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Effects of Dietary Energy and Protein on Growth Performance and Carcass Quality of Broilers During Finishing Phase

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Abstract: The present study was undertaken to investigate the influence of varying levels of dietary energy and protein on broiler performance and carcass quality of broilers from 22-42 days of age. A total of 720, 22 days old avian broiler chicks were randomly divided into 12 groups, each group had six replicates and each replicate contained 10 birds. These birds were randomly assigned to 12 dietary treatments in a 3×4 factorial arrangement with three Metabolizable Energy (ME) levels (12.55, 12.97 and 13.38 MJ kg^{-1}) and four Crude Protein (CP) levels (18.5, 19.0, 19.5 and 20.0%), respectively, from 22-42 days of age. The results showed that: both ME and CP significantly affected on daily gain, feed efficiency and body weight of 42 days of age ($p<0.05$); ME levels significantly affected on feed intake ($p<0.05$) while CP not affected ($p>0.05$). However, there were no significant interaction in BW, average daily gain, feed intake between dietary ME and CP; dietary ME significantly affected on semi-eviscerated percentage, dressing percentage, leg meat percentage and abdominal fat ($p<0.05$). Higher level of dietary ME (13.38 MJ kg^{-1}) significantly increased abdominal fat percentage when compared with lower ME (12.55 and 12.97 MJ kg^{-1}). Breast meat percentage was increased by dietary CP ($p<0.05$); L* of both leg meat and breast meat was not affected by dietary ME and CP ($p>0.05$), b* of both breast meat and leg meat was increased with increasing dietary ME ($p<0.05$). Both a* and b* were not affected by dietary CP; pH of breast meat was increased by dietary ME while not affected by dietary CP. The Water-Holding Capacity (WHC) of breast meat was decreased by dietary ME but the effect was not significantly ($p>0.05$). WHC of leg meat was increased by dietary ME ($p<0.05$). The results of present research indicated that the optimal dietary ME requirement of broilers from 22-42 days of age is 12.97 MJ kg^{-1} and the CP requirement is 19.0-20.0%.

Key words: Broilers, energy, protein, growth performance, meat quality

INTRODUCTION

The animal products are becoming more and more common food of human. In all aspects of animal products, growth of poultry meat production, in particular chicken meat has been very speedy over the last decades and up to now occupies second place in volume in the world, just following pork, becoming a type of the cheapest food derived from animals worldwide. In recent years, more and more concerns have being focused on poultry meat quality and its food safety (Le Behan-Dval, 2004). The quality of the meat is mainly influenced by genotype of animals and its environment, especially either nutrients or stress undergone during growing period or before slaughter. With the rapid expansion of the fast-food trade and increased public awareness of excess fat as a possible health hazard, the large amount of carcass fat in the modern broiler chickens is being questioned and criticized more and more by processors and consumers.

Energy and protein are important nutrients, representing majority of total cost of the diets for animals. All activities of animals including breathe, palpitation, blood cycle, muscle movement, growth and producing products, etc., need energy mainly derived from feeds. Protein is the key component of cell, playing an important role in the process of life. Growth rate and feed efficiency

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Table 1: Ingredients and nutrient level of experimental diets

	Diets											
Ingredients (%)	1	2	3	4	5	6	7	8	9	10	11	12
Corn	66.90	65.30	63.60	61.70	65.00	63.40	61.70	60.00	63.10	61.40	59.80	58.20
Soybean meal	17.40	18.30	19.20	20.30	20.50	21.30	22.20	23.10	21.40	22.40	23.40	24.40
Corn-gluten meal	2.40	2.50	2.60	2.70	2.75	2.80	2.85	2.90	3.05	3.05	3.20	3.30
Cottonseed meal	6.80	7.00	7.40	7.80	3.40	3.90	4.50	5.00	2.50	2.90	3.10	3.30
$CaHPO_4$	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
Limestone	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Fish meal	1.55	1.70	1.75	1.75	1.70	1.75	1.70	1.75	1.70	1.75	1.80	1.90
Corn oil	1.60	1.85	2.10	2.40	3.30	3.50	3.70	3.90	4.90	5.15	5.35	5.55
Salt	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25
Premix[1]	0.60	0.60	0.60	0.60	0.60	0.60	0.60	0.60	0.60	0.60	0.60	0.60
Nutrition level[2]												
CP (%)	20.00	21.00	22.00	23.00	20.00	21.00	22.00	23.00	20.00	21.00	22.00	23.00
ME (MJ kg^{-1})	12.55	12.55	12.55	12.55	12.97	12.97	12.97	12.97	13.38	13.38	13.38	13.38
Ca (%)	0.97	0.97	0.98	0.98	0.97	0.97	0.98	0.98	0.95	0.96	0.96	0.97
AP (%)	0.43	0.44	0.44	0.44	0.43	0.43	0.43	0.44	0.42	0.43	0.43	0.44
Lysine (%)	0.92	0.95	0.98	1.01	0.93	0.96	0.99	1.02	0.93	0.96	0.99	1.02
Methionine (%)	0.30	0.31	0.32	0.33	0.30	0.31	0.32	0.33	0.30	0.31	0.32	0.33
Met + Cys (%)	0.62	0.63	0.65	0.67	0.61	0.63	0.64	0.66	0.61	0.62	0.64	0.65

[1]Provided per kilogram of diet: Vitamin A, 12,000 IU; Vitamin E, 10 mg; Vitamin D_3, 2,200 IU; niacin, 35.0 mg; D-pantothenic acid, 12 mg; riboflavin 3.6 mg; pyridoxine, 3.5 mg; thiamine, 2.4 mg; menadione,1.3 mg; folic acid, 1.4 mg; biotin, 0.15 mg; Vitamin B_{12}, 0.03 mg; Mn, 60 mg; Zn, 40 mg; Fe, 80 mg; Cu, 8 mg; I, 0.3 mg; Se, 0.2 mg.[2] ME value is calculated, the other nutrition levels are analysized

of broilers were improved with in crease in dietary protein or energy. However, a significant interaction between protein and energy indicated the importance of a balanced energy: protein ratio to achieve optimum performance (Jackson *et al*., 1982b; Wang and Liu, 2002). The research showed that broiler carcass composition could be altered through manipulation of dietary protein or energy (Fraps, 1943; Marion and Woodroof, 1966; Velu and Baker, 1974; Twining *et al*., 1978; Jackson *et al*., 1982a; Chen *et al*., 1998). Seaton *et al*. (1978) observed an increase in carcass fat and a decrease in moisture with an increase in the dietary energy level while carcass protein unaffected. This is in contrast to the reports of Summers *et al*. (1965) and Velu and Baker (1974). Higher level of dietary ME significantly increased abdominal fat percentage (Chen *et al*., 1998; Wang and Song, 1996; Zanusso *et al*., 1999). Song *et al*. (2005) reported that higher level of diet CP increased the rate the breast meat of broiler. However, wide fluctuations in feed ingredient cost have led to greater emphasis on factors other than bird performance when considering the economic return of broiler production. So, in determining optimum dietary nutrient levels, the cost of nutrients for production of edible protein is equally as important as performance or carcass quality. The present study was undergone to investigate the influence of varying levels of dietary energy and protein on broiler performance and carcass quality from 22-42 days of age (Table 1).

MATERIALS AND METHODS

Experimental design and birds: This experiment was conducted according to protocols approved by the Northwest A&F University Animal Care and Use Committee. A total of 720, 22 days old avian broiler chicks were randomly divided into 12 groups, each group had six replicates and each replicate contained 10 birds. These birds were randomly assigned to 12 dietary treatments in a 3×4 factorial arrangement with three Metabolizable Energy (ME) levels (12.55, 12.97 and 13.38 MJ kg^{-1}) and four Crude Protein (CP) levels (18.5, 19.0, 19.5 and 20.0%), respectively from 22-42 days of age. The diets were fed in mash form. The birds were provided feed and water *ad libitum* throughout the experimental period and feed intake and BW were recorded weekly. The photoperiod was set at 16L:8D throughout the whole experimental period. Room temperature was at 25°C.

Processing procedure: At 42 days of age, two birds from each replicate were euthanized under anaesthesia and exsanguinated after a 12 h fast and access to water *ad libitum* to measure eviscerated carcass percentage, breast meat percentage, leg meat percentage, abdominal fat percentage.

Muscle pH: At 30 min post-mortem, the breast and leg muscle pH was respectively determined at a depth of 2.5 cm below the surface by using a Model PH-211 Meter equipped with a spear electrode.

Color measurement: The surface color of chicken rolls was measured in package using a Hunter LabScan colorimeter and expressed as color L* (lightness), a* (redness) and b* (yellowness) values. A color reading was taken from both sides of rolls. The same packaging materials were used to cover a white standard plate in order to eliminate the influence of packaging material on meat color.

Water-holding capacity: Water-Holding Capacity (WHC) was estimated by determining expressible juice using a modification of the filter paper press method described by Wierbicki and Deatherage (1958). Briefly, a raw meat sample weighing about 1,000 mg was placed between 18 pieces of 11 cm diameter filter paper and pressed at 35 kg for 5 min. Expressed juice was defined as the loss in weight after pressing and presented as a percentage of the initial weight of the original sample (Bouton *et al*., 1971).

Shear force: The muscles were refrigerated overnight at 4°C and then brought to room temperature before cooking. The breast muscle from each bird was cooked to an internal temperature of 70°C on a digital thermostat water bath (HH-4, Jiangbo instrument, Jiangsu, China). End point internal temperature was monitored with a thermometer. Cooked muscle was cooled to room temperature. Slices of 1×1 cm were cut perpendicular to the fiber orientation of the muscle. Ten 1×1×1 cm cores about 3 cm thick were removed parallel to the fiber orientation through the thickest portion of the cooked muscle. Warner-Bratzler shear force was determined by using an Instron Universal Mechanical Machine (Instron Model 4411, Instron Corp., Canton, MA). A Warner-Bratzler apparatus was attached to a 50 kg load cell and tests were performed at a cross head speed of 127 mm min^{-1}. Signals were processed with the Instron Series Ninth Software package.

Statistical analysis: All the data were analyzed statistically using the general linear model procedure (SAS, 1996) and the treatment means were separated by Duncan's multiple range test.

RESULTS AND DISCUSSION

The effect of dietary ME or CP on broiler growth performance from 22-42 days of age was placed in Table 2. The results of this study showed that ME significantly affected on feed intake ($p<0.05$) while CP not affected ($p>0.05$). Both BW of 42 days of age and average daily gain were significantly influenced by dietary ME and CP ($p<0.05$). There was a tendency to increase in average daily gain and BW of 42 days of age with increase in dietary CP. Both ME and CP significantly improved the feed efficiency ($p<0.05$). These results were agreed with previous reports by Huo *et al*. (1987), Wang and Song (1996) and Yang *et al*. (2007). There were no significant interaction in BW, average daily gain and feed intake between dietary ME and CP. However, feed efficiency was significantly influenced by the interaction effect of dietary ME and CP ($p<0.05$). Usually, feed intake of broilers was decreased with increase in dietary ME level (Jackson *et al*., 1982b; Huo *et al*., 1987). However, in this study, feed intake of broilers fed 12.97 or 13.38 MJ of diet was significantly higher than that of birds fed 12.55 MJ of diet.

Both ME consumed per gain and CP consumed per gain were significantly affected by dietary CP and ME ($p<0.05$). ME consumed per gain linearly decreased with increasing in dietary CP as well as CP consumed per gain linearly decreased with increasing in dietary ME which indicated the efficiency of protein utilization was increased as dietary ME was increased. There were significant interaction in ME consumed per gain and CP consumed per gain between dietary ME and CP ($p<0.05$). These results were agreed with the result reported by Velu and Baker (1974).

The effect of dietary ME or CP on broiler carcass yield of broilers was showed in Table 3. Dietary ME significantly influenced dressing percentage, semi-eviscerated carcass percentage, leg meat percentage and abdominal fat percentage ($p<0.05$). Although, semi-eviscerated carcass (with giblet) percentage and leg meat percentage were increased ($p<0.05$) with increasing dietary ME from 12.97-13.38 MJ kg^{-1}, differences in semi-eviscerated carcass percentage and leg meat percentage of birds fed 12.97 and 13.38 MJ kg^{-1} were not significant

Table 2: Effects of energy and protein on broiler growth performance from 22-42days of age

ME (MJ kg^{-1})	CP (%)	Feed intake (g/day/bird)	Daily gain (g/day/bird)	Feed:gain	42 days BW	ME consumed per gain (kJ g^{-1})	CP consumed per gain (g)
12.55	-	123.32^{a}	65.11^{a}	1.9000^{a}	1920.03^{a}	23.8000^{a}	0.3650^{a}
12.97	-	128.85^{b}	70.29^{b}	1.8300^{b}	2022.38^{b}	23.7900^{a}	0.3530^{b}
13.38	-	126.93^{b}	70.25^{b}	1.8100^{c}	2020.14^{b}	24.1900^{b}	0.3480^{c}
-	18.5	124.34^{a}	65.40^{a}	1.9000^{a}	1926.76^{a}	24.6600^{a}	0.3520^{a}
-	19.0	128.70^{b}	68.79^{b}	1.8700^{b}	1993.01^{b}	24.2600^{b}	0.3560^{b}
	19.5	126.80^{ab}	69.49^{b}	1.8300^{c}	2008.78^{b}	23.6700^{c}	0.3560^{b}
-	20.0	125.61^{ab}	70.52^{b}	1.7800^{d}	2021.52^{b}	23.1000^{d}	0.3560^{b}
SEM		5.20	2.85	0.0100	54.21	0.1000	0.0010
Probability							
ME	-	0.0019	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
CP	-	NS	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
ME×CP	-	NS	NS	<0.0001	NS	<0.0001	<0.0001

$^{a-d}$Means with in columns with different superscripts differ significantly ($p<0.05$)

Table 3: Effects of energy and protein on carcass yield of broilers at 42 days of age

		Percentage					
ME (MJ kg^{-1})	CP (%)	Dressing	Eviscerated	Semi-eviscerated	Breast meat	Leg meat	Abdominal fat
12.55	-	93.39^{a}	72.09	87.10^{a}	12.62	15.84^{a}	1.87^{a}
12.97	-	92.84^{ab}	70.88	84.84^{b}	12.46	15.00^{b}	2.18^{b}
13.38	-	92.51^{b}	72.08	84.79^{b}	12.69	15.01^{b}	2.45^{c}
-	18.5	92.73^{ac}	71.26	86.04	11.91^{a}	15.47	2.10
-	19.0	93.67^{b}	71.49	85.31	12.29^{a}	15.14	2.29
-	19.5	92.14^{c}	71.07	85.03	12.82^{ab}	15.23	2.07
-	20.0	93.12^{ab}	72.92	85.91	13.34^{b}	15.29	2.21
SEM	-	1.18	2.82	2.62	1.43	0.38	0.27
Probalibility							
ME	-	0.0387	NS	0.0040	NS	0.0044	<0.0001
CP	-	0.0024	NS	NS	0.0224	NS	NS
ME×CP	-	NS	NS	NS	NS	NS	NS

$^{a-c}$Means with in columns with different superscripts differ significantly (p<0.05)

(p>0.05). Higher level of dietray dietary ME (13.38 MJ kg^{-1}) significantly increased abdominal fat percentage when compared with lower ME (12.55 or 12.97 MJ kg^{-1}). This result was in agreement with the results reported by Wang and Song (1996), Chen *et al.* (1998), Zanusso *et al.* (1999) and Widyaratne and Drew (2011).

Dietary CP significantly influenced dressing percentage and breast meat percentage (p<0.05). High level of dietray dietary CP (20.0%) significantly increased breast meat percentage when compared with lowe CP (18.5 and 19.0%) but there was no significant difference in breast meat percentage of birds fed with the dietary CP level at 19.5 and 20.0%. No significant influence of dietary CP on eviscerated carcass percentage, semi-eviscerated carcass percentage leg meat percentage and abdominal fat percentage in this experiment (p>0.05). The interaction effect of dietary ME and CP have no significant significant influence on broiler carcass yield (p>0.05).

The index of animal growth performance is often considered as a classical indicator on the requirements of animal dietary CP and ME because it is closely related with the actual production's economic efficiency. But it is not always able to reflect the requirements of the best carcass components of animals. Now a days, the carcass traits of animal have became the important indicators to measure the requirements of energy and protein. Based on this study, researchers considered abdominal fat percentage as a sensitive carcass characteristic index on the research of dietary CP and ME requirements. Although, genetic improvement in growth rate and feed efficiency has allowed modern broilers to reach market weight in a shorter period of time, selection for these economically important traits has been accompanied by an increase in the number of problems encountered during production including obesity, ascites, sudden death syndrome and leg abnormalities (Siegel and Dunnington, 1985; Tolkamp *et al*., 2005). Modern broilers are prone to be over fatty, resulting from hyperpyagia when provided free access to feed, especially fed higher level of dietary ME. Hence, during finishing phase, feeding strategy of modern broilers is that should discard high input-high output model in the past.

Table 4: Effects of energy and protein on meat color of broilers

		Breast meat			Leg meat		
ME (MJ kg^{-1})	CP (%)	L*	a*	b*	L*	a*	b*
12.55	-	33.47	11.46	17.25^{a}	32.33	12.64^{ab}	15.62^{a}
12.97	-	32.99	11.58	19.23^{b}	32.18	11.73^{b}	16.97^{b}
13.38	-	23.94	11.07	20.52^{b}	32.19	12.95^{a}	18.80^{c}
-	18.5	32.83	10.74^{a}	18.49	32.28	12.31	16.83
-	19.0	33.77	11.31^{ab}	18.74	32.78	12.53	16.85
-	19.5	34.46	11.24^{ab}	18.91	31.66	12.89	17.36
-	20.0	32.81	12.19^{b}	19.86	32.21	12.03	17.49
SEM	-	2.49	1.75	2.73	3.11	1.59	2.02
Probalibility							
ME	-	NS	NS	0.0005	NS	0.0268	<0.0001
CP	-	NS	NS	NS	NS	NS	NS
ME×CP	-	NS	NS	NS	NS	NS	NS

Table 5: Effects of energy and protein on meat quality of broilers at 42 days of age

		Shear force (N)		pH		WHC (%)	
ME (MJ kg^{-1})	CP (%)	Breast muscle	Leg muscle	Breast muscle	Leg muscle1	Breast muscle	Leg muscle
12.55	-	26.85	36.28	6.15^{a}	6.27	14.69	20.92^{a}
12.97	-	26.24	37.98	6.02^{b}	6.20	15.50	26.08^{b}
13.38	-	26.23	39.61	6.05^{b}	6.27	16.51	26.08^{b}
-	18.5	26.61	37.96	6.10	6.22^{a}	14.22^{a}	23.49
-	19.0	26.91	37.72	6.01	6.21^{a}	13.91^{a}	24.61
-	19.5	26.34	38.80	6.11	6.34^{b}	15.42^{ab}	22.78
-	20.0	25.87	37.35	6.08	6.22^{a}	18.71^{b}	26.56
SEM		4.00	4.49	0.16	0.15	0.06	0.05
Probalibility							
ME	-	NS	NS	0.0167	NS	NS	0.0011
CP	-	NS	NS	NS	0.0269	NS	NS
ME×CP	-	NS	NS	NS	NS	NS	0.0452

$^{a-b}$Means with in columns with different superscripts differ significantly (p<0.05)

The effect of ME or CP on meat quality of broilers at 42 days of age was presented in Table 4 and 5. Dietary ME significantly influenced b* of breast meat, a* of leg meat and b* of leg meat (p<0.05). Although, b* of breast meat was increased by increasing dietary ME from

12.97-13.38 MJ kg^{-1}, differences in b* of breast meat between 12.97 and 13.38 MJ kg^{-1} of ME were not significant ($p>0.05$). Higher level of dietary ME (13.38 MJ kg^{-1}) significantly increased b* of leg meat when compared with lower ME (12.55 and 12.97 MJ kg^{-1}). Dietary CP and the interaction effect of dietary ME and CP have no significant influences in meat color of broilers ($p>0.05$).

Dietary ME significantly influenced pH of breast muscle and WHC of leg muscle ($p<0.05$) while did not significantly influence pH of leg muscle and WHC of breast muscle ($p>0.05$). Differences in pH of breast meat between 12.97 and 13.38 MJ kg^{-1} of ME were not significant but both significantly lower than the pH of breast meat at the ME level of 12.55 MJ kg^{-1}. Although, WHC of leg meat was increased by increasing dietary ME from 12.97-13.38 MJ kg^{-1}, differences in WHC of leg meat between 12.97 and 13.38 MJ kg^{-1} of ME were not significant ($p>0.05$). Dietary CP significantly influenced pH of leg muscle ($p<0.05$) while did not significantly influence pH of breast muscle ($p>0.05$). There were no effect of dietary CP on WHC and shear force both in breast meat and leg meat ($p>0.05$). The results above were in agreement with the results reported by Yang *et al.* (2007) and Widyaratne and Drew (2011).

CONCLUSION

In general, based on the data of growth performance, carcass yield and meat quality. It was indicated that the optimal dietary ME requirement of broilers from 1-21 days of age is 12.97 MJ kg^{-1} and the CP requirement is 19-20%.

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