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Effect of Dietary Supplementation of Graded Levels of Butyric Acid on Growth Performance and Nutrient Utilization in Broiler Chicken

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ABSTRACT

Butyric acid, a short- chain fatty acid is considered as a potential alternative to antibiotic growth promoter in poultry feed. The present study investigated the effect of feeding graded levels of butyric acid on the performance of broiler chickens. Day-old broiler chicks (n=180) were divided into 6 groups with 3 replicates of 10 chicks in each. The diets were formulated using conventional feed ingredients. Six diets were formulated for pre starter, starter and finisher phases. Diet I was NC (T0), diet II contained antibiotic bacitracin @ 50 mg/kg (T1) and diets III,IV,V and VI contained butyric acid at graded levels *i.e.* 0.2,0.4,0.6 and 0.8% in groups T2 to T5 respectively. The average body weight during the 4th and 5th weeks of study increased significantly (P<0.01) in T3 as compared to other groups. The weekly feed intake at 4th week was significantly (P<0.01) lower in birds of supplemented groups (T1, T2, T3, T4, T5) as compared to NC(T0). The cumulative feed conversion ratio was significantly (P<0.01) better in T3 as compared to T1, T2 and T5,however no significant difference was observed between T3 and T4. The dry matter and crude protein metabolizability were significantly (P<0.01) higher in all the treatment groups as compared to negative control(T0).Among the treatment groups the per cent retention of phosphorus was significantly higher in supplemented groups as compared to NC. It is concluded that butyric acid @ 0.4% could be a better alternative to antibiotic bacitracin, which is widely used in commercial broiler feed regimens to improve performance.

KEYWORDS: Broiler Chicken, Butyric acid, Growth, Nutrient utilization

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INTRODUCTION

Antibiotic feed additives as growth a promoter have long been used in poultry feed (Hassan et al., 2010). The emergence of microbial resistance to antibiotics (Robinson et al., 2016) and the presence of antibiotics residues in feed and environment (Gonzalez et al., 2017) has resulted in compromised human and animal health. Organic acid (OAs) supplementation was initially targeted for improving performance in broiler chickens, but there is growing evidence that dietary organic acids supplementation may completely replace antibiotics and can act as an alternative to antibiotic growth promoter. OAs are used in feeds for their various beneficial effects on gut microflora and its functions and, inhibition of pathogenic bacteria (Dehghani-Tafti and Jahanian, 2016). Amongst the OAs, short- chain fatty acids like, butyric acid has higher bactericidal activity, when added in an un-dissociated form (Leeson, 2007).

Although the organic acid supplementation was initially targeted for improving performance in broiler chickens, there is growing evidence that dietary supplementation with organic acids may also contribute to reduced nitrogen and P excretion with lower environmental pollution (Khodambashi Emami et al., 2013). Recent studies indicated that organic acids could increase the utilization of phytate-P in poultry (Vieira et al., 2018).Many researchers have investigated its beneficial effects in the poultry birds but still, there is a dearth of literature citing an ideal level of butyric acid that can be incorporated in the poultry feed to achieve optimal growth without any adverse effects. Thereby, the present study aimed to evaluate the effect of different dietary levels of butyric acid on the growth performance and nutrient utilization so as to optimize its dietary inclusion level as an alternative to antibiotic growth promoter in broiler chicken.

MATERIALS AND METHODS

A biological experiment of five weeks duration was conducted following a completely randomized design (CRD) in broiler chicks in the poultry shed of the College of Veterinary Science & Animal Husbandry, Anjora, Durg. The experiment followed the guidelines of Institutional Animal Ethics Committee. A total of 180, day-old Ross AP strain broiler chicks were reared under a deep litter system. The chicks were divided into 6 dietary treatment groups (T0-T5). Each group had3 replicates of 10 chicks in each. The diets were formulated as per ICAR (2013) specifications for pre-starter (0-14 d), starter (15-21 d) and finisher (22-35 d) stages. The pre- starter diets contained 22% CP and 3000 kcal ME, starter 21.5% CP and 3050 kcal ME and finisher diet contained 19.5% CP and 3100 kcal ME/kg feed. Six diets were formulated for each starter, grower and finisher (Table 1).

Diet I was served as negative control (T0), diet II contained antibiotic bacitracin @ 50 mg/kg (T1) and diets III,IV,V and VI contained butyric acid (BA) at graded levels i.e. 0.2,0.4,0.6 and 0.8%in groups T2 to T5 respectively. All the diets were made iso-caloric and iso-nitrogenous. The body weight of an individual bird was recorded every week and a gain in weight was calculated. Weekly and cumulative feed consumption was recorded and the feed conversion ratio was calculated in each treatment group. A metabolism trial of 4 -day duration was conducted between 30-35 d of age to determine the nutrient utilization and nutrient balance (N, Ca and P) in the broilers. The sample of diet and excreta were analyzed for various proximate principles and P (AOAC, 2000), Ca (Talapatra et al., 1940) to determine the nutrient utilization and balance. For interpretation of the results the data were analyzed by one-way Analysis of Variance (ANOVA) using a complete randomized deign. Overall data were analyzed as per the standard procedure given by Snedecor and Cochran, 1994 and the mean value were compared using the SPSS package (SPSS ver 26.0) and significant difference was expressed as 1 and 5 % of probability.

RESULT AND DISCUSSION

Dietary supplementation of different levels of Butyric acid (BA) accrued no significant variation in the average body weight of chicks at the end of pre-starter phase (14 d).The weight was higher in birds of all the treatment groups but the value differ non significantly with birds of NC (T0) and C (T1) groups at the end of pre -starter phase. The average body weight of birds on 21st day ranged between 827 to 867 g in different groups, the variation among the group was not significant. The supplementation of BA led to a significant effect on body weight during the finisher phase. The body weight at 4th week was significantly ($P<0.01$) higher in birds fed diet supplemented with BA @ 0.4% (T3) and 0.6 % (T4) as compared to all other groups except T1. Significantly ($P<0.01$) higher body weight was observed in birds of all the treatment groups as compared to NC at 35th day. Among the treatment group the body weight was significantly ($P<0.01$) higher in birds of group T3 (BA @ 0.4%) as compared to all other groups (Table 2).

Table 1. Ingredient and chemical composition of pre- starter, starter and finisher broiler diet

Particular	Pre starter						Starter						Finisher			
%	T0	T1	T2	T3	T4	T5	T0	T1	T2	T3	T4	T5	T0	T1	T2	T3
Maize	54.98	54.98	54.98	54.98	54.98	54.98	55.24	55.24	55.24	55.24	55.24	55.24	61.31	61.31	61.31	61.31
Soy DOC	37.69	37.69	37.69	37.69	37.69	37.69	36.83	36.83	36.83	36.83	36.83	36.83	31.44	31.44	31.44	31.44
Soy.Oil	03.30	03.30	03.30	03.30	03.30	03.30	4.09	4.09	4.09	4.09	4.09	4.09	3.80	3.80	3.80	3.80
LSP	0.97	0.97	0.97	0.97	0.97	0.97	1.01	1.01	1.01	1.01	1.01	1.01	0.99	0.99	0.99	0.99
DCP	1.72	1.72	1.72	1.72	1.72	1.72	1.67	1.67	1.67	1.67	1.67	1.67	1.30	1.30	1.30	1.30
Salt	0.33	0.33	0.33	0.33	0.33	0.33	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35
Sodabicarb	0.11	0.11	0.11	0.11	0.11	0.11	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08
Lysine	0.12	0.12	0.12	0.12	0.12	0.12	-	-	-	-	-	-	-	-	-	-
Methionine	0.25	0.25	0.25	0.25	0.25	0.25	0.21	0.21	0.21	0.21	0.21	0.21	0.15	0.15	0.15	0.15
Choline	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.08	0.08	0.08
Phytase	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Premix	0.42	0.42	0.42	0.42	0.42	0.42	0.42	0.42	0.42	0.42	0.42	0.42	0.42	0.42	0.42	0.42
Bacitracin (mg/kg)	-	50	-	-	-	-	-	50	-	-	-	-	-	50	-	-
Butyric acid%	-	-	0.2	0.4	0.6	0.8	-	-	0.2	0.4	0.6	0.8			0.2	0.4
Chemical Composition (%)																
Moisture	11.2	10.9	10.6	11.0	10.8	10.7	10.4	10.1	10.4	10.5	10.7	10.2	11.2	10.8	10.7	10.4
CP	21.9	21.9	22.0	22.1	21.8	22.0	21.3	21.5	21.6	21.7	21.6	21.5	19.5	19.6	19.5	19.7
ME kcal/kg	3000	3000	3000	3000	3000	3000	3050	3050	3050	3050	3050	3050	3100	3100	3100	3100
EE	5.22	5.14	5.32	5.24	5.06	5.11	6.03	5.88	5.24	5.89	5.05	5.32	5.21	5.84	5.25	5.67
CF	3.77	3.84	3.26	3.44	3.67	4.11	3.70	3.06	3.42	3.65	3.44	3.22	3.55	3.67	3.72	3.95
Total ash	3.95	3.34	3.80	3.42	3.81	3.64	3.82	3.94	3.18	3.14	3.83	3.16	3.19	3.36	2.86	2.95
Ca	1.07	1.03	0.99	1.05	1.18	1.08	1.19	1.21	1.23	1.19	1.22	1.18	1.22	1.25	1.24	1.19
P	0.80	0.78	0.66	0.69	0.64	0.62	0.74	0.81	0.77	0.83	0.89	0.77	0.64	0.74	0.66	0.68

*Trace mineral, vitamin premix and additives,Trace mineral premix per kg diet contained CoCo3 0.20 mg, ZnO 112.0 mg, Fe (So4)3 85 mg, MnSo4 105 mg, CuSo4 22.5, Sodium selenite 0.30 mg and potassium iodide 2.5 mg.Vitamin premix per kg diet contained Vit A 15.60 MIU, Vit D3 5.25 MIU, Vit B1 3.60 mg, B2 12.0 mg, B6 8.0 mg, B12 0.02 mg, Biotin 0.18 mg, Ca D pentothenate 15.0 mg, Vit E 120 mg, folic acid 5 mg, Vit K 4 mg and niacin 57.5 mg . T1 bacitracin methylene disalicylate (AGP)

Table.2. Effect of butyric acid supplementation on feed intake, body weight gain and FCR

Particulars	T0	T1	T2	T3	T4	
			Average body weight(g)			
0 d	47.5±0.73	47.9±1.25	48.9±0.27	47.2±0.15	48.1±1.00	4
7 d	132.6±4.32	129.7±2.30	141.3±4.76	134.8±7.38	134.8±8.88	1
14 d	424.5±11.93	441.6±18.74	468.2±14.74	463.6±17.13	455.4±4.12	45
21 d	827.4±3.92	867.5±31.26	859.7±10.18	840.5±8.54	841.6±15.35	8
28 d	1230.1^{d}±14.04	1331.1^{bc}±24.53	1272.8^{cd}±19.54	1421.1^{a}±27.43	1375.6^{ab}±14.41	12
35 d	1787.1^{d}±18.84	1916.9^{c}±14.49	1954.6^{bc}±25.28	2173.9^{a}±27.25	2049.7^{b}±3.59	19
			Weekly feed intake(g)			
1st wk	140.0±4.93	137.1±2.59	137.1±2.59	138.8±0.73	139.1±0.83	1
2st wk	364.8±41.40	378.0±18.96	403.9±11.77	368.5±21.02	394.2±13.10	40
3st wk	619.5±65.00	644.5±19.04	644.5±24.61	611.4±14.82	648.4±22.45	58
4st wk	1000.8^{a}±44.60	874.6^{bc}±32.69	820.2^{c}±12.59	872.2^{bc}±16.01	950.7^{ab}±26.10	92
5st wk	1201.4±50.14	1116.7±106.87	1213.8±64.80	1108.0±60.71	1016.1±9.54	11
			Feed conversion ratio			
0-7 d	1.66±0.13	1.68±0.05	1.49±0.05	1.61±0.15	1.63±0.16	1
0-14 d	1.34±0.12	1.31±0.02	1.29±0.02	1.22±0.06	1.31±0.02	1
0-21 d	1.55±0.03	1.42±0.06	1.46±0.02	1.41±0.04	1.49±0.04	1
0-28 d	1.87^{a}±0.03	1.59^{b}±0.01	1.63^{b}±0.02	1.45^{c}±0.02	1.61^{b}±0.02	1
0-35 d	1.96^{a}±0.01	1.69^{b}±0.07	1.69^{b}±0.04	1.46^{c}±0.02	1.57^{bc}±0.01	1

T0-NC, T1-C(AGP), T2 –0.2% BA, T3 - 0.4% BA, T4 -0.6% BA and T5-0.8% BA
Means in the same row with different superscript a, b, c differs significantly* ($P<0.05$), **($P<0.01$)

The findings corroborate with Raza et al.(2017) who reported increased average body weight in broilers in butyric acid (0.3 and 0.4%) supplemented diet as compared to bacitracin methylene disalicylate. Deghani-Tafti and Jahanian, (2016) found that OA supplementation (2.5 g citric acid/ kgand 2.5 g butyric acid/kg) in diets increased (P=0.002) ADGand improved (P=0.027) FCR values at the finisher period. However, Leeson et al., (2005) reported that butyric acid supplementation (0.1 or 0.2%, 0.4%) had no effect on body weight gain similarly Aghazadeh and TahaYazdi, (2012) reported that dietary supplementation with BA (2.5g BA/ kg)had no effect on AWG or FCR in broiler chicken.

Table 3. Effect of butyric acid supplementation at different levels on average DM, EE and CP metabolizability in broilers

	Particulars	T0	T1	T2	T3	T4	T5	Sig
Dry	Intake (g/b/d)	102.0 ± 2.02	127.4 ± 6.12	115.5 ± 9.75	110.1 ± 8.61	126.3 ± 3.44	122.1 ± 3.21	NS
matter	Outgo (g/b/d)	$27.8^{a}\pm0.29$	$27.4^{a}\pm2.28$	$20.3^{b}\pm2.67$	$19.7^{b}\pm1.39$	$27.1^{a}\pm0.61$	$27.5^{a}\pm1.66$	**
	Balance(g/b/d)	$74.2^{b}\pm1.74$	$100.0^{a}\pm4.51$	$95.1^{a}\pm7.20$	$90.4^{ab}\pm7.46$	$99.1^{a}\pm3.86$	$94.6^{a}\pm4.86$	*
	Metabolizability(%)	$72.7^{d}\pm0.27$	$78.5^{bc}\pm1.21$	$82.5^{a}\pm1.03$	$82.0^{ab}\pm0.78$	$78.4^{bc}\pm0.95$	$78.6^{c}\pm1.21$	**
Ether	Intake (g/b/d)	5.30 ± 0.10	6.88 ± 0.33	6.06 ± 0.51	6.24 ± 0.48	6.64 ± 0.18	6.68 ± 0.17	NS
extract	Outgo (g/b/d)	0.78 ± 0.05	0.88 ± 0.09	0.68 ± 0.13	0.67 ± 0.11	0.92 ± 0.01	0.88 ± 0.02	NS
	Balance(g/b/d)	$4.53^{b}\pm0.15$	$5.99^{a}\pm0.25$	$5.38^{ab}\pm0.38$	$5.56^{a}\pm0.39$	$5.72^{a}\pm0.19$	$5.79^{a}\pm0.17$	*
	Metabolizability (%)	85.2 ± 1.47	87.1 ± 0.94	88.9 ± 1.44	89.2 ± 1.10	86.1 ± 0.55	$86.7\pm.51$	NS
Crude	Intake (g/b/d)	20.1 ± 0.46	25.0 ± 1.20	22.5 ± 1.90	21.7 ± 1.70	24.8 ± 0.67	23.9 ± 0.63	NS
Protein	Outgo (g/b/d)	$12.0^{a}\pm0.94$	$10.2^{ab}\pm0.97$	$8.45^{bc}\pm.55$	$6.43^{c}\pm1.05$	$9.04^{abc}\pm1.08$	$10.13^{ab}\pm1.16$	*
	Balance((g/b/d)	$8.14^{b}\pm1.00$	$14.8^{a}\pm0.44$	$14.0^{a}\pm1.43$	15.3a±0.98	$15.7\ ^{a}\pm.95$	$13.8^{a}\pm.55$	**
	Metabolizability (%)	$40.5^{c}\pm3.73$	$59.3^{b}\pm2.16$	$62.3^{ab}\pm1.46$	$70.7^{a}\pm3.28$	$63.6^{ab}\pm4.07$	$57.8^{b}\pm3.66$	**

T0-NC, T1-C(AGP), T2 –0.2% BA, T3 - 0.4% BA, T4 -0.6% BA and T5-0.8% BA
Means in the same row with different superscript a, b, c differs significantly* (P<0.05), **(P<0.01)

Previous studies (Mahdavi and Torki 2009; Nari et al., 2020) documented no improvement in bodyweight due to supplementation of sodium butyrate or butyric acid in broiler feed.

The weekly feed intake due to supplementation of different dietary levels of BA differed non-significantly amongst the groups during pre-starter and starter phase. The weekly feed intake during the 4th week of study differed significantly (P<0.05) among the groups. The birds of NC group consumed significantly (P<0.05) higher feed as compared to birds of group T1, T2 and T3. During 5th week no definite trend was observed with regard to weekly feed intake, the value differed non-significantly between the groups. The results of present findings corroborated with (Panda et al., 2009; Adil et al., 2010; Dehghani-Tafti and Jahanian, 2016; Abdelqader and Al-Fataftah, 2016) they documented no difference in the feed consumption between the groups fed organic acids with the control group. Previous reports regarding effect of the butyric acid on feed intake are variable, Sikandar et al. (2017) observed higher average weekly feed intake in sodium butyrate supplemented groups as com¬pared to control and some literature (Lesson et al., 2005) reported less feed intake by birds supplemented with BA during starter phase as compared to birds of a control group.

The cumulative FCR upto 28th day improved significantly (P<0.05) in all the treatment groups as compared to NC. Among the treatment groups significantly improved FCR was observed in birds of group T3 as compared to other groups. A similar trend was observed at the end of the experiment i.e 35th day also, in which significantly(P<0.05) better FCR was observed in birds of group T3 fed diet supplemented with BA@0.4% as compared to other groups.

In the present study BA supplementation @ 0.4% improved FCR at the end of the experiment. The better performance in 0.4 % BA supplemented group may be due to the creation of the acidic envi-ronment in the gut (Moquet et al., 2016), which in turns minimizes the load of pathogens (Hassan et al., 2010).Similar finding was reported by Panda et al. (2009) who reported that BA supplementation @0.4% was more effective in reducing the pH of upper GI tract (crop, proventiculus and gizzard) and duodenum as compared to other inclusion levels (0.2,0.6%) in the diets of broilers and thus adequate for optimum BWG and FCR in broiler chicken. Beneficial growth-promoting effects of butyric acid are well documented, and it has been shown to have positive effects on production parameters such as improved weight gain and FCR (Hernandez et al., 2013; Qaisrani et al., 2015; Levy et al., 2015; El-Ghany et al., 2016; Kaczmarek et al., 2016; Sikandar et al.,2017 and Raza et al., 2019).

Contrary to these several previous literatures (Leeson et al., 2005; Mahdavi and Torki 2009; Aghazadeh and TahaYazdi, 2012) concluded no improvement in weight gain and FCR of broiler chicken when sodium butyrate or butyric acid was supplemented in diet. Under nutrient metabolizability the dry matter outgo was significantly (P<0.01) lower in birds of group T2 and T3 as compared to all others groups. The dry matter balance (g/b/d) was significantly (P<0.05) higher in birds of group T1, T2,T4 and T5 as compared to NC. Among the treatment groups, DM metabolizability was significantly (P<0.01) higher in group T2 as compared to T1, T4 and T5. No significant (P<0.05) effect of dietary supplementation of either AGP or different levels of BA on intake and outgo of ether extract was observed however the EE balance was significantly (P<0.05) higher in birds of group T1, T3, T4 and T5 as compared to NC. The CP outgo was significantly (P<0.05) lower in birds of group T2 and T3 as compared to NC (T0). The CP balance (g/b/d) was significantly (P<0.01) higher in all the treatment group irrespective of level of BA as compared to birds of NC group, consequently the CP metabolizability was also significantly higher(P<0.01) in all the treatment groups as compared to NC. Among the treatment groups the value was significantly higher (P<0.01) in T3 as compared to T1 and T0.

The results are in agreement with the findings of Kaczmarek et al.(2016) who reported that supplementation of protected butyrate @0.3 g/kg improves ileal protein digestibility in broiler chicken. Similarly, Qaisrani et al.(2015) reported that the feeding a coarse diet supplemented with BA (2 kg/ ton) improved performance of broilers fed a diet containing a poorly digestible protein source. Contrary to this, Pires et al. (2021) reported no differences in dry matter, nitrogen and ether extract metabolizability due to supplementation of sodium butyrate (105,210,300 g/kg protected sodium butyrate).

The effect of dietary supplementation of different level of BA on Ca intake, outgo and retention were not significantly among the groups. The phosphorus intake and balance were significantly (P<0.05) higher in AGP and BA supplemented group irrespective of level as compared to NC.

Table 4. Effect of butyric acid supplementation at different levels on Ca and P balance in broilers

Particulars		T0	T1	T2	T3	T4	T5	Sig
Calcium	Intake (g/b/d)	1.24±0.02	1.60±0.08	1.43±0.12	1.31±0.11	1.54±0.04	1.48±0.09	NS
	Outgo (g/b/d)	0.72±0.07	0.86±0.22	0.63±0.08	0.55±0.07	0.75±0.13	0.78±0.10	NS
	Balance (g/b/d)	0.52±0.04	0.73±0.26	0.80±0.07	0.76±0.04	0.79±0.17	0.69±0.08	NS
	Retention (%)	42.1±4.57	45.0±15.75	55.9±2.54	58.0±2.02	50.5±9.29	47.2±6.30	NS
Phosphorus	Intake (g/b/d)	0.65^{c}±0.01	0.94^{a}±0.05	0.76^{bc}±0.06	0.80^{b}±0.06	0.89^{ab}±0.02	0.86^{ab}±0.02	**
	Outgo (g/b/d)	0.31±0.16	0.31±0.08	0.23±0.04	0.25±0.05	0.31±0.05	0.29±0.06	NS
	Balance (g/b/d)	0.33^{b}±0.01	0.63^{a}±0.10	0.53^{a}±0.03	0.54^{a}±0.06	0.57^{a}±0.04	0.56^{a}±0.05	*
	Retention (%)	51.7±2.01	66.8±9.13	70.6±4.26	69.3±4.67	64.3±6.50	65.8±5.86	NS

T0-NC, T1-C(AGP), T2 –0.2% BA, T3 - 0.4% BA, T4 -0.6% BA and T5-0.8% BA
Means in the same row with different superscript a, b, c differ significantly* (P<0.05), **(P<0.01)

The results are in agreement with the findings of Vieira et al. (2018) who reported that organic acids supplementation increased the P balance in broilers. The dietary addition of organic acids can improve the digestibility of minerals (Boling et al., 2000; Park et al., 2009). Supplementation of organic acid in the broiler diet caused an increase in digestibility and availability of nutrients due to the increased number of desirable microflora of the digestive tract, resulting in improved mineral retention and bone mineralization (Ziaie et al., 2011). The acidic anion has been shown to complex with Ca, P, Mg and Zn, which results in an improved digestibility of these minerals (Edwards and, Baker 1999).

CONCLUSION

In the present study, 0.4% butyric acid was at par with commonly used antibiotic bacitracin in enhancing performance indices and nutrient utilization in broiler chicken. Thus, it is concluded that butyric acid @ 0.4% in diet is optimal for desirable growth performance in broiler chicken.

REFERENCES

Abdelqader, A. and Al-Fataftah, A.R. 2016. Effect of dietary butyric acid on performance, intestinal morphology, microflora composition and intestinal recovery of heat-stressed broilers. Livestock Science. 183:78–83.

Adil, S., Banday, T., Bhat, G.A., Mir, M.S. and Rehman, M. 2010. Effect of dietary supplementation of organic acids on performance, intestinal histomorphology, and serum biochemistry of broiler chicken. Veterinary Medicine International. 479485. DOI: 10.4061/2010/479485

Aghazadeh, A.M and Taha Yazdi, M. 2012. Effect of butyric acid supplementation and whole wheat inclusion on the performance and carcass traits of broilers.South African Journal of Animal Science. 42(3):241-248.

AOAC. 2000. Official methods of analysis. 17th Edn. Association of Official Analytical Chemists, Washington, D.C., USA.

Boling, S.D., Douglas, M.W., Snow, J.L., Parsons, C., and Baker, D.H. 2000. Citric acid does not improve phosphorus utilization in laying hens fed a corn-soybean meal diet. Poultry Science. 79:1335–1337.

Dehghani-Tafti, N and Jahanian, R. 2016. Effect of supplemental organic acids on performance, carcass characteristics, and serum biochemical metabolites in broilers fed diets containing different crude protein levels. Animal Feed Science and Technology.211:109–116.

Edwards, H.M and Baker, D.D.H. 1999. Effect of dietary citric acid on zinc bioavailability from soy products using an egg white diet with zinc sulfate heptahydrate as the standard. Poultry Science. 78:576–580.

El-Ghany, W., Awaad, M.,Nasef, S. and Gaber, A.2016. Effect of sodium butyrate on Salmonella enteritidis infection in broiler chickens. Asian Journal of Poultry Science.10:104-110.

Gonzalez R., Angeles, M. and Hernandez, J.C. 2017. Antibiotic and synthetic growth promoters in animal diets: review of impact and analytical methods. Food Control.72: 255-267.

Hassan, H.M.A., Mohamed, M.A., Youssef, A, W and Hassan, E.R. 2010. Effect of using organic acids to substitute antibiotic growth promoters on performance and intestinal microflora of broilers. Asian-Australian Journal of Animal Science. 23:1348–53.

Hernandez, J., Afanador, G., Ariza-Nieto, C. and Avellaneda, Y. 2013. Evaluation of coated and powder sodium butyrate in diets for broilers reared with reused litter during a commercial production cycle. Journal of Animal Science. 91(2): 335

ICAR. 2013. Nutrient Requirement of Poultry. Indian Council of Agricultural Research, New Delhi.

Kaczmarek, S. A., Barri, A., Hejdysz, M. and Rutkowski, A.2016. Effect of different doses of coated butyric acid on growth performance and energy utilization in broilers. Poultry Science. 95 (4): 851-9.

Khodambashi Emami., N., S.Z and Ruiz-Feria, C.A.2013. Growth performance, digestibility, immune response and intestinal morphology of male broilers fed phosphorus deficient diets supplemented with microbial phytase and organic acids, Livestock Science, 157, 2–3:506-513

Leeson, S., Namkung, H., Antongiovanni, M. and Lee. E. H. 2005. Effect of butyric acid on the performance and carcass yield of broiler chickens. Poultry Science. 84:1418–1422.

Lesson, S. 2007. Butyrate lancing science versus societal issues in poultry nutrition. Nutrition Abstract Review. 71:1-5

Levy, A.W., Kessler, J. W., Fuller, L., Williams, S., Mathis, G. F., Lumpkins, B. and Valdez, F. 2015. Effect of feeding an encapsulated source of butyric acid (ButiPEARL) on the performance of male Cobb broilers reared to 42 d of age. Poultry Science. 94:1864–1870.

Mahdavi, R and Torki, M. 2009. Study on usage period of dietary protected butyric acid on performance, carcass characteristics, serum metabolite level and humoral immune response of broiler chickens. Advances in Animal and Veterinary Sciences .8:1702-1709.

Moquet, P.C.A., Onrust, L., Van Immerseel, F., Ducatelle, R., Hendriks, W.H. and Kwakkel, R.P. 2016. Importance of release location on the mode of action of butyrate derivatives in the avian gastrointestinal tract. World's Poultry Science Journal. DOI: 10.1017/ S00 43933 91500269X

Nari, N. Ghasemi, H.A., Hajkhodadadi, I and Farahani, A.H.K. 2020. Intestinal microbial ecology, immune response, stress indicators, and gut morphology of male broiler chickens fed low-phosphorus diets supplemented with phytase, butyric acid, or *Saccharomyces boulardii*. Livestock Science. 234.103975, ISSN 1871-1413, https:// DOI.org/10.1016/ j.livsci.2020.103975.

Panda,A.K., Rama Rao, S. V., Raju M. V. L. N. and Shyam, S. G. 2009. Effect of butyric acid on performance, gastrointestinal tract health and carcass characteristics in broiler chickens. Asian-Australian Journal of Animal Sciences. 22(7):1026–1031.

Park, K.W., Rhee, A.R., Um, J.S and Paik, I.K. 2009. Effect of dietary available phosphorus and organic acids on the performance and egg quality of laying hens. Journal of Applied Poultry Research. 18:598–604.

Pires, M.F.,Leandro, N.S.M., Oliveira, H.F., Jacob, D.V., Carvalho, F.B., Stringhini, J.H., Carvalho, D.P. and Andrade, C.L. 2021. Effect of dietary inclusion of protected sodium butyrate on the digestibility and intestinal histo-morphometry of commercial laying hens. Brazilian Journal of Poultry Science. http://dx.doi.org/10.1590/1806-9061-2020-1406

Qaisrani, S. N.,VanKrimpen, M. M., Kwakkel, R. P.,Verstegen, M. W. A. and Hendriks, W. H. 2015. Diet structure, butyric acid, and fermentable carbohydrates influence growth performance, gut morphology, and cecal fermentation characteristics in broilers. Poultry Science.94:2152–2164.

Raza,M., Biswas,A., Mandal, A.B and Yadav, A.S. 2017. Effect of dietary supplementation of butyric acid on growth performance and intestinal microbial load in broiler chickens. Animal Nutrition and Feed Technology.17: 353-359.

Robinson, T. P., Bu, D. P., Carrique-Mas, J., Fèvre, E.M., Gilbert, M., Grace, D., Hay,S.I., Jiwakanon,J., Kakkar, M., Kariuki, S., Laxminarayan, R., Lubroth, J.,Magnusson, U., Thingoc, P., Van Boeckel, T.P. and Woolhouse, M.E.J. 2016. Antibiotic resistance is the quintessential one health issue. Transactions of the Royal Society of Tropical Medicine and Hygiene .110 (7):377–380.

Sikandar, A., Hafsa, Z., Muhammad, Y., Saima, M., Asim A., Farina, K., Saima,A., and Muhammad, S.Y.2017. Effect of sodium butyrate on performance, immune status, micro architecture of small intestinal mucosa and lymphoid organs in broiler chickens. Asian-Australasian Journal of Animal Sciences.30:690-699.

Snedecor, G.W. and Cochran, W.G. 1994. Statistical Methods. 8th Edn.Iowa State University Press, Ames, Iowa.

Talapatra, S.K., Ray, S.N and Sen, K.C. 1940. Estimation of phosphorus, chlorine, calcium, magnesium, sodium and potassium in food stuffs. Indian Journal of Veterinary Science and Biotechnology.10:243-246.

Vieira, B. S., Caramori, J. G., Oliveira, C. F. S, and G. S. S. Correa. 2018. Combination of phytase and organic acid for broilers: role in mineral digestibility and phytic acid degradation. Worlds Poultry Science Journal. 74:711–726

Ziaie, H., Bashtani, M., Karimi, T.M.A., NaeeimiIpour, H., Farhangfar, H and Zeinai, A. 2011. Effect of antibiotic and its alternatives on morphometric characteristics, mineral content and bone strength of tibia in Ross broiler chickens. Global Veterinary Services and Agriculture. 7(4):315–322.