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REGULAR ARTICLES

Effect of energy density of diet on growth performance of Thai indigenous (50% crossbred) Korat chickens from hatch to 42 days of age

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Abstract

The aim of the current study was to investigate the effect of the energy density of diet on the growth performance of Thai indigenous crossbred (50%) chickens known as Korat chicken (KRC). A total of 1440 mixed-sex KRC (720 birds in each phase) were randomly allocated to 4 dietary treatments containing 2750, 2900, 3050, or 3200 kcal ME/kg diet with 6 replicates of each treatment in a completely randomized design. The experimental diets were tested from hatch to 21 days and from 22 to 42 days of age. In both age groups, body weight gain was not affected ($P > 0.05$) by the ME density of the diets. Feed intake however decreased with increasing (metabolizable energy) ME ($P < 0.05$), thereby significantly improving the feed conversion ratio (FCR). Broken-line analysis was performed to estimate the ME content of feed to obtain minimum FCR and maximum protein efficiency ratio (PER) values. Minimum FCR and maximum PER values were found when the diet contained 3000 kcal ME/kg from hatch to 21 days of age and 3175 kcal ME/kg from 22 to 42 days of age, respectively, using diets containing 7.5 and 6.6 g of protein/100 kcal ME, respectively. In conclusion, we established that the ME requirements of KRC from hatch to 21 days and 22 to 42 days of age were 3000 and 3175 kcal/kg, respectively.

Keywords Growth performance · Indigenous crossbred chicken · Metabolizable energy · Requirement

Introduction

To date, public concern is increasing about the use of modern broiler genotype to produce chicken meat and a tendency exists towards the preferential consumption of meat that originates from slow instead of fast growing broilers (Jaturasitha et al. 2008; Dyubele et al. 2010). Furthermore, meat produced by modern broiler genotype instead of indigenous breeds is perceived as less palatable, at least in Southeast Asian countries, including Thailand (Choprakarn and Wongpichet 2008; Wattanachant 2008). Therefore, the initiative was taken in Thailand to breed a new genotype of broilers complying with the consumer's demand. Male Thai indigenous fighting cocks (Leung Hang Khoa) and females from modern genotype breeder lines such as Ross were crossed to produce the Korat chicken (KRC). The meat produced by KRC is highly appreciated by the local consumers and market prices are up to two times higher than for meat from modern broiler genotypes. The KRC can reach a marketable live weight of 1.2–1.7 kg after 63 to 84 days of age, while native chicken can reach a weight of 1.2 kg only at 112 days of age (Jaturasitha et al. 2008).

Energy density is an important determinant of the feed costs per unit of poultry product, and it is well known that a high energy density of the feed sustained low feed intakes and improved the feed conversion ratio (FCR) in poultry (Fan et al. 2008; Dozier et al. 2011; Wickramasuriya et al. 2015). On the other hand, it cannot be excluded that the intake of feed with high energy density leads to excess intake of energy, thereby causing greater deposition of abdominal fat or carcass fat (Summers et al. 1992; Fan et al. 2008; Dozier et al. 2011),

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leading to a reduced growth performance. Previous studies reported that the energy requirements of various Thai indigenous crossbred chickens during 0−112 days of age were about 2600−3200 kcal ME/kg (Tangtaweewipat et al. 2000; Pingmuang et al. 2001; Chomchai et al. 2003; Nguyen and Bunchasak 2005; Nguyen et al. 2010), while NRC (1994) recommended a level of ME of 3200 kcal/kg for broilers up to 56 days of age. The genetic profile of KRC can be considered unique, but until now, there is no published information about the optimum energy density of feed required to efficiently use the genetic potential of KRC to produce meat. The objective of the current study was therefore to investigate the effect of energy density of the diet on growth performance of KRC from hatch to 21 days and from 22 to 42 days of age.

Materials and methods

Animal care and treatment

Two phases were conducted in order to investigate the effect of energy density of diet in KRC (from hatch to 21 days and from 22 to 42 days of age). A total of 1440 1-day-old KRC were obtained from a local hatchery. All chicks were vaccinated at the hatchery against Marek's disease (FATRO S.p.A., Bologna, Italy). On days 7 and 21, the birds were inoculated with Newcastle disease and infectious bronchitis vaccines (FATRO S.p.A., Bologna, Italy). On day 14, the birds were vaccinated against infectious bursal disease vaccine (FATRO S.p.A., Bologna, Italy) and on day 35 against flow pox (FATRO S.p.A., Bologna, Italy). All procedures of our experiment were conducted according to the principles and guidelines approved by the Animal Care and Use Committee of Suranaree University of Technology.

In phase 1, the aim of this study was to evaluate the effect of energy density of diets in KRC from hatch to 21 days of age. A total of 720 1-day-old mixed-sex KRC were randomly allocated to 4 dietary treatments with 6 replicates of 30 birds per pen (1.75×2.40 m^2). The experimental diets having 4 energy density levels (2750, 2900, 3050, and 3200 kcal ME/kg diet) and containing 24% crude protein (Table 1) were fed until 21 days of age. With the exception of the energy density, all experimental diets were formulated to meet the nutrient requirements as recommended by the NRC (1994) and they were fed in a mash form. Each pen was equipped with a nipple-type drinker line (7 nipples), and until day 14, a tray feeder was used to supply feed. From day 15 onwards, a round-bottomed feeder was used. Both feed and water were available for ad libitum consumption throughout the experiment. All birds were raised in an open-sided, naturally ventilated barn, with a 23-h photoperiod using a fluorescent bulb as a light source, and they were housed on a floor covered by rice husks disinfected with a disinfectant solution (glutaraldehyde). Brooding heat was provided throughout this phase by using an infrared heat lamp bulb 175 W above the birds (one for each pen). A brooding temperature of 35 °C was provided for the first week and reduced by 3° every week until reaching room temperature.

In phase 2, this study was conducted to determine the effect of energy density in diet of KRC from 22 to 42 days of age. The remaining 720 of 1-day-old mixed-sex KRC were initially fed with a commercial broiler diet (CPF Public Company Ltd., Nakhon Ratchasima, Thailand) containing 3300 kcal ME/kg diet (21% crude protein (CP), as fed) from hatch to 21 days of age. At day 22, these birds were randomly allocated to the experimental diets that contained 21% CP (as fed) and 4 energy density levels (2750, 2900, 3050, and 3200 kcal ME/kg diet) (Table 2). The diets were fed until the birds were 42 days of age. Each dietary treatment contained 6 replicates with 30 birds per pen (1.75×2.40 m^2). Feed and water were provided ad libitum throughout the experiment. All bids were raised under the same conditions than for phase 1.

Data collection and analysis

Feed intake and body weight (BW) were recorded throughout the experimental period. Feed intake and BW gain were corrected for mortality which was found to be 0.28% in both periods. Upon arrival, the experimental diets were sampled (about 500 g) in duplicate and samples were stored (about 5 °C) until analysis. The DM content of the experimental diets was determined by drying at 135 °C for 3 h (AOAC 1990; ID 930.15). The ash content was analyzed by combustion at 550 °C for 3 h (AOAC 1990; ID 942.05), and nitrogen content was determined by the macro Kjeldahl method (AOAC 1990; ID 988.05) and the factor 6.25 used to convert nitrogen into CP. Ether extract and crude fiber were determined as described by the AOAC (1990) procedures ID 920.39 and ID 962.09, respectively.

Statistical analysis

All data were analyzed by means of one-way ANOVA using SAS software (SAS Institute 1996), after checking for normality of the distributions. When the influence of dietary treatments reached statistical significance, Tukey's posttest was used to evaluate the specific effect of each ME level. A broken-line regression analysis (Robbins et al. 2006) was used to estimate the required ME content of feed needed to provide constant values of FCR or the protein efficiency ratio (PER) using the NLIN procedure of SAS software. The broken-line model

$$y = L + U \times (R - x)$$

was used in which y = FCR or PER (dependent variable); x = dietary ME content (kcal/kg) (independent variable); R = required dietary ME content (kcal/kg); L = the response at x =

Table 1 Ingredient and nutrient composition of the experimental diets fed to Korat chickens from hatch to 21 days of age

	Experimental diets (0 to 21 days)			
	1	2	3	4
Ingredient (% of total diet)				
Corn	36.74	37.10	37.59	38.60
Soybean meal, 44% CP	31.20	32.25	33.30	34.43
Extracted rice bran	13.99	10.58	7.08	3.09
Rice bran oil	2.11	4.10	6.07	7.92
Meat meal, 60% CP	6.00	6.00	6.00	6.00
Full-fat soybean	4.00	4.00	4.00	4.00
Cassava pulp	3.00	3.00	3.00	3.00
Calcium carbonate, $CaCO_3$	0.80	0.80	0.80	0.80
Monocalcium phosphate, $Ca(H_2PO_4)_2$	0.85	0.85	0.85	0.85
DL-Methionine	0.30	0.31	0.31	0.31
L-Threonine	0.06	0.06	0.05	0.05
Salt	0.45	0.45	0.45	0.45
Premix[1]	0.50	0.50	0.50	0.50
Analyzed composition, % as fed				
Dry matter	91.4	91.6	91.2	91.1
Ash	8.6	8.2	7.7	7.1
Crude protein	24.0	24.0	23.8	24.0
Crude fiber	5.3	4.9	4.6	4.1
Ether extract	5.4	7.3	8.8	10.6
Calculated composition, % as fed				
Metabolizable energy, kcal/kg as fed[2]	2750	2900	3050	3200
Digestible lysine	1.15	1.16	1.17	1.18
Digestible methionine	0.62	0.63	0.63	0.63
Digestible methionine + cystine	0.90	0.90	0.90	0.90
Digestible threonine	0.80	0.80	0.80	0.80
Digestible tryptophan	0.27	0.28	0.28	0.28
Calcium	1.00	1.00	1.00	1.00
Available phosphorus[3]	0.52	0.52	0.52	0.53

[1] Premix (1 kg): vitamin A, 15,000 IU; vitamin D_3, 3000 IU; vitamin E, 25 IU; vitamin K_3, 5 mg; vitamin B_1, 2 mg; vitamin B_2, 7 mg; vitamin B_6, 4 mg; vitamin B_{12}, 25 mg; pantothenic acid, 11.04 mg; nicotinic acid, 35 mg; folic acid, 1 mg; biotin, 15 μg; choline chloride, 250 mg; Cu, 1.6 mg; Mn, 60 mg; Zn, 45 mg; Fe, 80 mg; I, 0.4 mg; Se, 0.15 mg

[2] The values were calculated on the basis of the ME values of the individual ingredients (NRC 1994; Leeson and Summers 2005)

[3] Available phosphorus = total P − phytate-P

R; and U = the slope of the curve. In this model, $y = L$ when $x > R$. Throughout, statistical significance was preset at $P \leq 0.05$.

Results and discussion

Growth performance from hatch to 21 days of age (phase 1)

Body weight gain was not significantly affected by the energy density of the diet (Table 3) while the feed intake decreased significantly ($P < 0.001$) with increasing energy density. Consequently, energy intake was found to be similar ($P = 0.857$) between the experimental diets. This observation indicates that the birds were able to keep their energy intake constant within a range of 2750 to 3200 kcal ME/kg in order to meet their requirement. This observation is corroborated by Leeson and Summers (2005), who also showed that energy intake was independent from the energy density of the feed within a range of 2700 to 3300 kcal ME/kg. In general, birds can adjust their feed intake to primary meet the energy requirements and changing demands for calories (Golian and

Table 2 Ingredient and nutrient composition of the experimental diets fed to Korat chickens from 22 to 42 days of age

	Experimental diets (22 to 42 days)			
	1	2	3	4
Ingredient (% of total diet)				
Corn	43.22	43.60	44.05	44.50
Soybean meal, 44% CP	23.49	24.52	25.57	26.62
Extracted rice bran	17.46	14.09	10.63	7.18
Rice bran oil	1.34	3.33	5.30	7.27
Meat meal, 60% CP	6.00	6.00	6.00	6.00
Full-fat soybean	2.00	2.00	2.00	2.00
Cassava pulp	4.00	4.00	4.00	4.00
Calcium carbonate, $CaCO_3$	0.71	0.71	0.71	0.71
Monocalcium phosphate, $Ca(H_2PO_4)_2$	0.60	0.60	0.60	0.60
DL-Methionine	0.19	0.19	0.19	0.19
L-Lysine	0.06	0.04	0.03	0.01
L-Threonine	0.11	0.10	0.10	0.10
Salt	0.32	0.32	0.32	0.32
Premix[1]	0.50	0.50	0.50	0.50
Analyzed composition, % as fed				
Dry matter	91.5	91.3	90.9	90.8
Ash	7.5	7.1	6.8	6.6
Crude protein	20.9	20.8	20.9	20.7
Crude fiber	5.4	5.0	4.6	4.3
Ether extract	4.4	6.3	8.4	10.3
Calculated composition, % as fed				
Metabolizable energy, kcal/kg as fed[2]	2750	2900	3050	3200
Digestible lysine	1.01	1.01	1.00	1.00
Digestible methionine	0.48	0.48	0.48	0.48
Digestible methionine + cysteine	0.72	0.72	0.72	0.72
Digestible threonine	0.74	0.74	0.74	0.74
Digestible tryptophan	0.22	0.22	0.23	0.23
Calcium	0.90	0.90	0.90	0.90
Available phosphorus[3]	0.44	0.45	0.45	0.45

[1] Premix (1 kg): vitamin A, 15,000 IU; vitamin D_3, 3000 IU; vitamin E, 25 IU; vitamin K_3, 5 mg; vitamin B_1, 2 mg; vitamin B_2, 7 mg; vitamin B_6, 4 mg; vitamin B_{12}, 25 mg; pantothenic acid, 11.04 mg; nicotinic acid, 35 mg; folic acid, 1 mg; biotin, 15 μg; choline chloride, 250 mg; Cu, 1.6 mg; Mn, 60 mg; Zn, 45 mg; Fe, 80 mg; I, 0.4 mg; Se, 0.15 mg

[2] The values were calculated on the basis of the ME values of the individual ingredients (NRC 1994; Leeson and Summers 2005)

[3] Available phosphorus = total P − phytate-P

Maurice 1992; Leeson et al. 1993). Normally, energy concentration in diets plays a key role in the control of feed intake (MacLeod 1997). Other factors are regulating the feed intake, such as size and age, environmental temperature, photoperiod, activity, stage of reproduction, feed palatability, dietary factors, dietary toxicities, and availability of water (Ferket and Gernat 2006). The FCR decreased ($P <$ 0.001) by 13.4% with increasing energy density while the energy efficiency ratio (EER) was not affected ($P =$ 0.398) by the energy density of the diets because energy intake was steady, resulting in similar BW gain that was similar between the experimental treatments.

The experimental diets were formulated to be iso-nitrogenous. Consequently, protein intake dropped by 12.4% when the energy density increased from 2750 to 3200 kcal ME/kg diet. The ingestion of the diet containing 3200 kcal/kg however provided 7.5 g protein/100 kcal ME, and this value is still 4.3% higher than the value that can be calculated on the basis of NRC (1994) recommendations. It can therefore be speculated that protein gain was not limited by the amount of

Table 3 Effects of dietary energy on growth performance of Korat chickens from hatch to 21 days and from 22 to 42 days of age

	Energy density of the diet (kcal/kg)				SEM[1]	*P* value
	2750	2900	3050	3200		
From hatch to 21 days of age						
Body weight, g						
Post hatch	39	39	39	39	0.18	0.570
21 days old	271	279	279	274	2.60	0.116
Body weight gain, g	232	240	240	235	2.59	0.131
Feed intake, g	416^{a}	395^{ab}	378^{bc}	365^{c}	7.02	< 0.001
FCR, g/g	1.79^{a}	1.64^{b}	1.58^{b}	1.55^{b}	0.03	< 0.001
Energy intake, kcal ME	1143	1146	1153	1167	21.04	0.857
EER, g/100 kcal[2]	20.35	20.98	20.79	20.19	0.36	0.398
Protein intake, g	99.7^{a}	94.7^{ab}	90.1^{bc}	87.4^{c}	1.68	< 0.001
PER, g/g[3]	2.33^{b}	2.54^{a}	2.66^{a}	2.70^{a}	0.05	< 0.001
From 22 to 42 days of age						
Body weight, g						
22 days old	277	279	278	278	2.07	0.843
42 days old	784	792	792	794	4.42	0.393
Body weight gain, g	507	512	514	517	3.12	0.188
Feed intake, g	1,104^{a}	1,056^{b}	1,021^{bc}	989^{c}	10.52	< 0.001
FCR, g/g	2.18^{a}	2.06^{b}	1.99^{c}	1.91^{d}	0.02	< 0.001
Energy intake, kcal ME	3,036^{b}	3,062^{ab}	3,113^{ab}	3,166^{a}	30.91	0.036
EER, g/100 kcal	16.71	16.74	16.52	16.33	0.14	0.166
Protein intake, g	230.9^{a}	219.9^{b}	213.4^{bc}	205.0^{c}	2.19	< 0.001
PER, g/g	2.20^{d}	2.33^{c}	2.41^{b}	2.52^{a}	0.02	< 0.001

Means within each row with different superscripts are significantly different ($P < 0.05$)

[1] Standard error of the mean ($n = 6$)

[2] EER, energy efficiency ratio calculated as grams of BW gain/energy intake

[3] PER, protein efficiency ratio calculated as grams of BW gain/grams of protein intake

protein that was supplied at the lowest level of protein intake. This speculation is corroborated by the observation that the drop of protein intake did not affect BW gain of the birds. This observation also explains the increase of PER ($P < 0.001$) with increasing energy density of the feed. Moreover, it is well known that a shift from protein gain to fat gain has a major negative impact on BW gain due to the fact that the retention of 1 g of protein vs. fat results in a 3.5-fold higher BW gain due to the protein-associated retention of water (Boekholt et al. 1994). This result also implies that relative CP intake of 7.5 g/100 kcal is sufficient to meet the bird's genetic capacity for protein gain.

Growth performance from 22 to 42 days of age (phase 2)

Body weight gain was similar ($P = 0.188$) between experimental treatments (Table 3) but feed intake declined ($P < 0.001$) with increasing energy density. In line with these observations, FCR was found to be negatively related to the energy density of the feed ($P < 0.001$). The decline in feed intake did not fully counteract the increase in energy density of the feed, and energy intake was found to be 4.3% greater ($P = 0.036$) when the feed contained 3200 instead of 2750 kcal ME/kg, without affecting the BW gain. Since iso-nitrogenous diets were fed, it is obvious that PER was positively related ($P < 0.001$) with the ME content of the feed. It can therefore be suggested that the protein gain of the older birds was not limited at the lowest level of protein intake. This suggestion is in line with the fact that the diet provided at least 6.6 g protein/100 kcal ME (3200 kcal/kg) which is 5.0% higher than the value recommended by NRC (1994). This is in line with the observation that EER was not affected ($P = 0.166$) by the experimental diets. The FCR and PER were improved with the increasing levels of dietary energy. In fact, although birds were able to adapt their feed intake to fulfill the energy requirement, other nutrients such as protein which were balanced between diets may excess the birds' requirements, resulting in reduced feed efficiency. Similar results of feed intake in high energy concentration diets were also found in broilers, Pekin ducks, and Japanese quails (Fan et al. 2008; Dozier et al. 2006, 2011).

Broken-line analysis

From hatch to 21 days of age, FCR ratio and PER became constant when estimated ME contents were 2978 or 3003 kcal ME/kg of feed, respectively, while corresponding values of the birds from 22 to 42 days of age were estimated to be 3151 or 3194 kcal ME/kg of feed (Table 4). Given the standard errors of the regression lines (Table 4), the respective values could be rounded at 3000 and 3175 kcal/kg of feed. Thus, the estimated ME content of the diet to obtain minimum FCR was found to be 5.5% lower from hatch to 21 days of age compared to later phase (22 to 42 days of age). This discrepancy in energy density between the two age groups cannot be easily explained but it can be suggested that it is, at least partly, related to an increase in energy requirement for maintenance. Indeed, it was shown by Leeson and Summers (2005) and Sales and Du Preez (1997) that the energy requirement for maintenance of the broilers from 19 to 30 days of age was 1.64% higher than that of the broilers from hatch to 18 days of age. Furthermore, the energy requirements for optimum growth can be varied according to the different chicken breeds, which should be related to the differences in the growth rate, body size, and body compositions (NRC 1994; Zhao et al. 2009). Although in this study the FCR and PER values in both periods did not appear to reach a plateau, increasing energy density above 3200 kcal ME/diet may still improve the FCR and PER. However, when considering other parameters such as feed cost/BW gain, it was shown a decreased value when the dietary energy density reached 3200 kcal ME/diet. This implies that the energy density within a range 2750 to 3200 kcal ME/diet might be deemed appropriate for investigating in KRC.

Predicted minimum FCR values were found to be 1.57 and 1.92 for phases 1 and 2, respectively, while respective maximum PER values were calculated to be 2.68 and 2.52. In modern genotype birds however, lower FCR and higher PER values are commonly found at the same phases (i.e., FCR values of 1.39 and 1.76, respectively; PER values of 3.15 and 2.78, respectively) (Zhao et al. 2009). Clearly, current data do not provide clues to explain these discrepancies but it can be speculated that the differences in FCR and PER are related to growth rate and difference in growth composition (i.e., protein and fat gain per unit of BW gain) between the two genotypes of broilers. To the author's knowledge however, comparative slaughter data between modern genotype broilers and KRC are currently not available to substantiate speculation on growth composition.

Table 4 Metabolizable energy requirement of Korat chickens based on broken-line model analyses from hatch to 21 days and from 22 to 42 days of age

Items	Regression equations[1]	SE[2]	*P* value	R^2
From hatch to 21 days of age				
FCR, g/g	$y = 1.566 + 0.000989 \times (2978 - x)$	52.7	< 0.001	0.65
PER, g/g	$y = 2.677 - 0.001360 \times (3003 - x)$	64.6	< 0.001	0.65
From 22 to 42 days of age				
FCR, g/g	$y = 1.915 + 0.000639 \times (3151 - x)$	45.8	< 0.001	0.85
PER, g/g	$y = 2.523 - 0.000720 \times (3194 - x)$	47.9	< 0.001	0.88

[1] The linear broken-line model is $y = L + U \times (R - x)$, where y = feed to gain or protein efficiency ratio; x = dietary ME content (kcal/kg); R = required dietary ME content (kcal/kg) to become constant values of feed to gain or protein efficiency ratio; L = the response at $x = R$; and U = the slope of the curve. In this model, $y = L$ when $x > R$

[2] SE, standard error

In conclusion, optimal FCR and PER values were obtained in KRC when the diet contained 3000 kcal ME/kg from hatch to 21 days of age and 3175 kcal ME/kg from 22 to 42 days of age, respectively, using diets containing 7.5 and 6.6 g of protein/100 kcal ME, respectively. Since the use of crossbred chicken is a worldwide tendency in tropical and subtropical areas, we believe that these observations might benefit to other breeding systems involving crossbred chicken with growth rates similar to KRC to optimize the feed efficiency and cost at early ages.

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Compliance with ethical standards

All procedures of our experiment were conducted according to the principles and guidelines approved by the Animal Care and Use Committee of Suranaree University of Technology.

Conflict of interest The authors declare that they have no conflict of interest.

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