40.0 | 17.3 | 22.1 | 40.0 | 50.0 | 18.2 | 28.0 | 55.0 | 50.0 | 34.6 | 49.0 | 60.0 |
| Rapeseed meal | | 100.0 | 19.5 | | 96.2 | 94.0 | | | 100.0 | 100.0 | | | 100.0 | 100.0 | | | 88.5 |
| Pea | | 100.0 | 100.0 | 66.3 | 48.4 | 100.0 | 45.5 | 7.4 | | 100.0 | 46.4 | 100.0 | 47.7 | 36.7 | 95.6 | 100.0 | 29.0 |
| Barely | | 300.6 | | | 300.1 | 300.0 | | | 83.0 | 285.0 | | 22.0 | 299.7 | 196.0 | | 125.0 | 211.0 |
| Extruded soybean | | 21.0 | | | 100.0 | 91.0 | | | 100.0 | 60.0 | | | 90.0 | 80.0 | | | 80.0 |
| Palm Ouricuri Meal | | 30.0 | | | 30.0 | | | | 30.0 | 30.0 | | | 30.0 | 22.0 | | | 30.0 |
| Lysine-$H_2SO_4$ (70%) | 4.9 | 6.4 | 7.2 | 7.2 | 5.3 | 4.7 | 7.3 | 7.5 | 6.0 | 4.2 | 6.9 | 6.2 | 4.6 | 4.8 | 6.1 | 6.4 | 5.1 |
| DL-Methionine (98%) | 1.8 | 3.0 | 2.5 | 2.6 | 2.9 | 3.0 | 2.5 | 2.5 | 2.8 | 2.2 | 1.8 | 1.8 | 2.0 | 1.9 | 1.8 | 1.9 | 1.9 |
| Threonine (98%) | 0.4 | 1.8 | 1.3 | 1.2 | 1.5 | 1.5 | 1.2 | 1.1 | 1.5 | 1.3 | 1.0 | 1.0 | 1.3 | 1.1 | 1.0 | 1.1 | 1.2 |
| Salt | 3.5 | 3.5 | 3.6 | 3.6 | 3.5 | 3.5 | 3.6 | 3.6 | 3.4 | 2.9 | 3.0 | 3.1 | 2.9 | 2.9 | 3.1 | 3.1 | 2.9 |
| Na-Bicarbonate | | | | | | | | | | 1.5 | 1.5 | 1.5 | 1.5 | 1.5 | 1.5 | 1.5 | 1.5 |
| Limestone | 13.7 | 13.4 | 14.2 | 14.2 | 13.2 | 13.3 | 14.2 | 14.1 | 13.3 | 12.9 | 14.1 | 14.0 | 12.9 | 13.0 | 13.9 | 14.0 | 13.0 |
| Dicalcium phosphate | 12.4 | 8.6 | 10.8 | 11.0 | 8.5 | 8.6 | 11.1 | 11.1 | 8.9 | 6.9 | 9.2 | 9.2 | 6.9 | 7.3 | 9.4 | 9.0 | 7.4 |
| [a]Premix compound | 4.0 | 4.0 | 4.0 | 4.0 | 4.0 | 4.0 | 4.0 | 4.0 | 4.0 | 4.0 | 4.0 | 4.0 | 4.0 | 4.0 | 4.0 | 4.0 | 4.0 |
| Choline chloride (60%) | 0.8 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.4 | 0.4 | 0.4 | 0.4 | 0.4 | 0.4 | 0.4 | 0.4 |
| Total Batch | 1000 | 1000 | 1000 | 1000 | 1000 | 1000 | 1000 | 1000 | 1000 | 1000 | 1000 | 1000 | 1000 | 1000 | 1000 | 1000 | 1000 |
| Calculated nutrient levels, % | | | | | | | | | | | | | | | | | |
| Crude protein | 20.50 | 17.47 | 17.5 | 17.5 | 17.5 | 17.51 | 17.5 | 17.5 | 17.5 | 17.49 | 17.51 | 17.49 | 17.49 | 17.5 | 17.49 | 17.5 | 17.5 |
| Ether extract | 2.96 | 6.71 | 2.77 | 3.33 | 8.1 | 7.68 | 4.06 | 4.56 | 8.32 | 8.21 | 4.05 | 4.91 | 9.24 | 8.6 | 5.56 | 6.86 | 9.6 |
| crude fiber | 2.43 | 4.74 | 2.28 | 2 | 4.57 | 4.2 | 1.93 | 1.8 | 3.88 | 4.66 | 2.02 | 2.2 | 4.49 | 3.95 | 2.08 | 2.54 | 3.97 |
| Calcium, % | 0.90 | 0.85 | 0.85 | 0.85 | 0.85 | 0.85 | 0.85 | 0.85 | 0.85 | 0.8 | 0.8 | 0.8 | 0.8 | 0.8 | 0.8 | 0.8 | 0.8 |
| Available phosphorus | 0.351 | 0.31 | 0.311 | 0.31 | 0.311 | 0.31 | 0.31 | 0.309 | 0.31 | 0.28 | 0.281 | 0.28 | 0.281 | 0.28 | 0.281 | 0.281 | 0.28 |
| $Na^+$ | 0.16 | 0.16 | 0.16 | 0.16 | 0.16 | 0.16 | 0.16 | 0.16 | 0.16 | 0.18 | 0.18 | 0.18 | 0.18 | 0.18 | 0.18 | 0.18 | 0.18 |
| $K^+$ | 0.73 | 0.57 | 0.44 | 0.47 | 0.67 | 0.65 | 0.48 | 0.51 | 0.65 | 0.62 | 0.47 | 0.44 | 0.65 | 0.63 | 0.44 | 0.45 | 0.62 |
| AME, kcal/kg | 2900 | 2920 | 2955 | 3000 | 3000 | 3014 | 3046 | 3080 | 3080 | 3022 | 3059 | 3100 | 3100 | 3120 | 3148 | 3180 | 3180 |
| NE, kcal/kg (prediction) | 2148 | 2210 | 2210 | 2249 | 2282 | 2290 | 2290 | 2320 | 2346 | 2300 | 2300 | 2338 | 2368 | 2379 | 2380 | 2414 | 2433 |
| SID Lysin | 1.05 | 0.96 | 0.96 | 0.96 | 0.96 | 0.96 | 0.96 | 0.96 | 0.96 | 0.90 | 0.90 | 0.90 | 0.90 | 0.90 | 0.90 | 0.90 | 0.90 |
| SID Met + Cys | 0.71 | 0.75 | 0.75 | 0.75 | 0.75 | 0.75 | 0.75 | 0.75 | 0.75 | 0.67 | 0.67 | 0.67 | 0.67 | 0.67 | 0.67 | 0.67 | 0.67 |
| SID Threonin | 0.65 | 0.62 | 0.62 | 0.62 | 0.62 | 0.62 | 0.62 | 0.62 | 0.62 | 0.59 | 0.59 | 0.59 | 0.59 | 0.59 | 0.59 | 0.59 | 0.59 |
| SID Arginin | 1.17 | 0.86 | 0.81 | 0.83 | 0.87 | 0.87 | 0.83 | 0.82 | 0.91 | 0.9 | 0.86 | 0.85 | 0.87 | 0.86 | 0.85 | 0.85 | 0.85 |
| SID Tryptophan | 0.18 | 0.15 | 0.12 | 0.13 | 0.16 | 0.15 | 0.13 | 0.13 | 0.16 | 0.15 | 0.13 | 0.12 | 0.15 | 0.15 | 0.13 | 0.12 | 0.15 |

a Premix compound provided per kg of diet: retinol, 3.0 mg; cholecalciferol, 0.045 mg; tocopherol, 20mg; menadione, 3.5 mg; riboflavin, 8.0 mg; niacin, 35 mg; D-pantothenic acid, 10 mg; cobalamin, 0.015 mg; biotin, 0.18mg; folacin, 1.2mg; thiamine, 2.0 mg; pyridoxine, 3.5 mg; 8.0 mg of Cu from $CuSO_4 \cdot 5H_2O$; 80 mg of Zn from $ZnSO_4 \cdot H_2O$; 100 mg of Mn from $MnSO_4 \cdot H_2O$; 60 mg of Fe from $FeSO_4 \cdot H_2O$; 0.7 mg of I from KI; 0.3 mg of Se from $Na_2SeO_3$.

the starter phase. Diets 1 through 8 were formulated to provide 2920 (2210), 2955 (2210), 3000 (2249), 3000 (2282), 3014 (2290), 3046 (2290), 3080 (2320), 3080 (2346) kcal AME (or NE)/kg, respectively, in the grower phase. Diets 1 through 8 were formulated to provide 3022 (2300), 3059 (2300), 3100 (2338), 3100 (2368), 3120 (2380), 3148 (2280), 3180 (2414), 3180 (2433) kcal AME (NE)/kg, respectively, in the finisher phase. The AME values of feed ingredients, crude protein and crude fat levels are shown in Table 2. The NE values of feed ingredients were calculated using the predictive equation reported by Wu *et al.* (2019). The room temperature was maintained at 32–34°C for the first 3 days, and then reduced by 2–3°C per week to a final temperature of 20°C. The chickens had *ad libitum* access to feed and water throughout the experimental period. At 21, 42, and 58 days of age, the weights of the chickens were measured after 12-h feed deprivation, and feed consumption was recorded to calculate the average daily feed intake (ADFI), the average daily gain (ADG), and the feed: gain ratio (F/G).

**Table 2 –** Main measured characteristics of the diets used in the NE prediction equation.

| Items | Composition, % DM basis | | Energy values, Kcal/ kg DM | |
|---|---|---|---|---|
| | CP[a] | EE[a] | AME[b] | NE[c] |
| Corn | 9.07 | 4.07 | 3686 | 2846 |
| Soybean meal | 53.51 | 2.03 | 2791 | 1836 |
| Cottonseed meal | 52.82 | 2.18 | 2437 | 1565 |
| Corn gluten meal | 67.43 | 0.94 | 3928 | 2623 |
| Wheat | 13.64 | 3.98 | 3750 | 2865 |
| Soybean oil | | 100.00 | 9091 | 7793 |
| Rapeseed meal | 42.67 | 3.47 | 2469 | 1667 |
| Pea | 21.28 | 1.77 | 3058 | 2258 |
| Barely | 10.09 | 2.47 | 2976 | 2273 |
| Extruded soybean | 38.97 | 21.20 | 3981 | 2996 |
| Palm Ouricuri Meal | 16.13 | 10.42 | 1954 | 1490 |
| Lysine-$H_2SO_4$ (70%) | 78.57 | | 2296 | 1267 |
| DL-Methionine (98%) | 58.99 | | 4684 | 3263 |
| Threonine (98%) | 73.88 | | 3077 | 1908 |

[a] CP and EE were measured value.

[b] AME data from poultry feed database of Wens Foodstuff Group.

[c] NE predicted using regression equations: NE (MJ/kg DM basis) = 0.781 × AME (MJ/kg DM basis) – 0.028 × CP (% DM basis) + 0.029 × EE (% DM basis) produced from Wu et al (2019).

### Statistical analyses

The data were analyzed by one-way analysis of variance (ANOVA) using SAS version 9.4 (SAS Inst. Inc., Cary, NC). The performance of each pen was used as the experimental unit. All data were tested for normality and homoscedasticity before analysis using the Shapiro–Wilk and Levene tests, respectively. Significant differences among treatments were determined by Duncan's multiple range test (Duncan, 1955). Significance was set at $p<0.05$ and values are presented as means ± standard error of the mean (SEM). The linear regression model is expressed as $Y = \beta 0+\beta 1\times X$, $R^2$, where Y is the energy level, X is the response variable (ADG, ADFI, or F/G), and β0 and β1 are regression parameters.

## RESULTS AND DISCUSSION

The more accurate the energy system, the better the prediction of production performance. In pigs, NE, which is a measure of 'true' energy available for maintenance and production, predicted the production performance more accurately than the digestible energy (DE) or ME did. In chickens, the efficiency of AME and NE for prediction of production were less dependent on dietary nutrient contents than they were in pigs, suggesting that the NE system might not be more suitable than the AME system. Our study assessed whether the NE system was advantageous to determine the efficiency of feed utilization in Chinese Yellow Chickens. In the starter phase of the experiment, a large number of unconventional raw materials were used and formulations differed among treatments. To avoid the effects of these factors on the analysis, the starter phase was excluded from the experiment.

Dietary energy affects broiler growth performance in terms of ADG and ADFI. Live weight gain is higher, feed intake is lower, and food conversion efficiency improves with the increase in dietary energy levels. In the present study, an increase in AME content from 2975 to 3117 kcal/kg was associated with an increase by ADG to 2.85%. Accordingly, the ADFI and FCR of the chickens decreased by 0.69% and 3.51%, respectively (Table 3). The correlations between energy value and production performance indicators suggested significant differences among ADG, ADFI and FCR, favoring the use of NE. In contrast to ADG and ADFI, FCR significantly changed with dietary energy values. However, there were no significant differences in production performance between the different treatments with graded levels of dietary energy ($p>0.05$), because the chickens were fed at the same growth stage. In the later stages of the diet, FCR values decreased as ME of the diet increased, and the differences became highly significant ($p<0.01$). In addition, a strong linear correlation between ME values in the diets and FCRs in chickens was found, with correlation coefficients of 0.373, 0.9287 and

**Table 3 –** Growth performance of broilers from 1 to 58 days of age.

| Phase | Item | Treatment 1 | Treatment 2 | Treatment 3 | Treatment 4 | Treatment 5 | Treatment 6 | Treatment 7 | Treatment 8 | SEM | *p* value |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Energy (Kcal/kg) | | | | | | | | | |
| Starter (1-21 days) | | AME 2900 NE 2148 | AME 2900 NE 2148 | AME 2900 NE 2148 | AME 2900 NE 2148 | AME 2900 NE 2148 | AME 2900 NE 2148 | AME 2900 NE 2148 | AME 2900 NE 2148 | | |
| | Initial BW (kg) | 0.032 | 0.032 | 0.032 | 0.032 | 0.032 | 0.032 | 0.032 | 0.032 | 0.000 | 0.998 |
| | Final BW (kg) | 0.366 | 0.370 | 0.370 | 0.367 | 0.367 | 0.373 | 0.375 | 0.375 | 0.001 | 0.226 |
| | ADG (g/day$^{-1)}$ | 15.9 | 16.1 | 16.1 | 16.0 | 16.0 | 16.3 | 16.4 | 16.4 | 0.054 | 0.227 |
| | ADFI (g/day$^{-1}$) | 26.6 | 27.1 | 26.9 | 26.6 | 26.6 | 27.0 | 27.1 | 27.3 | 0.080 | 0.179 |
| | F/G | 1.67 | 1.68 | 1.67 | 1.67 | 1.67 | 1.66 | 1.66 | 1.67 | 0.002 | 0.557 |
| Grower (22-42 days) | | AME 2920 NE 2210 | AME 2955 NE 2210 | AME 3000 NE 2249 | AME 3000 NE 2282 | AME 3014 NE 2290 | AME 3046 NE 2290 | AME 3080 NE 2320 | AME 3080 NE 2346 | | |
| | Initial BW (kg) | 0.366 | 0.370 | 0.370 | 0.367 | 0.367 | 0.373 | 0.375 | 0.375 | 0.001 | 0.226 |
| | Final BW (kg) | 1.213 | 1.214 | 1.213 | 1.198 | 1.204 | 1.215 | 1.238 | 1.239 | 0.005 | 0.497 |
| | ADG (g/day$^{-1)}$ | 40.3 | 40.1 | 40.0 | 39.5 | 39.8 | 40.0 | 41.0 | 41.0 | 0.223 | 0.696 |
| | ADFI (g/day$^{-1}$) | 86.2$^{ab}$ | 88.2$^{a}$ | 86.6$^{ab}$ | 82.9$^{bc}$ | 82.2$^{c}$ | 85.2$^{abc}$ | 86.4$^{ab}$ | 84.4$^{abc}$ | 0.459 | 0.014 |
| | F/G | 2.14$^{bc}$ | 2.20$^{a}$ | 2.17$^{b}$ | 2.10$^{f}$ | 2.07$^{e}$ | 2.13$^{cd}$ | 2.11$^{de}$ | 2.06$^{f}$ | 0.006 | 0.001 |
| Finisher (42-58 days) | | AME 3022 NE 2300 | AME 3059 NE 2300 | AME 3100 NE 2338 | AME 3100 NE 2368 | AME 3120 NE 2379 | AME 3148 NE 2380 | AME 3180 NE 2414 | AME 3180 NE 2433 | | |
| | Initial BW (kg) | 1.213 | 1.214 | 1.213 | 1.198 | 1.204 | 1.215 | 1.238 | 1.239 | 0.005 | 0.497 |
| | Final BW (kg) | 1.835 | 1.826 | 1.817 | 1.813 | 1.823 | 1.805 | 1.877 | 1.889 | 0.008 | 0.124 |
| | ADG (g/day$^{-1)}$ | 41.4$^{abc}$ | 40.8$^{bc}$ | 39.6$^{c}$ | 41.9$^{abc}$ | 41.8$^{abc}$ | 40.4$^{bc}$ | 42.6$^{ab}$ | 43.3a | 0.263 | 0.023 |
| | ADFI (g/day$^{-1}$) | 115.9 | 112.1 | 109.1 | 114.1 | 112.8 | 108.6 | 113.5 | 115.8 | 0.689 | 0.079 |
| | F/G | 2.80$^{a}$ | 2.75$^{b}$ | 2.76$^{b}$ | 2.72$^{bc}$ | 2.70$^{cd}$ | 2.69$^{cd}$ | 2.66$^{d}$ | 2.67d | 0.007 | 0.001 |
| Overall (1-58 days) | | AME 2975 NE 2254 | AME 3006 NE 2253 | AME 3044 NE 2286 | AME 3046 NE 2316 | AME 3061 NE 2325 | AME 3086 NE 2324 | AME 3116 NE 2354 | AME 3117 NE 2374 | | |
| | Initial BW (kg) | 0.032 | 0.032 | 0.032 | 0.032 | 0.032 | 0.032 | 0.032 | 0.032 | 0.000 | 0.998 |
| | Final BW (kg) | 1.835 | 1.826 | 1.817 | 1.813 | 1.823 | 1.805 | 1.877 | 1.889 | 0.008 | 0.124 |
| | ADG (g/day$^{-1)}$ | 31.6 | 31.4 | 31.3 | 31.2 | 31.4 | 31.1 | 32.3 | 32.5 | 0.142 | 0.134 |
| | ADFI (g/day$^{-1}$) | 72.1 | 72.0 | 70.9 | 70.1 | 69.7 | 69.4 | 71.6 | 71.6 | 0.326 | 0.287 |
| | F/G | 2.28$^{ab}$ | 2.29$^{a}$ | 2.27$^{b}$ | 2.25$^{c}$ | 2.22$^{de}$ | 2.23$^{dc}$ | 2.22$^{de}$ | 2.20$^{e}$ | 0.004 | 0.001 |

BW, body weight; ADG, average daily gain; ADFI, average daily feed intake; F/G, feed intake/gain; AME, apparent metabolizable energy; NE, net energy.

$^{a-f}$ Letters within a row denote statistical differences between means.

0.8272, respectively, in the grower, finisher and overall stages (Table 4). There were non-significant linear correlations between the ADFI and AME values, and ADG ($p$>0.05). Therefore, compared with ADFI and ADG, FCR is a sensitive measure for evaluation of the effects of energy value on production performance, because chickens fed a balanced diet responded to the energy level of the diet. Thus, when the energy level is accurately known, the relationship between FCR, as a major indicator of performance, and dietary energy level improves.

Indeed, in the current study, energy levels and FCR were highly correlated. The regression analyses of FCRs and diets prepared in accordance with the ME and NE databases for chickens are shown in Table 4. There was a significant linear correlation between FCR and the ME value of the feed prepared in accordance with our own ME database specifically for the Chinese Yellow Chicken ($p$<0.01). The linear regression equation between the ME value and FCR was AME=−1435.5×F/G+6278.2, where $R^2$=0.8272. The correlation became much stronger when the feed was formulated using our NE database ($p$<0.01). The linear regression equation between the NE value and FCR was NE=−1350.1×F/G+5340.9, where $R^2$=0.9551. This clearly indicates that the diets prepared using the NE database were more accurate for evaluating production performance in chickens than those based on an ME database. However, there were differences in the correlations between FCRs and diets prepared in accordance with NE and ME systems at different stages. At the grower stage, the linear regression equation between ME and FCR was AME=−733.9×F/G+4569.4, where $R^2$=0.3743. The

**Table 4 –** The relationship between growth performance and diet energy.

| Energy system | | Item | Regression Equations | $R^{2\,a}$ |
|---|---|---|---|---|
| AME | Grower (22-42 days) | ADG (g/day$^{-1)}$ | AME=55.953×ADG+762.98 | 0.2716 |
| | | ADFI (g/day$^{-1}$) | AME=-8.3973×ADFI+3727.9 | 0.0881 |
| | | F/G | AME=-733.9×F/G+4569.4 | 0.3743 |
| | Finisher (42-58 days) | ADG (g/day$^{-1)}$ | AME=22.614×ADG+2175.7 | 0.2363 |
| | | ADFI (g/day$^{-1}$) | AME=-2.1659×ADFI+3357.8 | 0.0115 |
| | | F/G | AME=-1127.2×F/G+6178.1 | 0.9287 |
| | Overall (22-58 days) | ADG (g/day$^{-1)}$ | AME=49.782×ADG+1483.2 | 0.2761 |
| | | ADFI (g/day$^{-1}$) | AME=-13.082×ADFI+3984.2 | 0.0781 |
| | | F/G | AME=-1435.5×F/G+6278.2 | 0.8272 |
| NE | Grower (22-42 days) | ADG (g/day$^{-1)}$ | NE=42.624×ADG+561.46 | 0.2116 |
| | | ADFI (g/day$^{-1}$) | NE=-12.914×ADFI+3727.9 | 0.0881 |
| | | F/G | NE=-851.07×F/G+4080.8 | 0.6758 |
| | Finisher (42-58 days) | ADG (g/day$^{-1)}$ | NE=26.974×ADG+1245.2 | 0.4405 |
| | | ADFI (g/day$^{-1}$) | NE=2.2725×ADFI+2107.8 | 0.0166 |
| | | F/G | NE=-954.72×F/G+4959.5 | 0.8729 |
| | Overall (22-58 days) | ADG (g/day$^{-1)}$ | NE=47.991×ADG+794.17 | 0.3349 |
| | | ADFI (g/day$^{-1}$) | NE=-11.578×F/G+3131.9 | 0.0799 |
| | | F/G | NE=-1350.1×F/G+5340.9 | 0.9551 |

[a] Coefficient of determination ($R^2$) was obtained using data from all treatments.

linear regression equation between NE value and FCR was NE=−851.07×F/G+4080.8, where $R^2$=0.6758. At different stages of production, there were differences between the two databases. At the grower stage, the improved accuracy of the NE over the ME database was very apparent. However, at the finisher stage, the linear regression equation between ME value and FCR was AME=−1127.2×F/G+6178.1, where $R^2$=0.9287. The linear regression equation between NE and FCR was NE=−954.72×F/G+4959.5, where $R^2$=0.8729. Compared with ME, NE showed a significant difference in the production performances of chickens at the finisher stage. The reasons for the non-significant differences might be related to the sources of ME data for the feed ingredients used at the fattening stage (128 d) in this study; the NE equation generated by Wu *et al.* (2019) was obtained using broiler chickens, at the grower phase (25 d). Although Chinese Yellow Chickens are long-lived birds with a slaughter age reaching over 100 d. The final stage of growth is slow and the diet is very different to that of the modern broiler. Wu et al might need to look at NE values at different stages of growth to make corrections to their equations.

## CONCLUSION

The NE system developed by Wu *et al.* (2019) was evaluated in the Chinese Yellow Chicken to examine wether it could predicted bird performance better than the current AME system. The NE is more accurate in predicting FCR than the AME system, especially during the grower phase of the Chinese Yellow Chicken. However, the differences in the NE system and ME systems blurred during the fattening stage of chickens, suggesting that further optimization of the NE system is required to tailor the energy needs of the Chinese Yellow Chicken for the later stages of its production.

## CONFLICT OF INTERESTS

The authors declare that there is no conflict of interest regarding the publication of this paper.

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