Agr. Nat. Resour. 54 (2020) 121–129

AGRICULTURE AND NATURAL RESOURCES

Journal homepage: http://anres.kasetsart.org

Research article

Proper dietary crude protein and metabolizable energy levels on growth performance, carcass characteristics and meat quality of Royal Project Bresse capon

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Article Info

Article history:
Received 21 September 2019
Revised 25 December 2019
Accepted 27 January 2020
Available online 24 April 2020

Keywords:
Bresse,
Capon,
Metabolizable energy,
Protein,
Royal Project Foundation

Abstract

The optimum crude protein (CP) and metabolizable energy (ME) levels were determined in a Bresse capon diet. In each trial, 120 Bresse cockerels aged 4 wk were castrated using the laparoscopic vacuum testectomy technique and allotted to four dietary groups according to a 2 × 2 factorial complete randomized design. Trial 1 (age 5–10 wk) consisting of a high CP diet (21%) promoted significantly higher final body weight (FBW), body weight gain (BWG), average daily gain (ADG), CP and ME intake with a better feed conversion ratio (FCR) than a low CP diet (19%), while a high ME diet (3.3 kcal ME/g) resulted in significantly lower feed intake (FI) and CP intake but promoted better FCR than a low ME diet (3.0 kcal ME/g). There was no interaction between the CP and ME levels for all parameters ($p > 0.05$). Trial 2 (age 11–13 wk) resulted in the high CP diet (19%) promoting significantly ($p < 0.05$) better FBW, BWG, FCR, ADG, CP intake, percentage of carcass, breast, thigh, liver, drumstick and breast moisture content than the low CP diet (17%). In contrast, the low ME diet (3.0 kcal/g) significantly ($p < 0.05$) provided higher FI, FBW, thigh moisture and fat, BWG, ADG, CP intake, breast moisture content and fat but lower abdominal fat, thigh meat and breast shear force than the high ME diet (3.3 kcal/g). There were interactions between the main factors on FI, FCR, ME intake and thigh meat. In conclusion, the optimum diet for Bresse capon aged 5–10 wk should contain 21% CP with 3.3 kcal ME/g and for age 11–13 wk should contain 19% CP with 3.0 kcal ME/g to achieve the best performance of the tested parameters.

Introduction

Capon, a castrated male chicken, is popular among consumers in many Asian countries such as Thailand, Malaysia, Singapore and China due to the meat being juicy, more tender and having a better flavor than that of a normal chicken (Jacob and Mather, 2000). Caponization has diverse effects on hepatic lipogenic enzyme activity and growth performance and also results in increased intramuscular and abdominal fat (Chen et al., 2006). Furthermore, it produces higher body weight (BW), carcass weight, breast weight and liver weight than intact chickens (Lin and Hsu, 2003; Duran, 2004; Symeon et al., 2010) with an improved feed conversion ratio (FCR) and fatty acid composition of the thigh muscle (Mašek et al., 2013). There is also an evident effect on meat quality regarding the color and intramuscular fat (Lin and Hsu, 2003) and shear values (Mast et al., 1981; Symeon et al., 2010). However, Shao et al. (2009) and Adamski et al. (2016) did not

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https://doi.org/10.34044/j.anres.2020.54.2.02

observe an increase in the body weight (BW) of caponized rooster. These inconsistent results might be attributed to the differences in breed/genotype, castration age, feeding level, rearing conditions and slaughter age of the birds studied (Calik, 2014).

Bresse chicken raised by the Royal Project Foundation (RPF) commenced as a present from France to HM King Bhumibol Adulyadej of Thailand in 1990 (Tangtaweewipat et al., 2008). The meat of Bresse is considered to be tighter and having a better flavor than broiler meat (Tangtaweewipat et al., 2008). It was introduced to highland farmers as an alternative economic animal due to its higher price than for a broiler (Tangtaweewipat et al., 2014). Castration of Bresse chicken is expected to produce a value-added product from the RPF to serve the high-end market and at the same time give better income to farmers. RPF poultry farming seeks for effective alternatives to reduce farming costs and improve production (Tangtaweewipat, 2014).

Tangtaweewipat et al. (2008) reported that the optimum diet for mixed sex Bresse chickens during ages 0–5 wk, 6–9 wk and 10–13 wk should contain 3.2 kcal metabolizable energy (ME)/g with 23%, 21% and 19% crude protein (CP), respectively. Rikimaru et al. (2011) suggested that the diets for Hinai-jidori capons aged 4–10 wk should contain 18% CP and 2.85 kcal ME/g and aged 10–26 wk should contain 16% CP and 2.9 kcal ME/g to achieve the highest average daily gain (ADG). Duran (2004) reported that Extremeña Azul capons fed with 18.2% CP and 2.9 kcal ME/g at age 6–32 wk had more breast meat and greater tenderness than roosters. However, no reports have been published to date on the proper dietary levels of CP and ME for Bresse capon performance and carcass quality; therefore this research work was carried out.

Materials and Methods

Birds and experimental design

Trial 1 (age 5–10 wk)

In total, 300 Bresse chickens from the RPF, Chiang Mai, Thailand aged 2 wk were used as experimental animals. They were raised in an open house on a highland farm at 800 m above mean sea level and fed on a commercial diet containing 21% CP and 3.2 kcal ME/g until age 4 wk. At the end of week 4, around 150 male birds were selected for castration using the Laparoscopic vacuum testectomy technique (Songsee et al., 2020). Of these birds, 120 healthy capons were allotted to four dietary groups according to a 2 × 2 Factorial arrangement in a Completely randomized design. The birds were raised in a litter floor pen containing 10 birds per 2.25 m^2. Each group was fed with one of the four diets containing either 19% or 21% CP with either 3.0 kcal ME/g or 3.3 kcal ME/g until age 10 wk (Table 1). Production performance was recorded based on body weight gain (BWG), feed intake (FI) and feed conversion ratio (FCR).

Trial 2 (age 11–13 wk)

In total, 300 Bresse chickens from the RPF, Chiang Mai, Thailand aged 2 wk were raised and fed with the same diet as in Trial 1 until age 4 wk. At the end of week 4, around 150 male birds were selected for castration using the Laparoscopic vacuum testectomy technique. They were raised until age 10 wk on 21% CP and 3.3 kcal ME/g according to the results of Trial 1. Then 120 healthy, completed castrated birds were selected and allotted to four groups according to a 2 × 2 Factorial arrangement in a Completely randomized design. Different groups of capon were fed on a diet containing either 17% or 19% CP with either 3.0 kcal ME/g or 3.3 kcal ME/g until age 13 wk (Table 1). Management and data collection were the same as in Trial 1. At the end of the trial, random samples of two birds from each pen were selected for slaughtering (Layfield et al., 1972). Carcass quality (weight and percentage of carcass as well as percentage of hot carcass of breast, thigh, drumstick, wing, liver and abdominal fat) was determined. Moisture and crude fat were analyzed according to the methods of Association of Official Analytical Chemists (2005) and the shear force was determined based on texture analysis (TA-HDi, Stable Micro Systems Ltd.; UK) in the thigh and breast meat.

Laparoscopic vacuum testectomy technique

At the end of age 4 wk, feed and water were removed at least 12 hr prior to the castration. The bird's legs and wings were fastened on an auto-locked table. Surgery was done using a scalpel (No.11), new spreader, hook and vacuum kit (Fig. 1A). Both testes were removed from the single incision using Laparoscopic vacuum testectomy. This was done by touching the tip of the head tube (3.92 mm) on the testes with clear view on a smart phone (Fig. 1B). Then the switch on the gun for activating the vacuum pump (flow rate 120 L/min) was pressed until the testes had been completely sucked into the bottle. After surgery, the incision was not stitched but the wound was disinfected with povidone-iodine solution (10% weight per volume). The air puff problem which occurred in some birds was addressed by repeatedly inserting a sharp-pointed knife into the wound.

Analytical methods

Initial values were calculated for BW, FBW, BWG, FI, FCR and carcass composition and meat quality. Statistical analyses were performed using the SAS University Edition software, using analysis of variance. Differences between means were tested using Duncan's new multiple range test for significance at the $p < 0.05$ level.

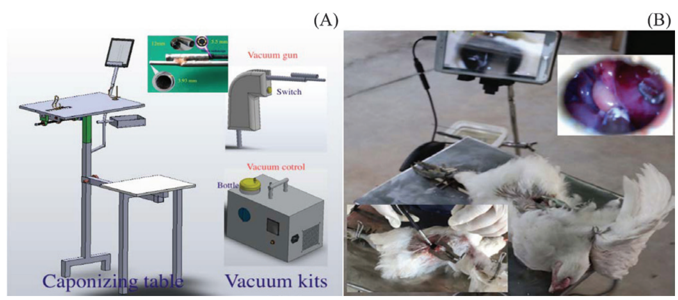

Fig. 1 Laparoscopic vacuum testectomy: (A) New caponizing kit; (B) Caponizing method

Table 1 Percentage ingredients and composition of experimental diets for Royal Project Bresse capon

Ingredient	Age 5–10 wk				Age 11–13 wk			
	1	2	3	4	1	2	3	4
Ground corn	54.47	62.39	61.52	57.48	66.00	60.50	64.40	65.39
Rice polishing	12.68	5.00	5.00	5.00	7.43	10.32	5.00	5.00
Soybean meal	14.74	5.00	25.00	5.00	20.53	5.00	24.22	10.00
Full fat soybean	9.17	19.48	–	22.22	–	15.57	–	6.77
Fish meal (61% CP)	5.00	5.84	7.15	8.19	3.00	5.00	4.00	10.00
Soybean oil	–	0.57	–	1.01	–	1.52	–	1.99
Dicalcium P14	0.36	0.19	–	–	1.00	0.35	0.73	–
Ground oyster shell	3.00	0.75	0.61	0.38	0.87	0.86	0.85	0.06
Salt	0.10	0.14	0.14	0.14	0.13	0.13	0.15	0.14
DL methionine	–	–	–	–	0.30	0.08	–	–
Threonine	0.05	0.11	0.05	0.05	0.18	0.05	0.09	0.09
L-lysine	–	–	–	–	–	0.06	–	–
Premix *	0.50	0.5	0.50	0.50	0.50	0.50	0.50	0.50
Ronozyme VP Enzyme**	0.03	0.03	0.03	0.03	0.06	0.06	0.06	0.06
Total	100	100	100	100	100	100	100	100
Nutrient composition (% air dry basis):								
Crude Protein	19.00	19.00	21.00	21.00	17.00	17.00	19.00	19.00
ME (kcal/g)	3.00	3.30	3.00	3.30	3.00	3.30	3.00	3.30
CF	4.41	3.54	3.96	3.58	4.01	3.93	3.95	3.37
EE	5.93	7.73	3.97	8.80	3.97	8.44	3.75	7.41
Ca	1.73	0.90	0.90	0.90	0.95	0.91	0.95	1.00
P, available	0.40	0.35	0.36	0.40	0.36	0.35	0.35	0.45
Met	0.42	0.42	0.59	0.42	0.75	0.38	0.51	0.46
Lys	1.07	1.06	1.20	1.22	0.91	1.00	1.11	1.16

ME = metabolizable energy; CF = crude fiber; EE = ether extract; Ca = calcium; P = phosphorus; Met = methionine; Lys = lysine.

* Provided per kilogram of diet: vitamin A, 2,000,000 IU; vitamin D_3, 400,000 IU; vitamin E, 3,509 IU; vitamin K_3, 0.180 g; vitamin B_1, 0.160 g; vitamin B_2, 0.800 g; pantothenic acid, 1.890 g; nicotinic acid, 4.000 g; vitamin B_6, 0.560 g; folic acid, 0.110 g; vitamin B_{12}, 0.002 g; biotin, 0.018 g; choline chloride, 95.000 g; Co, 0.060 g; Cu, 2.000 g; Fe, 12.000 g; I, 0.330 g; Mn, 16.000 g; Zn, 16.000 g; Se, 0.060 g; preservatives (feed quality), 25.000 g.

** Phytase enzyme 750,000 IU/kg.

Results

Growth performance

Trial 1 (age 5–10 wk): The effect of each factor (CP or ME levels) on performance is shown in Table 2. There was no significant difference among groups based on initial BW (IBW). At age 10 wk, capon fed 21% CP had significantly higher values for FBW, BWG and ADG and a better FCR than the 19% CP group, but there was no significant difference for FI per bird. The high ME diet (3.3 kcal/g) had a lower FI ($p < 0.01$) and thus resulted in a better FCR ($p < 0.01$) than the lower ME diet. However, no significant effect was found on FBW, BWG and ADG. Even though no significant interaction between the CP and ME levels was noticed for any parameter, there was a tendency for the capons fed on the high CP (21%) and high ME diet (3.3 kcal/g) to produce the highest FBW, BWG and ADG with the lowest FI, thus resulting in the best FCR compared to the other three groups.

Trial 2 (age 11–13 wk): Initial BW at the onset of week 11 and the performance of birds fed the four dietary groups are shown in Table 2. At the end of age 13 wk, capons fed the high CP diet (19%) had significantly higher FBW, BWG and ADG than those fed with the low CP diet (17%). In contrast, the birds fed with the low ME diet (3.0 kcal/g) had significantly higher BW, BWG and ADG than those fed with the high ME diet (3.3 kcal/g). No significant interaction between factors was found for these parameters. However, a significant interaction was found for FI and FCR. Capons fed the low ME and low CP diet had higher FI but this was not significantly different from the high CP group (101.85 g/bird/d versus 96.97 g/bird/d), while there was not a significant difference among the other three groups (96.97 g/bird/d versus 91.15 g/bird/d versus 94.99 g/bird/d). Therefore, the group fed with the low CP and low ME diet had the worst FCR, while there were no significant differences among the other three groups.

Crude protein and metabolizable energy intake

Trial 1 (age 5–10 wk): the CP and ME intakes of all four groups are shown in Table 3. No significant interactions were found between the dietary CP and ME levels. Capon fed with 21% CP had significantly higher CP intake than the 19% CP group ($p < 0.01$). In contrast, the high ME diet (3.3 kcal/g) caused significantly lower CP intake ($p < 0.01$) than the lower ME diet (3.0 kcal/g). Neither the dietary CP nor ME levels had a significant influence on the ME intake.

Trial 2 (age 11–13 wk): the CP and ME intakes of all four groups are shown in Table 3. Capon fed with 19% CP had significantly higher CP intake than the 17% CP group ($p < 0.01$). In contrast, the high ME diet (3.3 kcal/g) caused lower CP intake ($p < 0.05$) than the lower ME diet (3.0 kcal/g). There was significant interaction between the ME intake and dietary factors. Therefore the nutrient intake of the individual group was taken into consideration. The group fed the high CP with low ME diet had significantly less ME intake than the group fed the high CP with high ME diet (6,109.11 kcal/bird versus 6,582.81 kcal/bird) but was not significantly different from the low CP groups, while the other three groups did not differ significantly from each other.

Table 2 Effects of dietary crude protein and metabolizable energy levels on performance of Royal Project Bresse capon aged 5–10 wk and 11–13 wk old (Trial 1 and Trial 2, respectively)

Items	ME (kcal/g)	CP (%; age 5–10 wk)			CP (%; age 11–13 wk)		
		19	21	Mean*	17	19	Mean*
IBW (g)	3.0	361.60	360.12	360.86	1,576.71	1,580.46	1,578.59
	3.3	360.23	361.28	360.76	1,576.04	1,563.54	1,569.79
	Mean*	360.92	360.70		1,576.38	1,572.00	
FBW (g)	3.0	1,317.62	1,419.90	1,368.76	2,166.04	2,218.13	2,192.09^{m}
	3.3	1,355.42	1,434.01	1,394.71	2,151.70	2,170.50	2,161.10^{n}
	Mean	1,336.52^{y}	1,426.96^{x}		2,158.87^{y}	2,194.32^{x}	
BWG (g)	3.0	956.02	1,059.78	1,007.90	589.33	637.67	613.50^{m}
	3.3	995.18	1,072.73	1,033.96	575.65	606.96	591.31^{n}
	Mean	975.60^{y}	1,066.26^{x}		582.49^{y}	622.31^{x}	
ADG (g)	3.0	22.76	25.23	24.00	28.06	30.36	29.21^{m}
	3.3	23.67	25.54	24.61	27.41	28.90	28.16^{n}
	Mean	23.22^{y}	25.39^{x}		27.74^{y}	29.63^{x}	
FI (g/b/d)	3.0	90.11	89.39	89.75^{m}	101.85^{a}	96.97^{ab}	99.41^{m}
	3.3	82.20	82.06	82.13^{n}	91.15^{b}	94.99^{b}	93.07^{n}
	Mean	86.16	85.73		96.50	95.98	
FCR	3.0	3.96	3.54	3.75^{m}	3.63^{a}	3.20^{b}	3.41
	3.3	3.47	3.21	3.34^{n}	3.33^{b}	3.28^{b}	3.31
	Mean	3.72^{x}	3.38^{y}		3.48^{x}	3.24^{y}	

Source	*p*-value			SEM	*p*-value			SEM
	CP	ME	CP × ME		CP	ME	CP × ME	
IBW	0.8780	0.9397	0.3837	0.61	0.3569	0.0850	0.1070	2.70
FBW	0.0006	0.1557	0.4947	15.94	0.0015	0.0034	0.0582	8.18
BWG	0.0005	0.1466	0.4422	13.96	0.0004	0.0121	0.2504	7.58
ADG	0.0005	0.1462	0.4431	0.37	0.0004	0.0123	0.2518	0.36
FI	0.6662	<0.0001	0.7665	1.22	0.7787	0.0076	0.0408	1.39
FCR	0.0024	0.0007	0.3359	0.09	0.0112	0.1744	0.0278	0.05

ME = metabolizable energy; CP = crude protein; SEM = standard error of the mean.

[a-b, m-n, x-y] Values with no common superscript differ significantly ($p < 0.05$) when tested with Duncan's new multiple range test following analysis of variance.

*Mean of main effects.

Table 3 Effects of dietary crude protein (CP) and metabolizable energy (ME) levels on CP and ME intake of Royal Project Bresse capon aged 5–10 wk and 11–13 wk (Trial 1 and Trial 2, respectively)

Items	ME (kcal/g)	CP (%; age 5–10 wk)			CP (%; age 11–13 wk)		
		19	21	Mean*	17	19	Mean*
CP intake	3.0	719.03	788.40	753.72^{m}	363.59	386.91	375.25^{m}
(g/b)	3.3	655.92	723.80	689.86^{n}	325.41	379.01	352.21^{n}
	Mean*	687.48^{y}	756.10^{x}		344.50^{y}	382.96^{x}	
ME intake	3.0	11,353.14	11,262.95	11,308.05	6,416.41^{ab}	6,109.11^{b}	6,262.83
(kcal/b)	3.3	11,392.37	11,374.00	11,383.19	6,316.70^{ab}	6,582.81^{a}	6,449.75
	Mean	11,372.76	11,318.48		6,366.62	6,345.96	

Source	*p*-value			SEM	*p*-value			SEM
	CP	ME	CP × ME		CP	ME	CP × ME	
CP intake	<0.0001	<0.0001	0.9260	14.51	0.0006	0.0106	0.0610	7.72
ME intake	0.6893	0.5817	0.7908	57.79	0.8668	0.1563	0.0408	72.64

SEM = standard error of the mean.

[a-b, m-n, x-y] Values with no common superscript differ significantly when tested with Duncan's new multiple range test following analysis of variance.

*Mean of main effects.

Carcass composition

Carcass composition as a percentage of hot carcass is shown in Table 4. No significant interaction was found between the two dietary factors for all parameters except for the thigh meat. Capon fed with 19% CP had higher percentages of carcass ($p < 0.01$), breast ($p < 0.01$), drumstick ($p < 0.05$) and liver ($p < 0.01$) than those fed the 17% CP diet. However, there were no significant differences for percentage of wing and AF. Similarly, the dietary ME level also had an effect on some parameters for carcass composition. Birds fed with 3.0 kcal ME/g had significantly higher percentages of carcass ($p < 0.01$), breast ($p < 0.01$), drumstick ($p < 0.05$) and liver ($p < 0.05$) but lower AF ($p < 0.01$). No significant differences were found regarding wing meat.

Since a significant interaction between factors was noticed for the thigh meat, each dietary group was taken into consideration. Thigh meat had the significantly highest percentage of hot carcass in the group fed 19% CP with 3.0 kcal ME/g, while the other three groups had no significant differences from each other (13.84% versus 13.26% versus 13.04% versus 13.08%).

Breast and thigh meat quality

Table 5 presents the effects of CP and ME on meat quality. No significant interaction was found between the two dietary factors for all parameters. Capon fed with 17% CP diet had significantly lower moisture and higher fat percentages in the breast meat compared with the 19% CP diet. No significant differences were found between dietary CP levels and the moisture and fat percentages for thigh meat as well as for the shear force of breast and thigh meat. The high dietary ME level caused significantly lower moisture in the breast and thigh meat as well as fat in the thigh meat. It also resulted in higher shear force in the breast and thigh meat than for the low dietary ME level. Among the treatments, the high CP with low ME diet tended to have the lowest shear force in breast meat and a high fat percentage in thigh meat.

Table 4 Effects of dietary crude protein and metabolizable energy levels on carcass composition of Royal Project Bresse capon aged 11–13 wk

Item	ME (kcal/g)	CP (%)		Mean*
		17	19	
Carcass (%)	3.0	75.03	77.10	76.07^{m}
	3.3	74.16	75.58	74.87^{n}
	Mean*	74.60^{y}	76.34^{x}	
Carcass composition (% on hot carcass)				
Breast**	3.0	19.45	19.98	19.71^{m}
	3.3	18.44	19.47	18.96^{n}
	Mean	18.94^{y}	19.73^{x}	
Thigh**	3.0	13.26^{b}	13.84^{a}	13.55^{m}
	3.3	13.04^{b}	13.08^{b}	13.06^{n}
	Mean	13.15^{y}	13.46^{x}	
Drumstick**	3.0	8.77	8.84	8.81^{m}
	3.3	8.28	8.71	8.49^{n}
	Mean	8.53^{y}	8.77^{x}	
Wings	3.0	11.43	11.47	11.45
	3.3	11.44	11.67	11.56
	Mean	11.44	11.57	
Liver	3.0	2.76	2.86	2.81^{m}
	3.3	2.66	2.80	2.73^{n}
	Mean	2.71^{y}	2.83^{x}	
Abdominal fat	3.0	0.91	0.93	0.92^{n}
	3.3	1.29	1.11	1.20^{m}
	Mean	1.10	1.02	

Source	*p*-value			SEM
	CP	ME	CP × ME	
Carcass	0.0004	0.0044	0.3204	0.34
Breast	0.0007	0.0009	0.1305	0.17
Thigh	0.0022	0.0001	0.0048	0.10
Drumstick	0.0333	0.0122	0.1025	0.07
Wing	0.1750	0.5272	0.3445	0.04
Liver	0.0068	0.0380	0.4897	0.02
Abdominal fat	0.1490	0.0005	0.0821	0.05

ME = metabolizable energy; CP = crude protein; SEM = standard error of the mean

[a-b, m-n, x-y] Values with no common superscript differ significantly when tested with Duncan's new multiple range test following analysis of variance.

*Mean of main effects.

** Both sides of meat without skin and bone.

Table 5 Effects of dietary crude protein and metabolizable energy levels on breast and thigh meat quality of Royal Project Bresse capon aged 11–13 wk

Items	ME (kcal/g)	CP (%)		Mean*	SEM
		17	19		
Breast**					
	3.0	73.50	74.15	73.83^{m}	0.19
Moisture (%)	3.3	72.72	73.48	73.10^{n}	
	Mean*	73.11^{y}	73.82^{x}		
	3.0	4.36	3.97	4.17^{m}	0.10
Fat (%)	3.3	4.01	3.63	3.82^{n}	
	Mean	4.19^{x}	3.80^{y}		
	3.0	42.30	41.68	41.99^{n}	1.47
Shear force (%)	3.3	47.13	53.38	50.27^{m}	
	Mean	44.72	47.53		
Thigh**					
	3.0	73.53	73.86	73.70^{m}	0.08
Moisture (%)	3.3	73.30	73.26	73.28^{n}	
	Mean	73.42	73.56		
	3.0	22.89	24.15	23.52^{m}	0.80
Fat (%)	3.3	19.38	18.15	18.77^{n}	
	Mean	21.14	21.15		
	3.0	38.20	38.35	38.27^{n}	0.97
Shear force (%)	3.3	41.38	45.43	40.41^{m}	
	Mean	39.79	41.89		

Source	*p*-value		
	CP	ME	CP x ME
Breast			
Moisture	0.0301	0.0268	0.8424
Fat	0.0223	0.0364	0.9812
Shear force	0.2722	0.0086	0.1881
Thigh			
Moisture	0.2258	0.0054	0.1258
Fat	0.9804	0.0002	0.1232
Shear force	0.0593	0.0007	0.0758

ME = metabolizable energy; CP = crude protein; SEM = standard error of the mean

$^{a-b, m-n, x-y}$ Values with no common superscript differ significantly when tested with Duncan's new multiple range test following analysis of variance.

*Mean of main effects.

** Both sides of meat without skin and bone.

Discussion

Growth performance

Both trial periods showed that the FBW, BWG and ADG of Bresse capon increased and that the FCR improved in the groups fed the high level of dietary CP. These results agreed with several investigators who found that increased dietary protein improved the growth performance of other chickens. For example, Perween et al. (2016) found that higher CP (17%, 19% and 21%) and ME (2.6 kcal ME/g, 2.8 kcal ME/g and 3.0 kcal ME/g) levels had positive effects on BW and BWG of Vanaraja chicken aged 1–56 d in the tropics. Similar results were observed by Nguyen and Bunchasak (2005) who reported that increasing the dietary CP level from 17% to 23% had a positive relationship to BW and BWG in Betong chickens aged 1–21 d. In addition, Liu et al. (2015) found that increasing the dietary CP content from 120g/kg to 180 g/kg improved the BWG of Lueyang Black-bone chickens aged 7–12 wk. The improved performance of the higher dietary CP groups in both phases of the current study was due to the higher CP intake by the Bresse capon. However, these results contrasted with Layfield et al. (1972) who reported no significant differences in the BWG and FCR for capon aged 6–18 wk fed with diets containing 14%, 16%, 18% and 20% CP with 1,430.50±2.38 kcal ME/lb. (pound)

The improved performance of the higher dietary CP groups in both phases of the current study was due to the higher CP intake of the Royal Project Bresse capon as shown in Table 3. It has been well documented that CP is essential for muscle synthesis (Cheva-Isarakul, 2003) and thus the higher intake of CP resulted in higher growth and better performance. Berdanier (2000) stated that protein is the next most important macronutrient required after the energy need has been met. Proteins provide the amino acids that are needed to synthesize body protein. Protein, in its many forms, is an essential and universal constituent of all living cells (Berdanier, 2000). As much as one-half of the dry weight of the cell is protein and in the human body, on the average, 18% is protein (Berdanier, 2000). Besides being plentiful, proteins serve a variety of functions: as structural components, as bio-catalysts (in the form of enzymes), as antibodies, as lubricants, as messengers (in the form of hormones), and as carriers (Berdanier, 2000). Proteins composed of essential amino acids must be provided in food as they cannot be synthesized by the human body; after digestion, these amino acids are absorbed and used to synthesize body proteins. Morrison (1949) also stated that about 15% of BW is due to protein and this protein is distributed throughout the body in tissues, enzymes, and hormones. These statements supported the positive results of higher dietary protein and protein intake in the current study.

In contrast, the increase in dietary energy of Royal Project Bresse capon aged 5–10 wk in the current study did not show significant effect on BW and BWG. These results agreed with the observation of Nguyen and Bunchasak (2005) who found no effect of dietary ME levels on BW and BWG in Betong chicken aged 1–21 d. Similarly, Infante-Rodríguez et al. (2016) observed that for male broilers aged 1–21 d, an increase in the energy level from 2.96 kcal apparent metabolizable energy (AME)/g to 3.08 kcal AME/g (21.4% CP) and when the broilers were aged 22–42 d of 3.04 kcal AME/g to 3.16 kcal AME/g (18.7% CP) did not influence weight gain. However, this report disagreed with Terčič et al. (2012) who raised male layer-type capon aged 43–153 d and reported that when the dietary energy level increased from 10.54 MJ ME/kg to 12.90 MJ ME/kg, the BW of the capon aged 71 d increased significantly ($p > 0.05$).

Even though there were no significant negative influences of increasing dietary energy level on the FBW, BWG and ADG of Royal Project Bresse capon aged 5–10 wk in the current study, this effect was significantly in birds aged 11–13 wk (Table 2). These results agreed with Terčič et al. (2012) who reported that male layer-type capons at age 91 d fed with a high energy diet (12.90 MJ/kg; 17.5% CP) had significantly greater BW and higher BW and ADG at age 153 d than those fed with a low energy diet (10.54 MJ/kg; 17.3% CP).

The main reason for the negative influence of the high dietary energy level could have been due to the significantly lower FI which occurred in both phases. This phenomenon might suggest that the chickens regulated their intake according to dietary energy. The present results agreed with the findings of Perween et al. (2016) who also reported lower FI in Vanaraja chickens aged 1–8 wk with a diet containing 3.0 kcal ME/g than the lower ME levels.

In the current study, FI values at ages 5–10 wk and 11–13 wk were not influenced by the dietary CP levels, which agreed with Nguyen and Bunchasak (2005) who found no difference in FI values of Betong chickens aged 1–42 d fed with different levels of CP. Similarly, Ndegwa et al. (2001) showed that indigenous-grown Kenya chickens reared with diets containing 170–230 g CP/kg had similar FI values. In contrast, Melesse et al. (2013) reported that the feed consumption of Koekoek chickens aged 3–15 wk increased when the level of dietary CP increased.

The increased dietary CP and ME levels significantly improved the FCR which agreed with Layfield et al. (1972) who reported that broiler capon aged 6–18 wk fed with higher ME levels had better feed conversion efficiency. Similarly, the study of Nawaz et al. (2006) revealed that increased CP and ME levels in the feed of broilers aged 1–26 d resulted in a better FCR.

The interaction between the dietary CP and ME levels fed to birds aged 11–13 wk on FI and the FCR shown in Table 2 was due to the fact that these two factors did not affect the performance of each other with the same trend. In the case of FI, the increased level of ME significantly decreased FI, while no significant difference was found with the increasing level of CP. In the case of FCR, the increased ME level had no effect on this parameter, while the increased level of CP significantly improved the FCR. Raphulu and Jansen van Rensburg (2018) also found significant ($p < 0.05$) interactions of dietary CP and ME on the FCR of chicken aged 0–6 wk. In addition, Min et al. (2012) who fed four levels of CP (18.5%, 19.0%, 19.5% and 20.0%) and three levels of ME (12.55 MJ/kg, 12.97 MJ/kg and 13.38 MJ/kg) to broilers during the finishing phase (aged 22–42 d), also found significant ($p < 0.05$) interactions between dietary CP and ME on the FCR, ME consumed per gain and CP consumption per gain.

Carcass characteristics

The present study showed that the increased dietary CP significantly improved the percentages of the carcass and many parts of the carcass composition, such as breast, thigh, drumstick, liver and also tended to improve the percentage of wing. These results agreed with Liu et al. (2015) who reported that increased CP levels (120 g/kg, 140 g/kg, 160 g/kg, 180 g/kg and 200 g/kg) in the diet of Lueyang Black-boned chicken aged 7–12 wk improved the breast meat. The current results also agreed with Paitong (2017) who reported that Black-boned chicken of the RPF Thailand aged 1–16 wk being fed with a higher level CP diet had a significantly ($p < 0.05$) higher percentage of thigh meat than a lower dietary CP group.

Decreasing the ME level significantly improved the percentages of the carcass, breast, thigh, drumstick and AF, but not the wings and liver. Others have reported similar responses in broilers fed different energy levels. For example, Min et al. (2012) found that lower dietary ME level increased the percentages of carcass and leg. Niu et al. (2009) reported that decreased energy (12.13 MJ ME/kg versus 12.55 MJ ME/kg versus 12.97 MJ ME/kg) in the diet of broilers aged 1–21 d tended to increase the percentages of carcass and breast. These results disagreed with Terčič et al. (2012) who reported on male layer-type capon aged 43–153 d that there was a significant increase in the dressing percentage and the birds tended to have higher AF when fed with a high energy level diet. Miah et al. (2016) also reported on indigenous Bangladesh chicken fed increased energy in their starter diet (3.0 kcal ME/g versus 2.8 kcal ME/g; 23% CP) and grower diet (2.9 kcal ME/g versus 2.7 kcal ME/g; 17% CP) at age 4–14 wk increased the dressing percentage but had no significant impact on the breast, thigh and drumstick.

Royal Project Bresse capon fed on a diet high in CP with low ME had higher ratios of breast and thigh meat. These results were in accordance with broilers fed high energy and protein diets that resulted in an increased yield of breast meat (Marcu et al., 2013), carcass weight, breast meat and drumstick muscle (Marcu et al., 2012a) and thigh plus drumstick (Rosa et al., 2007). In contrast, Nawaz et al. (2006) reported no significant effect among groups on carcass characteristics for Hubbard broilers fed with starter diets containing either 2.8 kcal ME/g or 3.0 kcal ME/g with 20%, 21% or 22% CP and finisher diets containing either 3.0 kcal ME/g or 3.2 kcal ME/g with 16%, 17% or 18% CP .

The increased dietary ME level in the diet for Bresse capon in the current study resulted in a significantly higher proportion of AF. This might have been due to the fact that surplus energy can be easily changed into accumulated fat. This finding was consistent with Min et al. (2012) and Rebie et al. (2017). On the other hand, increasing dietary CP tended to lower AF in the current study, even though no significant difference was noticed. The result agreed with Tangtaweewipat et al. (2001) who found a significant negative effect of high CP diet on AF in three crossbred lines of native chicken in Thailand.

Breast and thigh meat quality

The current study produced evidence that an increase in dietary CP level had no effect on the shear force but significantly lowered the percentage of fat in breast muscle, in contrast, the lower dietary ME level produced more fat and tenderness in breast meat. This was consistent with Infante-Rodríguez et al. (2016) who reported that broiler chicken in the dry tropics fed with low ME starter and finisher diets (2.96 AME/g and 3.04 kcal AME/g, respectively) had a higher fat content in breast meat than the groups fed higher dietary ME levels (3.00 AME/g and 3.08 AME/g; 3.04 AME/g and 3.12 AME/g; 3.08 AME/g and 3.16 kcal AME/g, respectively). Another study by Layfield et al. (1972) found that increased CP levels in the broiler capon diet (14%, 16%, 18% and 20% CP with 1,430.50±2.38 kcal ME/lb) at age 6–18 wk resulted in no significant differences in the percentages of moisture and fat in breast and thigh muscle. The increased energy (from 800 kcal PE/lb to 1,067 kcal PE/lb) in diet containing 16% CP resulted in decreased moisture in breast and thigh muscles while the fat content increased in the thigh.

The thigh lipid percentage and shear force in the current study were not influenced by the CP level. However, there was a significantly higher thigh lipid level with lower shear force in Bresse capon fed on the low ME diet. This finding was also consistent with Marcu et al. (2012b) who reported that reducing the dietary ME level increased the fat content in the breast and thigh meat of broilers. Marcu et al. (2013) noticed that broilers fed with 2.860 kcal ME/g, 2.878 kcal ME/g and 2.890 kcal ME/g diets (starter, grower and finisher diets, respectively) had higher amounts of lipid (6.14±0.08% DM) in pectoral muscles than the group fed with the same respective diets with 3.041 kcal ME/g, 3.144 kcal ME/g and 3.190 kcal ME/g and the group fed with 3.270 kcal ME/g, 3.435 kcal ME/g and 3.490 kcal ME/g, respectively.

Some authors reported different results. For example, Ferreira et al., (2015) reported that broilers fed on a lower energy diet had lower fat in their muscles. Rosa et al. (2007) noticed increased fat in the carcass with an increased dietary energy level in commercial Ross 308 broilers. However, Corduk et al. (2007) found no influence of the dietary ME level on the chemical composition of broiler muscle.

The results of the current study indicated that the optimum diet for Royal Project Bresse capon aged 5–10 wk should contain 21% CP and 3.3 kcal ME/g, while at age 11–13 wk, the diet should contain 19% CP and 3.0 kcal ME/g to obtain the best performance, carcass composition and meat quality.

Conflict of Interest

The authors declare that there are no conflicts of interest.

Acknowledgements

The authors express their thanks to the Royal Project Foundation for donating the Bresse chickens used in the experiment. Financial support from the Highland Research and Development Institute (Public Organization) is also gratefully acknowledged.

References

Adamski, M., Kuźniacka, J., Banaszak, M., Wegner, M. 2016. The analysis of meat traits of Sussex cockerels and capons (S11) at different ages. *Poult. Sci.* 95: 125–132. doi.org/10.3382/ps/pev308

Association of Official Analytical Chemists. 2005. Official Method of Analysis, 18th ed., The Association of Official Analytical Chemists., Washington, DC., USA.

Berdanier, C.D. 2000. Advanced Nutrition: Macronutrients, 2nd ed., CRC Press., Washington, D.C., USA.

Calik, J. 2014. Capon production-breeding stock, rooster castration and rearing methods, and meat quality–A review. Ann. Anim. Sci. 4: 769–777.

Chen, K.L., Hsieh, T.Y., Chiou, P.W.S. 2006. Caponization effects on growth performance and lipid metabolism in Taiwan country chicken cockerels. Asian Australas. J. Anim. Sci. 19: 438–443.

Cheva-Isarakul, B. 2003. Animal Biochemistry, 2nd ed., Tanabanakarn Press. Chiang Mai, Thailand. [in Thai]

Corduk, M., Ceylan, N., Lldiz, F. 2007. Effects of dietary energy density and L-carnitine supplementation on growth performance, carcass traits and blood parameters of broiler chickens. S. Afr. J. Anim. Sci. 37: 65–73.

Duran, A.M. 2004. The effect of caponization on production indices and carcass and meat characteristics in free-range Extremeña Azul chickens. Span. J. Agric. Res. 2: 211–216.

Ferreira, G.D., Pinto, M.F., Neto, M.G., Ponsano, E.H., Goncalves, C.A., Bossolani, I.L. Pereira, A.G. 2015. Accurate adjustment of energy level in broiler chickens diet for controlling the performance and the lipid composition of meat. Cienc. Rural. 45: 104–110.

Infante-Rodríguez, F., Salinas-Chavira, J., Montaño-Gómez, M.F., Manríquez-Nuñez, O.M., González-Vizcarra, V.M., Guevara-Florentino, O.F., Ramírez De León, J.A. 2016. Effect of diets with different energy concentrations on growth performance, carcass characteristics and meat chemical composition of broiler chickens in dry tropics. Springer Plus. 5: 1–6. doi.org/10.1186/s40064-016-3608-0

Jacob, J., Mather, F.B. 2000. Capons, Factsheet PS-54, Department of Animal Science, Florida Cooperative Extension Service, Institute of Food and Agricultural Science, University of Florida. https://ufdcimages.uflib.ufl.edu/IR/00/00/30/38/00001/PS05100.pdf, 25 December 2019

Layfield, J.C., Owings, W.J., Balloun, S.L., Miller, D.L. 1972. Carcass composition and production criteria of surgical capons as affected by nutrition. Poult. Sci. 51: 1512–1518

Lin, C.Y., Hsu, J.C. 2003. Influence of caponization on the carcass characteristics in Taiwan country chicken cockerels. Asian Australas. J. Anim. Sci. 16: 575–580.

Liu, S.K., Niu, Z.Y., Min, Y.N., et al. 2015. Effects of dietary crude protein on the growth performance, carcass characteristics and serum biochemical indexes of Lueyang black-boned chickens from seven to twelve weeks of age. Rev. Bras. Cienc. Avic. 17: 103–108.

Marcu, A., Vacaru-Opriş, I., Marcu, A., Nicula, M., Dronca, D., Kelciov, B. 2012a. Effect of different levels of dietary protein and energy on the growth and slaughter performance at "Hybro PN+" broiler chickens. Scientific Papers Animal Sciences and Biotechnologies. 45: 424–431.

Marcu, A., Vacaru-Opriş, I., Marcu, A., Nicula, M., Dronca, D., Kelciov, B. 2012b. The influence of feed energy and protein level on meat quality at "Hubbard F15" broiler chickens. Scientific Papers Animal Sciences and Biotechnologies. 45: 432–439.

Marcu, A., Vacaru-Opris, I., Dumitrescu, G., et al. 2013. Effect of diets with different energy and protein levels on breast muscle characteristics of broiler chickens. Scientific Papers Animal Sciences and Biotechnologies. 46: 333–340.

Mašek, T., Severin, K., Gottstein, Z., Filipović, N., Stojević, Z., Mikulec, Z. 2013. Effects of early castration on production performance, serum lipids, fatty acid profile and desaturation indexes in male chicken broilers fed a diet with increased fat content. Vet. Arhiv. 83: 233–243.

Mast, M.G., Jordan, H.C., Macneil, J.H. 1981. The effect of partial and complete caponization on growth rate, yield and selected physical and sensory attributes of cockerels. Poult. Sci. 60: 1827–1833.

Melesse, A., Dotamo, E., Banerjee, S., Berihun, K., Beyan, M. 2013. Studies on carcass traits, nutrient retention and utilization of Koekoek chickens fed diets containing different protein levels with iso-caloric ration. J. Anim. Sci. Adv. 10: 532–543.

Miah, M.Y., Chowdhury, S.D., Bhuiyan, A.K.F.H. 2016. Effect of diets of different protein concentrations on indigenous growing chicks of Bangladesh in confinement. Asian J. Med. Biol. Res. 1: 109–113.

Min, Y.N., Shi, J.S., Wei, F.X., Wang, H.Y., Hou, X.F., Niu, Z.Y., Liu, F.Z. 2012. Effects of dietary energy and protein on growth performance and carcass quality of broilers during finishing phase. J. Anim. Vet. Adv. 11: 3652–3657.

Morrison, F.B. 1949. Proteins. In: Tisch, D. (Ed.). Animal Feeds, Feeding and Nutrition and Ration Evaluation with CD-ROM. Thomson Delmar Learning. Independence, KY, USA, pp. 96–109.

Nawaz, H., Mushtag, T., Yaqoob, M. 2006. Effect of varying levels of energy and protein on live performance and carcass characteristics of broiler chicks. J. Poult. Sci. 43: 388–393.

Ndegwa, J.M., Mead, R., Norrish, P., Kimani, K.W., Wachira, A.M. 2001. The growth performance of indigenous Kenyan chickens fed diets containing different levels of protein during rearing. Trop. Anim. Health Prod. 33: 441–448. doi.org/10.1023/a:1010552008639

Nguyen, T.V., Bunchasak, C. 2005. Effects of dietary protein and energy on growth performance and carcass characteristics of Betong chicken at early growth stage. Songklanakarin J. Sci. Technol. 27: 1171–1178.

Niu, Z., Shi, J., Liu, F., Wang, X., Gao, C., Yao, L. 2009. Effects of dietary energy and protein on growth performance and carcass quality of broilers during starter phase. Int. J. Poult. Sci. 8: 508–511.

Paitong, P. 2017. Optimum protein and metabolizable energy levels in Royal Project Black bone chicken diets during growing period. M.Sc. Thesis, Department of Animal and Aquatic Sciences, Chiang Mai University. Chiang Mai, Thailand. [in Thai]

Perween, S., Kumar, K., Chandramoni, Kumar, S., Singh, P.K., Kumar, M., Dey, A. 2016. Effect of feeding different dietary levels of energy and protein on growth performance and immune status of Vanaraja chicken in the tropic. Vet. World. 9: 893–899. doi.org/10.14202/vetworld.2016.893-899

Raphulu, T., Jansen van Rensburg, C. 2018. Dietary protein and energy requirements of Venda village chickens. J. Agr. Rural Dev. Trop. Subtrop. 119: 95–104.

Rebie, M.H., Sherif, K.E., El-Khalek, A.M.A., El-Gamal, A.A.A. 2017. Effect of dietary energy and protein on growth performance and carcass traits of Mamourah Cockerels. Asian J. Anim. Vet. Adv. 12: 142–151.

Rikimaru, K., Takahashi, H., Nichols, M.A. 2011. An efficient method of early caponization in slow-growing meat-type chickens. Poult. Sci. 90: 1852–1857. doi: 10.3382/ps.2010-01270.

Rosa, P.S., Faria Filho, D.E., Dahlke, F., Vieira, B.S., Macari, M., Furlan, R.L. 2007. Effect of energy intake on performance and carcass composition of broiler chickens from two different genetic groups. Braz. J. Poultry Sci. 9: 117–122.

Shao, Y., Wu, C., Li, J., Zhao, C. 2009. The effects of different caponization age on growth performance and blood parameters in male Tibetan chicken. Asian J. Anim. Vet. Adv. 4: 228–236.

Songsee, O., Tangtaweewipat, S., Cheva-Isarakul, B., Moonmanee, T. 2020. Laparoscopic vacuum testectomy technique for castration Royal Project Bresse chickens on highland of Thailand. Songklanakarin J. Sci. Technol. 42: [in Press].

Symeon, G.K., Mantis, F., Bizelis, I., Kominakis, A., Rogdakis, E. 2010. Effects of caponization on growth performance, carcass composition, and meat quality of medium growth broilers. Poult. Sci. 89: 1481–1489. doi.org/10.3382/ps.2009-00411

Tangtaweewipat, S., Cheva-Isarakul, B., Pingmuang, R., Tananchai, B. 2001. Proper dietary protein and energy levels for growing crossbred Native chickens. Final report submitted to Thailand Research Fund (TRF). Bangkok, Thailand. [in Thai]

Tangtaweewipat, S., Cheva-Isarakul, B., Keawma, M., Panput, S. 2008. The production of Bresse chicken as an alternative poultry for farmers in Royal Project Foundation areas. Final report submitted to Royal Project Foundation. Chiang Mai, Thailand. [in Thai]

Tangtaweewipat, S. 2014. GAP–Poultry Highland Farms: Production and quality development of Bresse chicken in Royal Project Foundation. Royal Project J. 18: 18–22. [in Thai]

Tangtaweewipat, S., Cheva-Isarakul, B., Poakjareon, K., Tangtarak, W., Maneethong, N., Songsee, O. 2014. Selection and improvement of poultry breedlines as new sustainable alternative economic animals in highland. Final report submitted to Agricultural Research Development Agency (Public Organization), Bangkok, Thailand. [in Thai]

Terčič, D., Kovač, M., Holcman, A. 2012. Effects of dietary energy density and coarsely ground maize supplementation on growth performance, carcass traits and meat quality of capons. Arch. Geflugelkd. 76: 26–30.