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Short Communication

Effect of dietary energy concentration on the growth of slow-growing Korat chickens from 43 to 84 days old

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Abstract

The aim of this study was to estimate the effect of diets with different energy levels on the growth performance of slow-growing chickens (so-called Korat chicken (KRC)). The KRC is a cross between a male Thai native chicken (Leung Hang Khoa) and females from crosses among modern broiler and layer lines. The study was divided into two experimental periods when the birds were from 43 to 63 days old and 64 to 84 days old. Birds received feed and water ad libitum throughout the trial. In this study, 1200 mixed-sex KRC (624 and 576 chicks in phases 1 and 2, respectively) were distributed equally to four diets, which provided 2750, 2900, 3050 and 3200 kcal ME/kg. There were six replicate pens of each treatment. At both ages, increased energy content of the diet resulted in decreased feed intake (FI) and thus improved the feed conversion ratio (FCR). Weight gain was unaffected by the treatments. Using a broken-line analysis, dietary energy containing about 3200 kcal ME/kg was found to have the most beneficial effect on FCR during both periods. Thus, the optimal ME for KRC between 43 and 84 days old was 3200 kcal/kg.

Keywords: feed efficiency, nutrient, production, requirement
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Energy is the main macronutrient in poultry diets, representing 40% to 70% of the feed cost. The management of energy consumption of broilers can reduce production costs and enhance product quality. In general, birds consume to satisfy their energy requirements and stop eating, even when the requirements for other nutrients such as proteins, minerals and vitamins have not been satisfied. To achieve success in chicken meat production, it is necessary to provide adequate energy to support tissue growth and effective tissue and organ physiology (Ahiwe *et al*., 2018). When the amount of energy consumed exceeds the physiological demand, the excess is deposited as fat in the carcass, which is considered a waste product and thus represents an economic loss for poultry producers (Ahiwe *et al*., 2018). The energy requirements of birds are known to vary with genotype, age, sex, strain, bodyweight, environmental temperature, activity level and their production (Infante-Rodríguez *et al*., 2016; Abouelezz *et al*., 2019).

Nowadays, consumers increasingly want healthful meat products, and producers have sought to improve meat quality to achieve consumer satisfaction. Because in some regions, consumers prefer meat from slow-growing types with functional properties such as high sensory quality and healthy meat, these are the main attributes that attract customers (Sokołowicz *et al*., 2016). Korat chicken meat contains more collagen and less fat and has a unique taste and a firmer chewier texture than commercial broilers. In practical production, the KRC can achieve a market live weight of 1.2 to 1.7 kg within 63 to 84 days, whereas native chickens can attain 1.2 kg in 112 days. Several studies estimated the optimum dietary energy for Thai indigenous crossbred chickens and revealed that the energy requirement of chickens between 0 and 112 days old was 2600–3200 kcal ME/kg (Tangtaweewipat *et al*., 2000; Nguyen *et al*., 2010). The recommended dietary energy level for broilers less than 56 days old is about 3200 kcal ME/kg diet (NRC, 1994). Maliwan *et al*. (2018) declared that the optimal dietary energy contents for KRC from hatching to 21 days and from 22 to 42 days old were 3000 and 3175 kcal ME/kg, respectively. However, this recommendation may not be appropriate for KRC to achieve market weight at a later age (1.2 - 1.7 kg at 63 to 84 days). Therefore, the aim

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of this study was to investigate the effects of diets with different energy concentrations on the growth performance of slow-growing KRC chicken from 43 to 63 days old and from 64 to 84 days old.

The experiment was carried out in two phases. There were four dietary energy levels of 2750, 2900, 3050 and 3200 kcal ME/kg diet in both phases. Each treatment was replicated in six pens with a completely randomized design. A total of 1,200 one-day-old KRC chicks were housed in a naturally ventilated litter-based housing system using rice husk as litter. Each pen (1.75 × 2.40 m^2) consisted of a chick drinker and a tray feeder until seven days, then a round-bottom feeder and nipple-type drinker line were used until the end of the experiment. Feed and water were provided ad libitum. The experimental protocol for this study was reviewed and approved by the Animal Care and Use Committee of Suranaree University of Technology (SUT3-303-58-36-06).

In phase 1 (from 43 to 63 days old) 624 day-old mixed sex chicks, with a mean initial weight of 39 ± 0.42 g, were acquired from a hatchery and fed a commercial broiler diet, with 21% crude protein (CP) from hatching to when they were 21 days old, then a similar diet with 10% CP from 22 to 42 days old. At 43 days old, when the birds had a mean bodyweight (BW) of 796 ± 12.03 g, they were randomly distributed to four treatments (Table 1), with six replicates of 26 birds (13 males and 13 females) in each pen. All diets were formulated to comply or exceed the NRC (1994) recommended nutrient allowances except energy content. The birds had free access to these diets until they were 63 days old.

In phase 2, 576 one-day-old mixed sex chicks were reared together to the age of 63 days. The chicks were fed commercial broiler diets, which contained 21%, 19% and 17% CP from hatching to 21 days, from 22 to 42 days and from 43 to 63 days, respectively. At 64 days old, the birds had a mean weight of 1265 ± 20.44 g and were randomly distributed between the four energy treatments (Table 1), with six replicates of 24 birds each (12 males and 12 females) per pen. Birds had free access to diets until they were 84 days old.

Table 1 Ingredients of experimental diets with differing metabolizable energy concentrations for Korat chickens from 43 to 63 days old and from 64 to 84 days old (as-fed basis)

	Phase 1				Phase 2			
Calculated energy density, kcal ME/kg	2,750	2,900	3,050	3,200	2,750	2,900	3,050	3,200
Ingredients, g/kg								
Corn	502.2	506.0	510.8	515.0	526.3	556.1	560.6	565.0
Soybean meal, 44% crude protein	184.1	194.4	205.0	215.6	132.7	145.8	156.3	166.6
Defatted rice bran	171.9	138.2	103.1	68.4	196.5	139.7	105.0	70.8
Crude rice bran oil	1.3	21.1	40.8	60.6	0.9	15.0	34.8	54.5
Full-fat soybean	10.0	10.0	10.0	10.0	0.0	0.0	0.0	0.0
Cassava pulp	50.0	50.0	50.0	50.0	60.0	60.0	60.0	60.0
Meat and bone meal, 60% crude protein	60.0	60.0	60.0	60.0	60.0	60.0	60.0	60.0
Limestone	5.5	5.5	5.5	5.5	5.8	5.8	5.8	5.8
Monocalcium phosphate	4.8	4.8	4.8	4.8	5.0	5.0	5.0	5.0
DL-Methionine	1.1	1.1	1.1	1.2	1.6	1.6	1.6	1.6
L-Lysine HCL	0.1	0.0	0.0	0.0	1.6	1.5	1.4	1.3
L-Threonine	1.2	1.1	1.1	1.1	1.9	1.8	1.8	1.7
Sodium chloride	2.8	2.8	2.8	2.8	2.7	2.7	2.7	2.7
Vitamin-mineral premix[1]	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0

[1]Vitamin A: 15,000 IU, vitamin D_3: 3,000 IU, vitamin E: 25 IU, vitamin K_3: 5 mg, thiamine: 2 mg, riboflavin: 7 mg, pyridoxine: 4 mg, vitamin B_{12}: 25 mg, pantothenic acid: 11.04 mg, niacin: 35 mg, folic acid: 1 mg, biotin: 15 µg, choline chloride: 250 mg, copper: 1.6 mg, manganese: 60 mg, zinc: 45 mg, iron: 80 mg, iodine: 0.4 mg, selenium: 0.15 mg

The BW and FI of each replicate were recorded at the start and end of each period. These data were then used to determine the average daily FI, BW gain, FCR, and protein and metabolizable energy (ME) intakes. The energy efficiency ratio (EER) was calculated in grams of (weight gain × 100)/total ME intake). AOAC (1990) methods were used to measure moisture, CP, ether extract, crude fibre, and ash in feedstuffs and experimental diets.

Table 2 shows the dry matter, CP, and crude fibre contents of the diets, and their values for digestible lysine, methionine and methionine plus cysteine. These values were based on information from NRC (1994) and Leeson & Summer (2005).

Table 2 Nutrient composition of experimental diets with various metabolizable energy concentrations for Korat chickens from 43 to 63 days old and from 64 to 84 days old (as-fed basis)

	Phase 1				Phase 2			
Calculated energy density, kcal ME/kg	2,750	2,900	3,050	3,200	2,750	2,900	3,050	3,200
Dry matter, g/kg	907	907	910	908	910	908	905	905
Crude Protein g/kg	188	188	189	189	169	168	168	169
Crude fibre, g/kg	52	49	45	41	53	47	44	40
Digestible lysine, g/kg	8.5	8.5	8.6	8.7	8.5	8.5	8.5	8.5
Digestible methionine, g/kg	3.8	3.8	3.8	3.9	4.1	4.1	4.1	4.1
Digestible methionine + cysteine, g/kg	6.0	6.0	6.0	6.0	6.0	6.0	6.0	6.0

Data were analysed with analysis of variance for a completely randomized design using SAS (SAS Institute Inc., Cary, North Carolina, USA). Tukey's test was used to compare treatment means. Differences between treatments were deemed significant when P <0.05. To estimate the ME requirements, a broken-line regression analysis (Robbins *et al*., 2006) was performed to evaluate four dietary ME levels required to provide minimum values of FCR, using the PROC NLIN procedure of SAS. The broken-line regression analysis was expressed as

$$Y = \beta_0 + \beta_1 \times (\beta_2 - X),$$

Where: Y = FCR (dependent variable),
X = dietary ME content (kcal/kg) (independent variable),
β_0 = the value at plateau,
β_1 = the slope at the breaking point, and
β_2 = ME requirement (kcal/kg).

The estimates of this function are valid if $X < \beta_2$, when $X > \beta_2$, $Y = \beta_0$. Differences were considered significant at P <0.05.

When the birds were from 43 to 63 days old, the treatments resulted in significantly reduced FI and FCR (P <0.05), with no significant responses being observed in BW, BW gain, ME, and protein intakes or EER (P >0.05) (Table 3). Average FI declined by approximately 8.2% when the caloric content of the diet was raised from 2750 to 3200 kcal ME/kg. However, the change in FI did not affect the energy intake (P =0.08). This slight difference in results between FI and energy intake may reflect a difference between the calculated energy value of the diets and their true levels of ME in which true ME content controls intake when feed consumption is determined by a chemostatic mechanism (Richards & Proszkowiec-Weglarz, 2007). This result indicated that the KRC aged 43 to 63 days had the ability to adjust their feed consumption for a steady energy intake to fulfil their requirements, as reported by Maliwan *et al*. (2018) from hatching to 21 days and from 22 to 42 days. Similarly, Infante-Rodríguez *et al*. (2016) reported that the level of dietary energy had no effect on performance. Thus, dietary energy content is a fundamental factor in poultry production. For example, Leeson and Summers (2005) revealed that birds can regulate energy intake when the feed contains between 2700 and 3300 kcal ME/kg.

Table 3 Growth and efficiency of Korat chickens that were 43 to 63 days old and were fed diets with various levels of metabolizable energy

Item	2750 kcal/kg	2900 kcal/kg	3050 kcal/kg	3200 kcal/kg	SE	*P*-value
43-day weight, g	799	795	797	791	5.06	0.657
63-day weight, g	1283	1302	1308	1,312	15.02	0.529
Bodyweight gain, g	483	508	511	521	44.12	0.205
Average daily feed intake, g/d	70.78^{a}	70.30^{ab}	67.81^{ab}	65.44^{b}	0.54	0.034
Feed conversion ratio, g/g	3.08^{a}	2.91^{b}	2.79^{c}	2.64^{d}	0.03	<0.001
Average daily ME intake, kcal/d	194.60	203.90	206.80	209.40	2.18	0.078
Energy efficiency ratio, g/100 kcal	11.82	11.85	11.76	11.85	0.10	0.911
Average daily CP intake, g/d	13.33	13.23	12.81	12.38	0.14	0.051
64-day weight, g	1262	1260	1275	1263	8.57	0.617
84-day weight, g	1703	1701	1727	1740	13.17	0.146
Body weight gain, g	441	442	453	476	9.25	0.050
Average daily feed intake, g/d	83.41^{a}	79.19^{ab}	78.05^{b}	77.93^{b}	0.47	0.009
Feed conversion ratio, g/g	3.97^{a}	3.77^{b}	3.63^{c}	3.44^{d}	0.03	<0.001
Average daily ME intake, kcal/d	229.39^{b}	229.64^{b}	238.05^{ab}	249.38^{a}	2.34	0.002
Energy efficiency ratio, g/100 kcal	9.16	9.16	9.05	9.09	0.09	0.720
Average daily CP intake, g/d	14.06^{a}	13.30^{ab}	13.14^{b}	13.15^{b}	0.12	0.009

^{a,b} Within a row, means with a common superscript were not different with probability *P* =0.05

Average FI of KRC from 64 to 84 days old decreased (*P* =0.010) with increased energy concentration, but, like the younger birds. BW gain was similar (*P* =0.1462) among treatments (Table 3). Again there was a gradual reduction in FCR, which occurred with the increased dietary energy concentration (*P* <0.001). A statistically significant increase in energy intake (*P* =0.002) was associated with the reduced FI. The energy intake was approximately 8.72% higher when the dietary energy concentration was raised from 2750 to 3200 kcal ME/kg diet. Thus, the decrease in FI of birds during this period did not fully compensate for the increase in dietary energy concentration. Although dietary energy plays an important role in regulating FI, many other factors affect the consumption of chickens, such as size and age, sex, stocking rate, flock size, temperature, light, activity, reproductive stage, feed palatability, anti-nutritional factors and water supply (Ferket & Gernat, 2006).

When the birds were from 64 to 84 days old, protein intake was reduced (*P* =0.009) as the concentration of dietary energy increased, but there were no significant treatment effects on BW gain. These results show that a diet that supplied a minimum of 5.3 g protein/100 kcal ME (in diet containing 3200 kcal ME/kg) was adequate to enable the birds to fully express their genetic potential. In fact, birds generally adapt their feed consumption to meet their energy requirements (Richards & Proszkowiec-Weglarz, 2007; Leeson & Summers, 2005). In line with this observation, the reduction of feed consumption at a high dietary energy level was observed in broiler chickens, Pekin ducks, and Japanese quails (Dozier III *et al*., 2011). Abouelezz *et al*. (2019) tested five dietary ME levels in slow-growing yellow-feathered male chickens from between 63 and 105 days old and found that a diet containing 3236 kcal ME/kg lowered feed consumption and improved feed efficiency relative to less energy dense diets.

The broken-line analysis implemented to estimate the optimal dietary ME content to minimize FCR of KRC over both periods produced a similar result, namely that a dietary energy density of approximately 3200 kcal ME/kg was optimal (Table 4). Compared with other slow-growing chickens at a similar age, the ME levels in the range of 2900 - 3236 kcal ME/kg were recommended (Tangtaweewipat *et al*., 2000; Nguyen *et al*., 2010; Abouelezz *et al*., 2019). Results from the present experiments conform to the NRC (1994) recommendations. In addition, Maliwan *et al*. (2018) reported that the dietary energy content to minimize FCR of KRC from hatching to 21 days old was 3,000 kcal ME/kg, whereas from 22 to 42 days old it was 3175 kcal ME/kg. The difference in optimum ME content between age groups might be related to an increase in maintenance energy requirements, which involve basal metabolism, temperature, thermoregulation and physiological activities such as feed digestion, blood circulation, tissue replacement and deposition (NRC, 1994; Leeson & Summers, 2005).

Table 4 Estimates of the metabolizable energy requirements of Korat chickens to minimize their feed conversion ratio

Item	Regression equations[1]	SE	*P*-value	R^2
43 to 63 days old	FCR = 2.6367 + 0.00097 × (3,199.4 - ME)	47.4	<0.001	0.89
64 to 84 days old	FCR = 3.4400 + 0.00116 × (3,199.5 - ME)	54.2	<0.001	0.86

ME: dietary metabolizable energy content (kcal/kg), FCR: feed conversion ratio

Based on the estimated daily ME requirement, KRC require about 2.83 times less ME than commercial broiler chickens (209 as opposed to 592 kcal/bird/d) when they are 43 to 63 days old. In fact, commercial broiler chickens consume about 2.30 times more feed than the KRC to reach the highest growth rate and meat yield. In this study, it was revealed that the energy requirement of KRC aged 43 to 63 days old and 64 to 84 days old expressed as gram of BW gain were 8.44 and 11.00 kcal ME, whereas the optimum energy for broilers during the finisher period (43 to 63 days) was 9.70 kcal/g of BW gain (NRC, 1994). Richards and Proszkowiec-Weglarz (2007) stated that this result might be because the genetic selection in developing the modern broiler chicken altered the regulation of FI in these birds.

The findings of this study revealed that the FCR value did not reach a plateau in both age periods. However, when other factors such as feed cost were considered, dietary energy concentrations in a range of 2750 to 3200 kcal ME/diet might be regarded as sufficient for the KRC between hatching and 42 days old (Maliwan *et al.*, 2018)

In conclusion, the dietary ME content for KRC to achieve optimum FCR should be 3200 kcal ME/kg from 43 to 84 days old, based on diets that contain 5.9 and 5.3 g of protein/100 kcal ME from 43 to 63 days old and from 64 to 84 days old, respectively. These observations could lead to further applications in slow-growing chickens that have similar growth rates to KRC to maximize feed efficiency and reduce production costs. Future research is needed to extend the dietary energy content to levels beyond 3200 Kcal ME/kg to achieve greater precision in the energy requirements of slow-growing chickens.

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Authors' Contributions

SK and PM designed research. CP and PP conducted experiment. SO analysed the data. PM and CP implemented the broken-line model. SK and PM wrote manuscript. All authors read and approved the manuscript.

Conflicts of Interest Declaration

The authors declare that they have no conflict of interest.

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