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Effect of Partial or Total Inclusion of Betaine and/or Choline Instead of Added Methionine in Broiler Diets on:
1- Growth Performance and Economic Efficiency.

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ABSTRACT

This investigation aimed to evaluate the effect of partial or total replacement of added DL-methionine (Met) with betaine or choline or both in diets of broilers chicks on growth performance and economic efficiency. A total numbers of 440 day-old straight- run Cobb500 broiler chicks were randomly taken, weighed and divided into eleven treatments (40 birds each). Each treatment contained 4 replicates of 10 birds. A basal diet was formulated as control according to NRC, recommendations for starter (0-12 days, 0.165% added Met.), grower (12-24 days, 0.135% added Met.) and finisher (24-36 days, 0.090% added Met.). Treatment one was fed the control ration while the other ten treatments were fed the control ration after partial or total replacement the added Met. with betaine or choline or both. The results of the present study indicated that replacement of added methionine with betaine and/or choline positively affected final live body weight (LBW) of broiler chicks compared with their control group. The highest LBW was achieved by chicks fed T10 (50% betaine and 50% choline) and T7 (100% betaine) when compared with other dietary treatments while the lowest value was recorded with the control group. The same trend of response was observed in body weight gain (BWG) of chicks fed on diets containing different levels of betaine or choline during the whole experimental period compared with their control counterparts. Slight differences were observed among the different experimental groups of broiler chicks in feed intake FI which seemed erratic and perhaps were not related to the effect of dietary treatments. Replacing added dietary methionine with betaine and/or choline in broiler diets led to superior means of feed conversion ratio (FCR) during the three phases of growth and the whole experimental period to those attained by the control group. During the whole experimental period (0-36 days old), birds fed diets in which betaine completely replaced added methionine achieved the lowest PER compared with their control group and other treatments. Also this level of replacement resulted in significantly ($P<0.05$) the best EEU value (4.82) as compared to the control group (5.22). Inclusion of 100% betaine instead of added methionine showed significantly ($P< 0.05$) higher PI value compared with the control group. Birds appeared health and total mortality rates throughout the experimental period were within the normal range among treatments. The lowest cost/kg body weight (11.96 LE) was observed with chicks fed diets completely replaced added methionine, while the highest value in which betaine (12.91 LE) was recorded with the control group. Similar results were observed with economic efficiency. It could be concluded that replacing methionine by betaine, choline or both improved body weight gain, feed conversion and economic efficiency of broiler production.

Keywords: Methionine; Betaine; Choline; Broiler chickens; Growth performance; Economic efficiency

INTRODUCTION

Feed additives are important materials that can improve the efficiency of utilization of dietary labile methyl (meth) groups. These compounds were proposed to be nutrients (McDevitt *et al*.; 2000). Methionine (Met.), choline, betaine (BET) and Folic acid are all considered as meth. donors to body metabolic reactions and have been shown to compensate for the partial deficiency of labile meth. groups in corn-soybean-based diets (Matthews and Southern; 2000). Modern nutrition has revealed that Met. is one of the most limiting amino acids that play a crucial role in body protein synthesis and therefore it would be beneficial to spare its function as a meth. donor. It has been shown that folic acid has to take meth. group before performing its rate as a meth. donor. Choline first has to be converted and then activated to betaine before methyl groups are liberated to fulfill methylation function (McKeever *et al.;* 1991). In contrast, BET contains three meth. groups in its structure and donates them in several metabolic reactions. On a molecular weight basis, BET contains about 3.75 times the meth. groups of Met. and therefore would be an effective compound to spare dietary Met as a methyl donor.

However, the Methionine sparing effect of BET has been the subject of some controversy. Some studies have shown positive responses of animals to BET supplementation in Methionine-deficient diets which included improved carcass characteristics and broiler performance (Gao *et al.;* 2006). These responses were obtained when one part of BET was supplemented to replace two parts of dietary DL-Met. However, the Met sparing effect of BET was not observed in other studies (Esteve-Garcia and Mack; 2000). It seems that the efficiency of Met sparing effect of BET is associated with dietary compositions, animal physiological stage and living conditions.

Betaine is a naturally occurring amino acid derivative found in a variety of feedstuffs of animal origin and plant. Betaine has two primary metabolic roles: it is an osmolyte that assists in cellular water homeostasis and it is a methyl group donor (Petronine *et al*.; 1992).

BET, choline and Met can serve as sources of methyl (-CH3) group. It is well understood that choline may acts as a methyl group donor, but in order to perform this function, it needs to be converted to betaine in the mitochondria (Rostagno and Pack; 1996). Many studies have examined the interrelationship between betaine and methionine to determine if betaine can spare the needs of the chick for Met. Some studies (Virtanen and Rossi, 1995) suggested that the response of broiler growth to betaine was greater than that obtained from the addition of Met, other have failed to demonstrate that the methionine content of the diet could be reduced by supplementation with betaine (El-Ganzory *et al*.; 2004). However, several studies suggested that addition of betaine may improve breast meat yield (McDevitt *et al*.; 2000). Betaine is indirectly involved in the synthesis of carnitine, which is required for transporting long chain fatty acids across the inner mitochondrial membrane for oxidation (McDevitt *et al.;* 2000) and therefore, may result in a leaner carcass.

Betaine is added to the feed of laying hens in an attempt to improve their productivity which could have an important economic value (Park *et al.;* 2006)

Therefore, in the present study, an attempt was made to evaluate the effect of dietary inclusion of betaine or choline or both instead of added methionine in broiler diets on growth performance and economic efficiency of broiler chicks.

MATERIALS AND METHODS

The study was carried out at the Poultry Experimental Station of the Regional Center for Food and Feed (RCFF) located in Nubaria, Alexandria, Egypt during May, 2016. All chemical analyses were performed in the laboratories of the Regional Center for Food and Feed (RCFF), Agricultural Research Center (ARC), Giza, Egypt.

Feed ingredients (y. corn, soybean, corn gluten, sun flower oil, di.ca. phosphate, limestone, L-lysine-HCl, DL-Methionine, Nacl and choline chloride, vitamins & mineral vixture and betaine) used in formulating the experimental diets were purchased from Dakahlia Poultry Company, Meet Ghamr, El-Dakahlia, Egypt. The chemical compositions of yellow corn, soybean meal and corn gluten are presented in Table 1.

Table 1. Chemical Composition of ingredients (%, on DM basis)

	Chemical Composition						
	OM	CP	EE	CF	Ash	NFE	ME (Kcal/kg)
Yellow corn	98.5	8.9	1.4	2.7	1.5	85.5	3350
Soybean meal	94.2	47.5	3.9	7.3	5.8	35.5	2230
Corn gluten meal	98.2	63.5	2.5	2.1	1.8	30.1	3710

1. Experimental chicks

A total number of 440 one-day old unsexed Cobb500 broiler chicks were obtained from Dakahlia Poultry Company, Meet Ghamr, El-Dakahlia, Egypt.

2. Experimental design

Day-old chicks were divided into 11 experimental groups each with 4 equal replications and kept in brooding batteries, and fed the experimental dites as described in Table 2. The diets were formulated to meet the nutrient requirements of broiler chicks during starting, growing and finishing periods according to the National Research Council (NRC, 1994). All chicks were fed a starter diet from one to 12 days of age containing 22.77% CP and 3026 kcal ME/kg diet. From 12 to 24 days of age, the birds were switched to a grower diet containing 21.44% CP and 3106.9 kcal ME/kg diet. While, during 24 to 36 days of age, they were fed a finisher diet containing 20.07% CP and 3198.6 kcal ME/kg diet (Table 3).

The first experimental group of chicks was fed the control rations which contained only methionine while the other ten groups were fed the control diets in which the added methionine was partially or completely replaced by betaine, choline or both. The control diets contained DL-methionine levels of 1.65, 1.35 and 0.9 g/kg in starter, grower and finisher periods, respectively. Composition and calculated chemical analysis of the basal diets during the three phases of growth are presented in Table 3.

Feed and water were available *ad-lib*-during the experimental period. Water was provided by drip nipples and the broilers were exposed to continuous light (24 hrs daily) throughout the experiment. The averages of initial body weights of the different groups were nearly equal. All chicks were vaccinated against different diseases according to the vaccination programs adopted in most Egyptian broiler farmers.

Table 2. Replacement levels of methionine with betaine or choline or both in the experimental rations

Treatments	Betaine%	Choline%	Methionine%
T1	0	0	100
T2	0	33	66
T3	0	66	33
T4	0	100	0
T5	33	0	66
T6	66	0	33
T7	100	0	0
T8	66	33	0
T9	33	66	0
T10	50	50	0
T11	33	33	33

Table 3. Composition and calculated chemical analysis of basal diets during the starter, grower and finisher periods

Ingredients	Starter	Grower	Finisher
Yellow corn	56.003	55.443	58.743
Soybean meal	28.000	28.500	24.800
Corn gluten meal	8.500	8.500	8.500
Sun flower oil	3.000	3.500	4.200
Dicalcium phosphate	2.000	1.850	1.700
Limestone	1.100	0.900	0.795
Vit. & Min. Mixture (1)	0.400	0.400	0.400
Nacl	0.400	0.400	0.400
L-Lysine-HCl	0.350	0.290	0.290
DL-Methionine	0.165	0.135	0.090
Choline chloride	0.082	0.082	0.082
Total	100.000	100.000	100.000
Calculated values (% As-fed basis; NRC, 1994)			
CP	22.77	21.44	20.07
EE	3.91	4.42	5.11
CE	3.73	3.75	3.56
ME (kcal/kg)	3026	3106.9	3198.6
Lysine	1.360	1.230	1.130
Methionine	0.580	0.540	0.470
Methionine + Cystine	0.980	0.920	0.840
Calcium	0.980	0.860	0.770
Available P	0.480	0.450	0.410

(1)Vitamins - minerals mixture supplied per kg of diet: vit. (A), 12000 I.U.; vit. (D_3), 2000 I.U; vit. (E), 10 mg; vit. (K_3), 2 mg; vit. (B_1), 1 mg; vit. (B_2), 5 mg; vit. (B_6), 1.5 mg; vit. (B_{12}), 10 µg; Biotin, 50 µg; Pantothenic acid, 10mg; Niacin, 30 mg; Folic acid, 1 mg; Manganese, 60 mg; Zinc, 50 mg; Iron, 30 mg; Copper, 10 mg; Iodine, 1 mg; Selenium, 0.1 mg and Cobalt, 0.1 mg.

Performance index of chicks was determined according to North.; (1984). Live body weight (LBW) and weight gain were measured weekly. Weekly feed consumption (FC) (g/d/bird), feed conversion ratio (FCR) (g feed/g live BWG) and mortality rate (MR%) were measured for each replicate group.

Growth performance of chicks:

All broilers chicks were weighed individually to the nearest gram. L.B.W and gains (g) of broiler chicks were recorded at three intervals (1-12, 12-24 and 24-36 days of age) and overall experimental period (1-36) days of age. Feed conversion ratio (FCR) was calculated, including the weight gain of the dead birds

Protein efficiency ratio (PER) was calculated during each studied growth periods according to the equation of Persia *et al*.; (2003) as follows: PER: Crude protein consumed (g) / Body weight gain (g)

Performance index (PI) was calculated according to the equation of North.; (1984) by using the following equation:

PI :(Live body weight (Kg) / feed conversion ratio) x100.

Efficiency of energy utilization (EEU) was calculated according to the equation of Ali.; (1999) as follows:

EEU: (ME consumed kcal / g body weight gain).

Mortality rate (MR%) was recorded daily and was calculated at the end of each age interval for each replicate throughout the experimental period. It was also calculated as a cumulative mortality.

Economic efficiency (EE)

For (EE) determination meat production management factors in all treatments were considered to be constants, and the amount of weight gains and feed consumption per treatment were calculated. Prices of feed additives and experimental diets (BET and Choline) were calculated according to the price of local market at the time of experiment. Economic efficiency was calculated as follows: [Net revenue / total cost/bird)]x100

Statistical analyses

Data from all response variables were subjected to one-way analysis of variance using General Linear Model (GLM) of SAS/STAT software (SAS Institute; 2004). Significant differences among treatment means of different variables were separated using Duncan's multiple range procedure (Duncan; 1955) at 5% probability.

RESULTS AND DISCUSSION

Growth performance:

The effect of feeding diets added methionine was partially or totally replaced with betaine, choline or both on live body weight, weight gain, feed intake and feed conversion during the studied growth periods of broilers are presented in Table 4. The results obtained indicated that feeding the diets containing betaine or choline instead of added methionine positively affected 36-days-old live body weight (LBW) of broiler chicks compared with their control group .The highest LBW was achieved by chicks fed T10 (50% betaine and 50% choline) and T7 (100% betaine) when compared with other dietary treatments followed by those fed the diet containing 66% betaine and 33% choline in place of added methionine and then those fed the diet containing 33% betaine and 66% choline in place of added methionine in a descending order, respectively. The same trend of response was observed in body weight gain (BWG) of chicks fed on the diets in which added methionine was replaced with betaine, choline or both during the whole experimental period compared with their control counterparts.

As indicated in Table 4, the effects of dietary treatments on feed intake (FI) of broilers during the starter, grower and finisher phases of growth were inconclusive. While results of overall period (1-36 days), showed that the highest FI values were recorded for chicks fed T11 (33% betaine + 33% choline +33% methionine in place of added methionine) and the lower FI values were recorded for chicks fed T6 (66% betaine + 33% methionine). Such slight differences among the different experimental groups of broiler chicks in FI, observed herein, seemed erratic and perhaps are not related to the effect of dietary treatments. However, dietary replacing the added methionine with betaine, choline or both led to superior means of feed conversion ratio of broilers during the three phases of growth and the whole experimental period to those attained by the control group.

Table 4. Effect of partial or complete replacing added dietary methionine with betaine, choline or both on live body weight (LBW), body weight gain (BWG), feed intake (FI), feed conversion ratio (FCR) and mortality rate (%) of broilers chicks from 0-36 days age.

Items	Tr. 1 (control)	Tr. 2	Tr. 3	Tr. 4	Tr. 5	Tr. 6	Tr.7	Tr. 8	Tr.9	Tr. 10	Tr.11
Initial weight	40.00	40.00	40.00	40.00	40.00	40.00	40.00	40.00	40.00	40.00	40.00
LBW (g) at:											
12 days old	309.79^{d}	310.83^{c}	313.44^{bc}	320.42^{b}	310.83^{c}	329.79^{ab}	334.17^{a}	335.83^{a}	314.17^{bc}	330.83^{ab}	311.67^{c}
24 days old	1077.08^{d}	1078.75^{cd}	1081.88^{bc}	1096.88^{bc}	1077.92^{d}	1120.98^{b}	1144.79^{a}	1143.75^{a}	1080.00^{c}	1130.76^{ab}	1091.02^{bc}
36 days old	1866.67^{d}	1870.83^{d}	1884.79^{cd}	1898.54^{c}	1876.93^{cd}	1902.92^{c}	1952.50^{b}	1926.25^{bc}	1911.04^{bc}	1980.45^{a}	1897.12^{c}
BWG (g) at:											
0-12 days old	269.79^{cd}	270.83^{c}	273.44^{bc}	280.42^{b}	270.83^{c}	289.79^{ab}	294.17^{a}	295.83^{a}	274.17^{bc}	290.83^{ab}	271.67^{c}
12-24 days old	767.29^{cd}	767.92^{cd}	768.44^{c}	776.46^{c}	767.08^{cd}	791.19^{bc}	810.63^{a}	807.92^{ab}	765.83^{d}	799.92^{b}	779.36^{c}
24-36 days old	789.58^{cd}	792.08^{cd}	802.92^{bc}	801.67^{c}	799.02^{c}	781.94^{d}	807.71^{bc}	782.50^{d}	831.04^{b}	849.70^{a}	806.10^{bc}
0-36 days old	1826.67^{d}	1830.83^{d}	1844.79^{cd}	1858.54^{c}	1836.93^{cd}	1862.92^{cd}	1912.50^{b}	1886.25^{bc}	1871.04^{bc}	1940.45^{a}	1857.12^{c}
FC(g) at:											
0-12 days old	370.12^{bc}	371.25^{b}	368.75^{bc}	367.08^{cd}	369.58^{c}	375.83^{ab}	376.25^{ab}	378.96^{a}	370.83^{bc}	376.67^{ab}	366.88^{d}
12-24days old	1262.50^{b}	1247.50^{bc}	1228.75^{c}	1215.83^{cd}	1236.25^{c}	1201.04^{d}	1200.42^{d}	1202.29^{d}	1199.17^{d}	1247.86^{bc}	1275.19^{a}
24-36 days old	1435.00^{ab}	1433.33^{b}	1431.88^{b}	1413.75^{c}	1398.75^{cd}	1377.92^{d}	1384.58^{d}	1392.29^{cd}	1451.25^{a}	1449.20^{a}	1436.59^{ab}
0-36 days old	3067.92^{ab}	3052.08^{ab}	3029.38^{b}	2996.67^{c}	3004.58^{bc}	2954.79^{d}	2961.25^{d}	2973.54^{cd}	3021.25^{b}	3073.73^{ab}	3078.66^{a}
(FCR) at:											
0-12 days old	1.38^{a}	1.37^{ab}	1.35^{b}	1.31^{bc}	1.37^{ab}	1.30^{bc}	1.28^{d}	1.28^{d}	1.35^{b}	1.30b^{c}	1.35^{ab}
12-24 days old	1.65^{a}	1.63^{ab}	1.60^{b}	1.57^{bc}	1.61^{b}	1.52^{cd}	1.48^{d}	1.49^{d}	1.57^{bc}	1.56^{c}	1.64^{a}
24-36 days old	1.82^{a}	1.81^{a}	1.78^{ab}	1.76^{b}	1.75^{bc}	1.76^{b}	1.72^{c}	1.78^{ab}	1.75^{bc}	1.71^{d}	1.79^{ab}
0-36 days old	1.68^{a}	1.67^{a}	1.64^{b}	1.61^{c}	1.64^{b}	1.59^{c}	1.55^{d}	1.58^{cd}	1.61^{c}	1.58^{cd}	1.66^{ab}
Mortality rate (%) at:											
0-36 days old	2.85^{a}	2.70^{b}	2.20^{cd}	2.00^{cd}	2.40^{c}	1.92^{cd}	1.76^{d}	1.80^{d}	1.92^{cd}	1.76^{d}	2.20^{cd}

a, b, c and d Means at the same row with different superscripts differ significantly ($P<0.05$) different.

It is evident that supplementation with betaine to broiler diets produced a positive effect on body weight gain and feed conversion ratio when compared with those of the control group. However, (Dorra *et al*.; 2012) indicated that betaine supplementation increased feed intake of growing toms, which is in contrast to the present results. In accordance with the present results, (Tolba *et al*.; 2007) showed that dietary supplemental betaine improved feed conversion and live body weight of fayoum laying hens as compared to the respective control. (Honarbakhsh *et al*.; 2007) stated that betaine supplementation increased body weight and improved feed conversion ratio of broiler chicks in grower and finisher periods. The aforementioned authors have hypothesized that betaine as an osmolyte that could improve intestinal structure and function to increase growth performance. Generally, a positive effect of betaine on performance of broilers was reported by others (Hamidi *et al*.; 2010) and ducks (Wang *et al*.; 2004).

Similar results were reported by several authors. In this respect, betaine supplementation (800 mg/kg diet) enhanced growth at 21 days and feed conversion efficiency at 42 days of age in broilers fed a diet containing 15 g Met/kg CP (Rama Rao *et al*.; (2011). Moreover, betaine significantly ($P \leq 0.05$) improved body weight and feed conversion of Matrouh chickens at a level of 1 g/kg diet (Ezzat *et al*.; 2011).

Also, (Enting *et al*.; 2007) showed that the addition of 1 and 2 g/kg betaine to the feed improved feed conversion ratio of broiler chickens from 0 to 14 days of age and body weight at 40 days of age. Moreover, (Honarbakhsh *et al*.; 2007) evaluated the effects of different exogenous betaine levels (0, 0.075, 0.150 and 0.225%) on growth performance of male broiler chicks (Ross). They observed that betaine supplementation increased body weight and improved feed conversion ratio in grower and finisher periods ($P \leq 0.01$).

Also, (Jahanian and Rahmani00; 2008) found that no effect on feed intake dietary betaine inclusion of broiler. These findings indicate that dietary betaine inclusion instead of choline had little benefit in terms of parameters performance. (El-Husseiny *et al*.; 2007) estimated the effect of methionine levels (0.33 and 0.45%) with betaine on broiler performance, revealing that B.W.G and F.C.E were significantly increased with increasing betaine levels up to 0.75 g/kg diet.

Mortality%:

The mortality rates as of broiler chicks affected by dietary treatments are presented in Table 4. It could be noticed that all birds appeared health and total mortality rates were within the normal range among treatments and ranged between 1.76-2.85% (birds), indicating that mortality rates were not related to the effect of dietary treatments. The obtained means of mortality rates are lower than those previously reported by (Tollba *et al*.; 2004), who found that mortality rate was 5% when they reared broiler chicks in normal conditions (24ºC).

In respect of dietary treatments, the results showed that birds fed the control ration recorded, the highest mortality rate. Among all dietary treatments studied, inclusion of betaine alone or 50% betaine and 50% choline instead of added dietary methionine had lower mortality rates when compared to those of other treatments. It is of interest to note that replacement of methionine with choline produced intermediate mortality rates.

Efficiency of protein (PER) and energy utilization (EEU) and performance index (PI):

The effect of replacing added dietary methionine with betaine, choline or both on PER, EEU and PI of broiler chicks throughout the entire experimental periods are summarized in Table 5. During starter period (0-12 days old) the results showed that complete replacement of methionine with betaine or with betaine replacement at a level of 100% and 66% betaine and 33% choline led to a significant increase in PER ($p<0.05$) values than other treatments and the control one. While through the grower period (12-24 days old), the highest PER values were recorded for chicks fed T7 (100% betaine), T8 (66% betaine plus 33% choline) and T10 (50% betaine plus 50% choline) when compared with other dietary treatments. Results of the finisher period (24 to 36 days old) showed similar results as starter period. Overall period (0-36 days old) birds fed 100% betaine in place of added dietary methionine achieved significantly higher PER ($P<0.05$) values than other treatments while control ration had the lowest value.

Table 5. Effect of partial or replacing added dietary methionine with betaine, choline or both on protein efficiency ratio (PER), efficiency of energy utilization (EEU) and performance index (PI) of broiler chicks from 0-36 days of ago

Items	Tr. 1 (control)	Tr. 2	Tr. 3	Tr. 4	Tr. 5	Tr. 6	Tr.7	Tr. 8	Tr. 9	Tr. 10	Tr. 11
Protein efficiency ratio (PER) at:											
0-12 days old	0.313^{d}	0.312^{d}	0.307^{c}	0.298^{bc}	0.311^{cd}	0.295^{b}	0.291^{a}	0.292^{a}	0.308^{c}	0.295^{b}	0.307^{c}
12-24 days old	0.353^{c}	0.348^{d}	0.343^{bd}	0.336^{b}	0.346^{d}	0.325^{ab}	0.317^{a}	0.319^{a}	0.336^{b}	0.334^{b}	0.351^{dc}
24-36 days old	0.365^{c}	0.363^{c}	0.358^{dc}	0.354^{bd}	0.351^{b}	0.354^{bd}	0.344^{a}	0.357^{d}	0.350^{b}	0.342^{a}	0.358^{d}
0-36 days old	0.352^{d}	0.349^{c}	0.344^{bc}	0.338^{b}	0.343^{b}	0.333^{b}	0.325^{a}	0.331^{ab}	0.338^{b}	0.332^{ab}	0.347^{c}
Efficiency of energy utilization (EEU) at:											
0-12 days old	4.15^{a}	4.15^{a}	4.08^{b}	3.46^{bd}	4.13^{ab}	3.92^{d}	3.87^{c}	3.88^{c}	4.09^{b}	3.92^{d}	4.09^{b}
12-24 days old	5.11^{a}	5.05^{ab}	4.97^{bc}	4.87^{c}	5.01^{b}	4.72^{cd}	4.60^{d}	4.62^{d}	4.86^{c}	4.85^{c}	5.08^{ab}
24-36 days old	5.81^{a}	5.79^{ab}	5.70^{b}	5.64^{bc}	5.60^{c}	5.64^{bc}	5.48^{cd}	5.69^{b}	5.59^{c}	5.46^{d}	5.70^{b}
0-36 days old	5.22^{a}	5.19^{b}	5.11^{bc}	5.02^{c}	5.09^{bc}	4.99^{c}	4.82^{d}	4.90^{cd}	5.02^{c}	4.93^{cd}	5.16^{b}
Performance index (PI) at:											
at 12 days old	22.51^{d}	22.68^{cd}	23.24^{bc}	24.48^{b}	22.67^{cd}	25.43^{ab}	26.13^{a}	26.21^{a}	23.22^{bc}	25.55^{ab}	23.08^{c}
at 24 days old	65.28^{d}	66.18^{d}	67.60^{cd}	70.05^{c}	66.87^{d}	73.82^{bc}	77.30^{a}	76.84^{b}	68.97^{cd}	72.49^{bc}	66.54^{cd}
at 36 days old	111.13^{d}	112.21^{cd}	114.78^{c}	117.75^{bc}	114.75^{c}	117.49^{bc}	126.10^{a}	122.19^{b}	118.35^{bc}	125.00^{ab}	114.46^{cd}

a, b, c and d Means at the same row with different superscripts are differ significantly (P<0.05) different.

During the overall period (0-36 days old), replacement inclusion of betaine to replace 100% of added methionine in broiler diet result significantly ($P<0.05$) the best EEU value (4.82) as compared to the control group (5.22), this finding positively corresponds with the highest BWG of 1912.5g /bird period for treatment seven and lowest BWG of 1826.7g /bird period of the control group, respectively. During all examined periods and the whole experimental period in comparison to all dietary treatments the EEU corresponding values ranged from 4.82-5.22 confirming that the control group had significantly lower EEU value ($P<0.05$) which corresponds with the lowest BWG. This agree with the results observed by (El-Shinnawy; 2015), who reported that EEU of broiler chicks was positively affected by dietary supplementation with graded levels of betaine during all phases of growth compared with those of their control.

Dietary inclusion of 100% betaine instead of added methionine in broiler diets resulted insignificantly higher PI value ($P<0.05$) through starter period (0-12 days of age) till the end of the experiment, followed by treatment 10 (50% betaine + 50% choline) and treatment 8 (66% betaine and

33% choline). It is worth to note that the control group recorded the lowest PI value during all experiment periods. Among all dietary treatments studied treatment 4 (100% choline), treatment 6 (66% betaine + 33% choline) showed intermediate values, when compared to those of other dietary treatments.

Economic efficiency:

The profitability of replacing added dietary methionine with betaine, choline or both in starting, growing and finishing diets of broiler depends on the cost of these ingredients and their effect on growth performance.

Data presented in Table 6, show that the lowest cost/kg body weight (11.96 LE) was observed with chicks fed diets in which betaine completely replaced the added methionine, followed by those fed treatment eight (66% betaine and 33% choline) and treatment 10 (50% betaine and 50% choline), while the highest (12.91 LE) was recorded with control group (zero replacement). This may be due to the fact that inclusion of betaine and/or choline in the diets scored better, B.W, W.G and F.C.R. beside the lower prices of these ingredients when compared with methionine.

These results reflected the highest economic efficiency value for T7 (151%) followed by T8 (147%) and T10 (146%). However, those in the control group showed the lowest value of economic efficiency (132%). The relative increases in economic efficiency of broiler due to adding betaine or betaine and choline as partial or complete substitutes for methionine ranged between 2.0 and 14.0% these improvements could be attributed to the improved body weight gain, feed conversion and low prices of betaine and choline compared with methionine.

In conclusion, partial or complete replacing added dietary methionine with different levels of betaine, choline or both had positive effect on final B.W, B.W.G, F.C.R and E.E of broiler chicks. Further experimentation on the subject may be carried out to establish the fact that added dietary methionine can be partly or totally provided by other available methyl donors.

Table 6. Effect of partial or complete replacing added dietary methionine with betaine, choline or both on economic efficiency of broiler production from 0-36 days old

Items	Tr. 1 (control)	Tr. 2	Tr. 3	Tr. 4	Tr. 5	Tr. 6	Tr.7	Tr. 8	Tr.9	Tr. 10	Tr.11
Fixed Cost (L.E)/(chicken)^{a}	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00
Feed intake (g/bird)											
Starter	370.12^{bc}	371.25^{b}	368.75^{bc}	367.08^{cd}	369.58^{c}	375.83^{ab}	376.25^{ab}	378.96^{a}	370.83^{bc}	376.67^{ab}	366.88^{d}
Grower	1262.50^{b}	1247.50^{bc}	1228.75^{c}	1215.83^{cd}	1236.25^{c}	1201.04^{d}	1200.42^{d}	1202.29^{d}	1199.17^{d}	1247.86^{bc}	1275.19^{a}
Finisher	1435.00^{ab}	1433.33^{b}	1431.88^{b}	1413.75^{c}	1398.75^{cd}	1377.92^{d}	1384.58^{d}	1392.29^{cd}	1451.25^{a}	1449.20^{a}	1436.59^{ab}
Feed cost (LE/bird)											
Starter	2.512^{bc}	2.519^{b}	2.50^{bc}	2.489^{cd}	2.508^{c}	2.550^{ab}	2.552^{ab}	2.570^{a}	2.515^{bc}	2.554^{ab}	2.489^{d}
Grower	8.718^{b}	8.612^{bc}	8.481^{c}	8.390^{cd}	8.534^{c}	8.290^{d}	8.285^{d}	8.297^{d}	8.275^{d}	8.611^{bc}	8.801^{a}
Finisher	9.863^{ab}	9.845^{b}	9.838^{b}	9.712^{c}	9.612^{cd}	9.469^{d}	9.513^{d}	9.564^{cd}	9.969^{a}	9.955^{a}	9.872^{ab}
Feed cost/bird (LE)^{b}	21.093^{b}	20.976^{bc}	20.820^{bc}	20.591^{cd}	20.654^{c}	20.309^{d}	20.350^{d}	20.431^{cd}	20.759^{c}	21.120^{b}	21.162^{a}
Total cost/bird(L.E)^{c}	24.093^{b}	23.976^{bc}	23.820^{bc}	23.591^{cd}	23.654^{c}	23.309^{d}	23.350^{d}	23.431^{cd}	23.759^{c}	24.130^{b}	24.162^{a}
Final LBW (kg)	1.866^{d}	1.870^{d}	1.884^{cd}	1.898^{c}	1.876^{cd}	1.902^{c}	1.952^{b}	1.926^{bc}	1.911^{bc}	1.980^{a}	1.897^{c}
Cost / Kg BW	12.91^{a}	12.82^{ab}	12.64^{b}	12.43^{c}	12.61^{bc}	12.26^{cd}	11.96^{d}	12.17^{cd}	12.43^{c}	12.19^{cd}	12.74^{b}
Total income (LE)^{d}	55.980^{d}	56.100^{d}	56.520^{c}	56.940^{bc}	56.280^{cd}	57.060^{bc}	58.560^{ab}	57.780^{b}	57.330^{b}	59.400^{a}	56.910^{c}
Net revenue (LE)e	31.887^{d}	32.124^{cd}	32.700^{c}	33.349^{bc}	32.628^{c}	33.751^{b}	35.210^{a}	34.349^{ab}	33.571^{b}	35.270^{a}	32.748^{c}
EE^{f} %	132^{d}	134^{cd}	137^{c}	141^{bc}	138^{c}	145^{b}	151^{a}	147^{ab}	141b^{c}	146^{ab}	136^{cd}
Relative EE^{h}	100.00^{d}	102.00^{cd}	104.00^{c}	107.00^{bc}	105.00^{c}	108.00^{b}	114.00^{a}	111.00^{ab}	107.00^{bc}	111.00^{ab}	103.00^{cd}

Where: c= (a+b) e= (d-c) f= (e/c) h= (EE of treatment/EE of control)x100. Free market prices (LE/ton) for feed ingredients used in formulating the experimental ration in the year (2017),

a, b, c and d Means at the same row with different superscripts differ significantly (P<0.05) different.

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تأثير إدخال البيتايين أوالكولين أوكليهما كلياً أوجزئياً فى علائق كتاكيت اللحم كبدائل للمثيونين المضاف على: 1- المظاهر الإنتاجية والكفاءة الإقتصادية لها

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تهدف هذه الدراسة إلى تقيم تأثير الإحلال الجزئى أو الكلى للمثيونين المضاف للعليقة بالبيتايين أو الكولين أو كليهما فى علائق كتاكيت اللحم على المظاهر الإنتاجية والكفاءة الإقتصادية. إستخدم فى هذه الدراسة 440 كتكوت عمر يوم واحد من سلالة كب 500، وتم وزنها وتقسيمها إلي إحدى عشر معاملة متساوية (40 طائر/ معاملة). وتحتوى كل معاملة على أربعة مكررات كل مكرر عشرة طيور، وتم تكوين العليقة الأساسية لتكون عليقة المقارنة طبقاً لتوصيات NRC سواء للبادئ (صفر - 12 يوم 0.165 % مثيونين مضاف)، النامى (12-24 يوماً، 0.135% مثيونين مضاف) و (24-36 يوماً، 0.90% مثيونين مضاف). وتم تغذية المعاملة الأولى على عليقة المقارنة بينما تم تغذية العشر معاملات الأخرى على عليقة المقارنة بعد الإحلال الجزئى أو الكلى للمثيونين المضاف بالبيتايين أو الكولين أو خليط منهما. وقد أظهرت النتائج أن إستبدال المثيونين المضاف جزئياً أو كلياً بالبيتايين أو الكولين كان له تأثير إيجابى على الوزن النهائى للجسم مقارنة بمجموعة المقارنة . وحققت المجموعة العاشرة (50% بيتايين + 50% كولين) والمجموعة السابعة (100% بيتايين) أكبر وزن جسم عند مقارنتها بالمعاملات الأخرى بينما سجلت مجموعة المقارنة أقل وزن. ولقد لوحظ نفس الإتجاه مع معدل النمو اليومى مع الكتاكيت المغذاة على عليقة تحتوى على مستويات مختلفة من اليتايين أو الكولين خلال الفترة الكلية للتجربة مقارنة بمجموعة المقارنة والفروق البسيطة فى المتناول من الغذاء بين المجاميع المختلفة من الطيور غير ملموسة وقد لا ترجع إلى تأثير المعاملات الغذائية. والإحلال الجزئى أو الكلى للبيتايين أو الكولين محل المثيونين المضاف فى علائق الكتاكيت أدى إلى معظمة التحويل الغذائى خلال فترات النمو الثلاث وخلال الفترة الكلية للتجربة عما تحقق من مجموعة المقارنة وخلال الفترة الكلية أدى إحلال البيتايين بنسبة 100% محل المثيونين المضاف إلى تحسن معنوى فى الكفاءه الغذائية عن المعاملات الأخرى بينما سجلت مجموعة المقارنة قيمة كفاءة اقل. خلال الفترة الكلية للتجربة (صفر-36يوم) إنخفضت قيم PER عند إحلال البيتايين بدلاُ من المثيونين عند مستوى 100% عن باقى المعاملات وسجلت مجموعة المقارنة أعلى قيمة، أيضا هذا المستوى من الإستبدال كان أقل قيمة فى EEU حيث سجلت 4.82 مقارنة بمجموعة المقارنة التى سجلت 5.22 ، أيضاً أظهر إحلال البيتايين بنسبة 100% محل المثيونين المضاف إلى تحسن معنوى فى قيمة PI مقارنة بالمجموعة المقارنة. كما أظهرت النتائج أن نسبة النفوق خلال فترة التجربة كانت فى المعدل الطبيعى فى جميع المعاملات وتراوحت نسبتها بين 1.76-2.85% وسجلت أعلى نسبة نفوق فى المجموعة المقارنة. وقد لوحظ أن اقل تكلفة للكيلوجرام من وزن الجسم كانت عند مستوى إستبدال 100% بيتايين محل المثيونين حيث كانت 11.96 جنية والتى فيها تم إحلال البيتاين كليا محل المثيونينوكانت أعلى تكلفة فى مجموعة المقارنة 12.91 جنية. وكانت النتائج على نفس السياق فى معدل الكفاءة الإقتصادية. وبالتالى يمكن أن نستنتج أن إستبدال المثيونين المضاف جزئياً أو كلياً بالبيتايين أو الكولين أدى إلى تحسين معدل الزيادة الوزنية وكفاءة تحويل الغذاء وإنخفاض نسبة النفوق ورفع الكفاءة الإقتصادية الإنتاجية للكتاكيت.