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Effects of Sodium Butyrate and Rosemary Leaf Meal on General Performance, Carcass Traits, Organ Sizes and Nutrient Digestibility of Broiler Chickens

Research Article

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ABSTRACT

The effect of sodium butyrate, rosemary meal and oxytetracycline supplementation on growth performance, carcass characteristics, visceral organs sizes and nutrient digestibility of broilers was investigated. A total of 320 one-day-old male “Arbor acres strain” broiler chicks were allotted to 10 dietary treatments with 4 replicates of 8 birds each. The treatments include: T1: basal diet (BD; negative control), T2: BD + 1 g/kg diet of oxytetracycline (positive control), T3: BD + 2 g sodium butyrate (SB)/kg diet, T4: BD + 4 g SB/kg diet, T5: BD + 2.5 g rosemary meal (RM)/kg diet, T6: BD + 5.0 g RM/kg diet, T7: BD + 2 g SB + 2.5 g RM/kg diet, T8: BD + 2 g SB + 5.0 g RM/kg diet, T9: BD + 4 g SB + 2.5 g RM/kg diet and T10: BD + 4 g SB + 5.0 g RM/kg diet. Birds fed T3, T4, and T5 had the highest ($P<0.05$) body weight with an improved feed conversion ratio. The dressed weight, breast weight and drumstick/thigh weight were better ($P<0.05$) for birds fed T3, T4 and T5. The weights of gizzard, liver and lungs were higher for birds fed T3, while, the length of small and large intestine were lower for birds fed T3, T4, and T5. The digestibility of the crude fiber, crude protein, crude fat and dry matter were higher ($P<0.05$) for birds fed T3, T4, and T5. It was concluded that, T3, T4, and T5 can be safely included for an improved performance; cut yields and nutrient digestibility. They also accelerated the development of health promoting (heart, kidney, and liver) and immune related (spleen) organs.

KEY WORDS antibiotics, birds, nutrient digestibility, organic acids, phytogenic.

INTRODUCTION

One of the quickest ways of producing a high-quality and quantity protein for human consumption is through broiler production, because of its low fat content with high protein and amino acid balance (Sleman *et al.* 2015). Again, broiler production requires less investment compared with rearing other livestock with rapid return on investment, and their intake of feed is comparatively very low while it produces maximum possible amount of food as meat for consumers (Yu *et al.* 2008). Many synthetic feed additives (antibiotic feed promoter) have been used not only to improve feed efficiency but also to improve the productive performance and improve the health of broilers (Hassan *et al.* 2018). Meanwhile, the European Union has placed a ban on the use of these products (antibiotics) in poultry production due to the increased problems associated with antibiotics resistance in birds and antibiotic residue in broiler meat (Forgetta *et al.* 2012; Carvalho and Santos, 2016). The harmful effects of the use of antibiotic growth promoters such as, penicillin, tetracycline, macrolide, aminoglycoside and amphenicol have been detected in foods (Diarra and

Malouin, 2014). The antibiotic residues in meat, when consumed, may cause antibiotic resistance in humans (Landers *et al*. 2012). According to Kummerer (2009), as women consume meat infected with tetracycline residue, it interferes with teeth development in young children. This is also the case with beta-agonists, such as clenbuterol, which may lead to food poisoning, muscle tremors, palpitations and tachycardia (Brambilla *et al*. 2000; Hoffman *et al*. 2001). However, in modern animal production, the removal of antibiotics in animal diet (due to its effect on the health of both animal and human) has been the primary focus of the scientists as they research for alternative to antibiotics. The search for synthetic antibiotic replacement involves the use of natural substances that are safe, increase performance without harmful residue on poultry products, and some of these natural additives include, Sodium butyrate and Rosemary powder (Geetha and Chakravarthula, 2018; Alagawany *et al*. 2019; Farag and Alagawany, 2019; Saeed *et al*. 2019). Various non-synthesized-antibiotic dietary supplements, therefore, have been suggested to serve as growth enhancers, including probiotics, prebiotics, synbiotics, organic acids, immunostimulants, amino acids, enzymes, and phytogenic feed additives (Ahsan *et al*. 2016; Kamboh *et al*. 2016; Mashayekhi *et al*. 2018; Abouelezz *et al*. 2019). Organic acids (sodium butyrate (SB) $Na(C_3H_7COO)$ and phytogenic feed additives (rosemary meal) are increasingly popular as growth promoters in poultry. The acidifiers, a group of organic acids and their salts, are typically used as feed additive in poultry, and they showed the ability to improve growth performance (Attia *et al*. 2013). Sodium butyrate (SB) belongs to this group and it exerts its beneficial effects by decreasing the gut mucosal pH, creating an optimal growth environment for beneficial bacteria, and preventing the development of pathogenic populations (Van Immerseel *et al*. 2004; Moquet *et al*. 2016). The dietary inclusion of SB showed some remarkable benefits on weight gain, carcass characteristics, nutrient digestibility, intestinal villus surface, and immune stimulatory properties of broilers (Qaisrani *et al*. 2015; Sikandar *et al*. 2017). Rosemary (*Rosmarinus officinalis)* is an example of the phytogenic feed additives (PFA), derived from plants, herbs, and spices, with positive effects on growth and health of animals (Yang and Liao, 2019). Rosemary meal is known to have antimicrobial, antiviral, antifungal, and antioxidative properties (Nieto *et al*. 2010). It also increases feed digestion and absorption process which results in more rapid gain, higher production, higher carcass yield, and better feed efficiency (Pintore *et al*. 2002; Ghazalah and Ali, 2008; Yang and Liao, 2019). Recently, the sodium butyrate and rosemary meal are receiving considerable interest; though, to the best of our knowledge, no studies compared their effect as growth-promoting feed additives in broilers. Therefore, the present study was designed to investigate the effects of different inclusion levels sodium butyrate and rosemary leaf meal on growth performance, carcass characteristics, organ sizes and nutrient digestibility in broilers.

MATERIALS AND METHODS

Ethical consideration

The experiment was carried out by the provisions of the Ethical Committee (MUC271SOYE01) on the use of animals and humans for biomedical research of the University of Nigeria, Nsukka, Nigeria.

Study site

The study was carried out at the Poultry Unit of the Department of Animal Science Teaching and Research Farm, University of Nigeria, Nsukka, Nigeria. Nsukka lies within longitude 6˚ 45′E and 7˚ E and latitude 7˚ 12.5 ′N and on the altitude 447 m above sea level. The climate of the study area is typically tropical, with relative humidity ranging from 65 to 80% and mean daily temperature of 26.8 ˚C (Okonkwo and Akubuo, 2007).

Characteristics of sodium butyrate, rosemary meal, and oxytetracycline

The tested Sodium butyrate (Gusto Bp70), was purchased from Agro Barmagen Nig Ltd, Ibadan; A subsidiary of Bar-Margen group Israel). The active substance in the butyrate is 40% free sodium Butyrate, 30% protected sodium butyrate. The rosemary leaf meal was purchased from the main market Onitsha, Anambra State, Nigeria and has the active ingredients of 24 flavonoids (mainly flavones), 5 phenolic acids, 24 diterpenoids (carnosic acid, carnosol and rosmanol derivatives), 1 triterpenoid (betulinic acid) and 3 lignans (medioresinol derivatives).

Oxytetracycline is a synthetic antibiotics that was used to generate a broader assessment of its similarities and differences with the effects of sodium butyrate and rosemary leaf meal used in the study. The tested Oxytetracycline ($C_{22}H_{24}N_2O_9$) (Tetracin® Vetindia Pharmaceuticals limited India; ®African Representative, Global Organics limited No 81A, Lamido Road, Kano, Nigeria) is a soluble powder of oxytetracycline hydrochloride 5% W/W. Each gram contains: Oxytetracycline Hydrochloride BP 50 mg.

Experimental diets

The feeding strategy consisted of starting (0-28 days) and finishing (29-56 days) basal diets (BD) (Tables 1 and 2), which were formulated to meet the birds' dietary nutritional requirements (NRC, 1994).

Table 1 Ingredient (%) and chemical composition (g/kg DM) of experimental diets for broiler chicks at starter phase (0-4 weeks)

Ingredients (%)	Diets									
	T1	**T2**	**T3**	**T4**	**T5**	**T6**	**T7**	**T8**	**T9**	**T10**
Maize	44.00	44.00	44.00	44.00	44.00	44.00	44.00	44.00	44.00	44.00
Wheat	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00
Soybean meal	14.00	14.00	14.00	14.00	14.00	14.00	14.00	14.00	14.00	14.00
Groundnut cake	24.00	24.00	24.00	24.00	24.00	24.00	24.00	24.00	24.00	24.00
Palm kernel cake	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00
Fish meal	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00
Bone meal	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00
Salt	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25
Vitamin + mineral premix*	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25
Methionine	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25
Lysine	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25
Total	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**
Butyrate	0.00	0.00	0.20	0.40	0.00	0.00	0.20	0.20	0.40	0.40
Rosemary	0.00	0.00	0.00	0.00	0.25	0.50	0.25	0.50	0.25	0.50
Oxytetracycline	0.00	0.10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Calculated composition										
Crude protein (%)	22.67	22.67	22.67	22.67	22.67	22.67	22.67	22.67	22.67	22.67
Metabolizable energy (kcal/kg)	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000
Crude fibre (%)	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0
Calcium	1.68	1.68	1.68	1.68	1.68	1.68	1.68	1.68	1.68	1.68
Phosphorus	0.76	.076	0.76	0.76	0.76	0.76	0.76	0.76	0.76	0.76
Chemical composition %										
Crude matter	90.00	88.40	90.40	89.89	91.60	91.40	90.40	91.60	91.60	92.80
Crude protein	21.56	22.00	21.96	21.78	21.89	21.15	22.85	21.08	22.00	21.96
Crude fat	3.00	3.00	4.00	3.00	3.00	5.00	1.00	4.00	3.00	5.00
Crude fibre	5.03	5.05	5.00	4.98	5.01	5.05	5.00	5.07	5.03	5.02
Crude ash	4.00	6.00	7.00	9.00	5.00	6.00	5.00	5.00	8.00	4.00
Nitrogen free extract	56.41	52.35	52.44	51.04	56.7	54.20	56.55	56.45	53.57	56.82
Carbohydrtae	56.04	53.40	52.44	46.02	54.71	58.25	54.55	58.52	54.60	56.84

T1: basal diet (BD: negative control); T2: BD + 1 g/kg diet of oxytetracycline (positive control); T3: BD + 2 g SB/kg diet; T4: BD + 4 g SB/kg diet; T5: BD + 2.5 g RM/kg diet; T6: BD + 5.0 g RM/kg diet; T7: BD +2 g SB + 2.5 g RM/kg diet; T8: BD + 2 g SB + 5.0 g RM/kg diet; T9: BD + 4 g SB + 2.5 g RM/kg diet and T10: BD + 4 g SB + 5.0 g RM/kg diet.

* Vitamin and mineral premix per kg of diet: vitamin A: 1000000 IU; vitamin D_3: 2000 IU; vitamin B_1: 0.75 g; vitamin B_2: 5 g; Nicotinic acid: 25 g; vitamin B_{12}: 0.015 g; K_3: 2.5 g; vitamin E: 25 g; Biotin: 0.050 g; Folic acid: 1 g; Calcium pantothenate: 12.5 g; Choline chloride: 250 g; Manganese: 64 g; Cobalt: 0.8 g; Copper: 8 g; Manganese: 64 g; Iron: 32 g; Zn: 40 g; Iodine: 0.8 g; Selenium 0.6 g; Flavomycin: 100 g; Spiramycin: 5 g; DL-methionie: 50 g and Lysine: 120 g.

At each feeding phase (starting and finishing), there were ten dietary treatment groups that contain different levels of Sodium butyrate (SB), and Rosemary meal (RM) as follows: T1: basal diet (BD: negative control), T2: BD + 1 g/kg diet of oxytetracycline (positive control), T3: BD + 2 g SB/kg diet, T4: BD + 4 g SB/kg diet, T5: BD + 2.5 g RM/kg diet, T6: BD + 5.0 g RM/kg diet, T7: BD +2 g SB + 2.5 g RM/kg diet, T8: BD + 2 g SB + 5.0 g RM/kg diet, T9: BD + 4 g SB + 2.5 g RM/kg diet and T10: BD + 4 g SB + 5.0 g RM/kg diet. The chemical (proximate) compositions of the experimental diets were analyzed according to the association of official agricultural chemists (AOAC, 1990) methods.

Experimental birds and management

A total of 320 one-day-old male “Arbor acre” strain broiler chicks were used for the study. Thirty- two (32) birds were assigned randomly to one of the ten experimental diets (T1, T2, T3, T4, T5, T6, T7, T8, T9 and T10).

Each experimental diet was replicated into four experimental pens measuring 2.6 m width X 3 m length with eight birds each.

The birds were housed in cages with fresh wood shavings as litter. General flock prophylactic management and routine vaccination were administered as follows; day 1: Intra ocular (new castle disease vaccine), week 2: Gumboro disease vaccine, week 3: Lasota (New castle disease vaccine), week 4: Gumboro disease vaccine, week 5: fowl pox vaccine, week 6-8: Lasota vaccine was repeated because of its prevalence in the farm.

A stress pack was administered to the birds via drinking water at 100 g/50 liters (according to manufacturer’s recommendation) to boost appetite and energy supply. Dietary treatments and clean water were provided *ad libitum* in an eight-week feeding trial.

The room temperature was monitored with the use of thermometer, and the lighting was provided using a 200v watt bulb.

Table 2 Ingredient (%) and chemical composition (g/kg DM) of experimental diets for broiler chicks at finisher phase (4-8 weeks)

Ingredients (%)	Diets									
	T1	T2	T3	T4	T5	T6	T7	T8	T9	T10
Maize	54.04	54.04	54.04	54.04	54.04	54.04	54.04	54.04	54.04	54.04
Wheat	5.14	5.14	5.14	5.14	5.14	5.14	5.14	5.14	5.14	5.14
Soybean meal	12.42	12.42	12.42	12.42	12.42	12.42	12.42	12.42	12.42	12.42
Groundnut cake	16.00	16.00	16.00	16.00	16.00	16.00	16.00	16.00	16.00	16.00
Palm kernel cake	5.4	5.4	5.4	5.4	5.4	5.4	5.4	5.4	5.4	5.4
Fish meal	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00
Bone meal	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00
Salt	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25
Vitamin + mineral pre-mix[2]	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25
Methionine	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25
Lysine	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25
Total	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**
Butyrate	0.00	0.00	0.20	0.40	0.00	0.00	0.20	0.20	0.40	0.40
Rosemary	0.00	0.00	0.00	0.00	0.25	0.50	0.25	0.50	0.25	0.50
Oxytetracycline	0.00	0.10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Calculated composition										
Crude protein (%)	18.00	18.00	18.00	18.00	18.00	18.00	18.00	18.00	18.00	18.00
Metabolizable energy (kcal/kg)	2900	2900	2900	2900	2900	2900	2900	2900	2900	2900
Crude fibre (%)	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00
Calcium	1.61	1.61	1.61	1.61	1.61	1.61	1.61	1.61	1.61	1.61
Phosphorus	0.71	0.71	0.71	0.71	0.71	0.71	0.71	0.71	0.71	0.71
Chemical composition (%)										
Crude matter	91.60	90.80	91.00	91.80	89.60	90.80	91.20	91.20	89.60	92.20
Crude protein	18.12	18.07	18.01	18.05	18.00	18.10	18.14	18.10	18.09	18.06
Crude fat	4.00	4.05	4.12	3.65	4.00	5.00	4.86	5.00	6.00	5.08
Crude Fibre	4.98	5.02	4.97	5.00	5.01	5.05	5.00	4.99	5.04	5.01
Crude ash	6.00	7.00	6.00	5.00	5.00	4.00	6.00	4.00	7.00	6.00
Nitrogen free extract	58.50	56.66	57.90	60.10	57.59	58.65	57.20	59.11	53.47	58.05
Carbohydrate	63.48	61.68	62.87	65.10	62.60	63.70	62.20	64.10	58.51	63.06

T1: basal diet (BD: negative control); T2: BD + 1 g/kg diet of oxytetracycline (positive control); T3: BD + 2 g SB/kg diet; T4: BD + 4 g SB/kg diet; T5: BD + 2.5 g RM/kg diet; T6: BD + 5.0 g RM/kg diet; T7: BD +2 g SB + 2.5 g RM/kg diet; T8: BD + 2 g SB + 5.0 g RM/kg diet; T9: BD + 4 g SB + 2.5 g RM/kg diet and T10: BD + 4 g SB + 5.0 g RM/kg diet.

* Vitamin and mineral premix per kg of diet: vitamin A: 1000000 IU; vitamin D_3: 2000 IU; vitamin B_1: 0.75 g; vitamin B_2: 5 g; Nicotinic acid: 25 g; vitamin B_{12}: 0.015 g; K_3: 2.5 g; vitamin E: 25 g; Biotin: 0.050 g; Folic acid: 1 g; Calcium pantothenate: 12.5 g; Choline chloride: 250 g; Manganese: 64 g; Cobalt: 0.8 g; Copper: 8 g; Manganese: 64 g; Iron: 32 g; Zn: 40 g; Iodine: 0.8 g; Selenium 0.6 g; Flavomycin: 100 g; Spiramycin: 5 g; DL-methionie: 50 g and Lysine: 120 g.

Growth performance

Average daily feed intake (ADFI) per bird was measured from day 1 to day 56 of age by subtracting the weight of the feed refused from the feed offered and dividing the difference by the total number of birds in each of the pen. The initial live-weight of the birds was measured at the beginning of the experiment.

Thereafter, average live-weight was measured weekly by weighing all the birds in each pen using a 10.1 kg capacity precision weighing balance (models A and D Weighing GK-10K industrial balance) made in China. These live-weights were used to calculate the average weekly weight gain (AWG) per bird according to the equation as outlined by Mnisi *et al*. (2017):

AWG (t0, T)= W (T) – W (t0)

Where:

t0: initial time (days).

T: final time.

W (T): final body weight/bird (g).

W (t0): initial body weight/bird (g).

Weekly feed conversion efficiency was calculated as average weekly feed intake divided by average weekly weight gain per bird.

Carcass characteristics

At the end of each phase (starter and finisher), three birds was randomly selected from each replicate (12 birds per treatment) for the determination of carcass characteristics. Immediately after slaughter, the feathers were plucked and the gastrointestinal tract (GIT) was removed.

The carcasses were then weighed to obtain the carcass weight of the birds. The birds were used for the determination of carcass and organ weight and sizes. For the measurement of carcass cuts, head and shanks were removed close to the skull and at hock joint, respectively. Wings were removed by cutting at the humeroscapular joint, the cuts were made through the rib head to the shoulder girdle, and the vertebrae were then removed intact by pulling outwardly. The breast muscle, neck, wings, shank, drumstick/thigh, and back cut were each weighed separately using a 10.1 kg capacity precision weighing balance (models A and D weighing GK-10K Industrial balance China).

Visceral organ weights and sizes

On days 28 and 56, three birds per replicate were randomly selected from the slaughtered birds to assess and measure the weight of the visceral organs (weights of liver, heart, gizzard, spleen, kidney, lungs, weight of the small intestine, length of the small intestine, weight of the large intestine, length of the large intestine and proventriculus).

Nutrient digestibility trial

At the last week of both the starter and finisher phases of the feeding trial, a bird was selected from each replicate (four birds per treatment), moved to a clean and disinfected metabolic cages. A 3-day adaptation period was allowed before the four-day data collection period. Feed intake was measured and droppings were collected per bird daily. The collected droppings were air-dried at room temperature before being ground for proximate analysis according to AOAC (1990) methods. Apparent nutrient digestibility of crude fibre, crude protein, crude fat, and dry matter was computed according to the following equation.

Nutrient digestibility= (nutrient in feed-nutrient in faeces/nutrient in feed) × 100

Statistical design and analysis

Data collected during the study were subjected to analysis of variance (ANOVA) for completely randomized design (CRD) as described by Steel and Torrie (1980) using general linear model procedure of SAS (2010). The statistical model used to test the effects of treatment on growth performance, carcass traits, size of visceral organs and nutrient digestibility was:

$$Y_{ij} = \mu + A_i + \Sigma_{ij}$$

Where:

Y_{ij}: observed value of a dependent variable.

μ: overall mean.

A_i: effect of different levels of sodium butyrate and rosemary leaf meal.

Σ_{ij}: residual error.

The differences between means were tested for significance at $P < 0.05$ using least significant difference (LSD) range test.

RESULTS AND DISCUSSION

The effects of different inclusion levels of sodium butyrate and rosemary leaf meal on weekly feed intake, body weight and feed conversion ratio of broilers are presented in Table 3. The inclusion of sodium butyrate and rosemary leaf meal had no influence (P>0.05) in week 1, week 2, week 5 week 6 and week 7of the broilers feed intake but significantly affected (P<0.05) the weekly feed intake at week 3, week 4 and week 8. At week 3, birds fed T2, T4, T5, T6 and T7 had the highest feed intake (P<0.05), although they were statistically the same with birds fed T3, T8, T9 and T10. Birds fed T1 consumed less fed at week 3, week 4 and week 8.

Weekly feed intake of birds fed T5 at week 4 was the highest (P<0.05), but similar to other treatments used in the study except for T1 that had the lowest (P<0.05) feed intake. At week 8, birds fed T10 consumed the highest (P<0.05) feed while birds on T1 had the lowest (P<0.05) feed consumption at week 8.

The body weight of birds fed diets containing sodium butyrate and rosemary leaf meal were significantly affected (P<0.05) at week 7 and week 8, while other weeks were not affected (P<0.05). The lowest (P<0.05) body weight at week 7 was recorded for T1 (control), While T3, T4, T5 and T10 had the highest body weight at week 7. At the last week of the feeding trial (week 8), birds fed T3, T4, and T5 had the highest (P<0.05) body weight, although they are statistically similar with birds fed T10.

Birds fed T1 had the lowest (P<0.05) body weight at week 8. The feed conversion ratio was affected (P<0.05) at week 4, week 7 and week 8, while other weeks were not affected (P>0.05). Birds fed T4 recorded a better (P<0.05) feed conversion ratio (FCR) at week 4 compared with those in other treatments. Birds fed T3, T4 and T5 had a better (P<0.05) feed conversion to meat ratio at week 7. At the last week of the feeding trial, (week 8) birds fed T3, T4 and T5 had a more improved (P<0.05) FCR compared with other treatments.

The growth performance of broiler birds fed different inclusion levels of sodium butyrate and rosemary leaf meal at different phases is presented in Table 4. All the growth parameters considered in this study were significantly (P<0.05) affected by the treatments at all phases. Birds fed T1 (control), recorded the lowest (P<0.05) daily feed intake as well as daily weight gain.

Table 3 The effect of sodium butyrate and rosemary meal supplementation on weekly feed intake, body weight gain and feed conversion ratio of broiler chicks (n=32 per treatment)

Item	Diets										SEM
	T1	T2	T3	T4	T5	T6	T7	T8	T9	T10	
Feed intake (g bird^{-1})											
Week 1	113.54	112.54	120.19	114.22	109.50	100.01	97.15	96.72	90.19	88.44	0.08
Week 2	261.44	328.32	340.84	324.51	317.34	332.07	302.94	317.47	312.75	305.97	2.81
Week 3	386.93^{b}	520.65^{a}	491.06^{ab}	502.97^{a}	528.91^{a}	502.97^{a}	521.25^{a}	491.90^{ab}	488.52^{ab}	496.03^{ab}	4.66
Week 4	538.04^{b}	643.52^{ab}	667.98^{ab}	628.26^{ab}	722.72^{a}	695.72^{ab}	649.97^{ab}	620.01^{ab}	653.29^{ab}	651.10^{ab}	7.76
Week 5	666.30	790.62	918.83	872.59	799.07	882.55	769.72	807.21	806.94	860.44	14.31
Week 6	932.19	1060.40	1174.70	1115.00	1078.80	1184.80	1137.40	1131.00	1083.20	1149.50	11.19
Week 7	1145.10	1266.90	1291.30	1285.80	1265.00	1316.70	1257.80	1235.90	1261.70	1379.70	14.53
Week 8	1137.50^{c}	1262.90^{bc}	1324.00^{b}	1312.10^{b}	1275.40^{bc}	1376.00^{b}	1356.10^{b}	1333.90^{b}	1297.90^{b}	1496.50^{a}	22.02
Body weight (g bird^{1})											
Week 1	116.38	135.13	135.66	125.78	133.91	123.82	125.63	119.69	119.25	107.06	0.99
Week 2	237.85	337.13	353.85	328.97	347.00	340.85	333.66	319.38	313.41	299.69	2.07
Week 3	449.25	611.50	672.34	629.10	669.06	648.28	644.44	607.56	584.13	592.91	4.85
Week 4	665.16	788.69	870.31	853.44	927.50	888.91	858.06	819.35	833.50	800.16	11.76
Week 5	980.62	1203.10	1285.10	1282.80	1271.00	1299.10	1237.60	1238.90	1212.50	1238.90	14.69
Week 6	1380.20	1628.60	1776.80	1727.20	1671.20	1752.50	1657.40	1576.40	1621.70	1683.30	21.35
Week 7	1873.50^{d}	2120.40^{b}	2287.80^{a}	2393.60^{a}	2265.10^{a}	2105.00^{b}	2070.50^{c}	2101.40^{b}	2142.00^{b}	2281.10^{a}	31.93
Week 8	2239.30^{d}	2626.10^{b}	2749.60^{a}	2758.70^{a}	2734.40^{a}	2646.70^{b}	2478.70^{c}	2655.50^{b}	2558.40^{c}	2698.10^{ab}	29.60
Feed conversion ratio											
Week 1	0.98	0.83	0.89	0.91	0.82	0.81	0.77	0.81	0.78	0.83	0.01
Week 2	1.10	0.98	0.96	0.99	0.91	0.97	0.91	0.99	1.00	1.02	0.01
Week 3	0.86	0.85	0.73	0.80	0.79	0.74	0.80	0.81	0.83	0.84	0.01
Week 4	0.81^{a}	0.82^{a}	0.77^{b}	0.73^{c}	0.78^{b}	0.79^{ab}	0.76^{b}	0.76^{b}	0.77^{b}	0.81^{a}	0.01
Week 5	0.68	0.66	0.71	0.68	0.63	0.68	0.63	0.65	0.67	0.69	0.01
Week 6	0.67	0.65	0.67	0.64	0.65	0.67	0.69	0.73	0.66	0.68	0.01
Week 7	0.61^{a}	0.58^{ab}	0.57^{b}	0.57^{b}	0.56^{b}	0.57^{ab}	0.62^{a}	0.59^{ab}	0.59^{ab}	0.61^{a}	0.01
Week 8	0.51^{b}	0.50^{b}	0.45^{c}	0.46^{c}	0.46^{c}	0.52^{b}	0.55^{a}	0.50^{b}	0.51^{b}	0.55^{a}	0.01

T1: basal diet (BD: negative control); T2: BD + 1 g/kg diet of oxytetracycline (positive control); T3: BD + 2 g SB/kg diet; T4: BD + 4 g SB/kg diet; T5: BD + 2.5 g RM/kg diet; T6: BD + 5.0 g RM/kg diet; T7: BD +2 g SB + 2.5 g RM/kg diet; T8: BD + 2 g SB + 5.0 g RM/kg diet; T9: BD + 4 g SB + 2.5 g RM/kg diet and T10: BD + 4 g SB + 5.0 g RM/kg diet.
The means within the same row with at least one common letter, do not have significant difference (P>0.05).
SEM: standard error of the means.

Table 4 The effect of sodium butyrate and rosemary meal on feed intake, body weight gain and feed conversion ratio of broiler chicks (n=32 per treatment)

Item	Diets										SEM
	T1	T2	T3	T4	T5	T6	T7	T8	T9	T10	
Starter phase											
Feed intake (g)	1299.90^{c}	1620.00^{a}	1620.10^{a}	1569.90^{b}	1678.50^{a}	1630.00^{a}	1589.00^{b}	1526.10^{b}	1544.80^{b}	1541.50^{b}	19.28
Body weight gain (g)	621.41^{c}	745.19^{b}	826.81^{ab}	809.94^{ab}	883.75^{a}	845.41^{a}	814.56^{ab}	775.35^{b}	782.25^{b}	756.53^{b}	15.09
FCR (g g^{-1})	2.09^{ab}	2.17^{a}	1.96^{b}	1.94^{b}	1.90^{c}	1.93^{b}	1.95^{b}	1.97^{b}	1.97^{b}	2.04^{ab}	0.02
Finisher phase											
Feed intake (g)	3881.10^{d}	4343.60^{c}	4708.80^{b}	4229.20^{c}	4417.70^{bc}	4760.00^{b}	4520.80^{c}	4508.00^{c}	4449.40^{bc}	4886.20^{a}	65.56
Body weight gain (g)	1573.70^{d}	1837.40^{ab}	1879.20^{a}	1835.30^{ab}	1806.90^{ab}	1757.70^{b}	1620.70^{c}	1836.10^{ab}	1724.90^{b}	1897.90^{a}	28.30
FCR (g g^{-1})	2.47^{bc}	2.36^{c}	2.51^{bc}	2.30^{d}	2.44^{bc}	2.71^{ab}	2.79^{a}	2.45^{bc}	2.58^{b}	2.57^{b}	0.03
Overall phase											
Feed intake (g)	5181.00^{c}	5963.60^{ab}	6328.90^{a}	5799.10^{b}	6096.20^{ab}	6390.00^{ab}	6109.80^{ab}	6034.10^{ab}	5994.20^{ab}	6427.70^{a}	78.60
Body weight gain (g)	2195.11^{c}	2582.59^{b}	2706.01^{a}	2645 24^{a}	2690.65^{a}	2603.11^{a}	2435.26^{bc}	2611.45^{a}	2507.15^{b}	2654.43^{a}	34.90
FCR (g g^{-1})	2.36^{b}	2.31^{b}	2.34^{b}	2.19^{c}	2.26^{c}	2.45^{ab}	2.51^{a}	2.31^{b}	2.39^{ab}	2.42^{ab}	0.02
Daily performance											
Initial weight (g)	43.75	43.00	43.50	43.50	43.70	43.50	43.50	44.00	43.75	43.50	0.07
Daily feed intake (g)	92.52^{c}	106.49^{ab}	113.01^{a}	103.55^{b}	108.86^{ab}	114.11^{a}	109.10^{ab}	107.75^{ab}	107.04^{ab}	114.78^{a}	1.40
Daily weight gain (g)	39.20^{c}	46.12^{ab}	48.32^{a}	47.24^{a}	48.04^{a}	46.48^{ab}	43.48^{b}	46.63^{ab}	44.77^{b}	47.40^{a}	1.63

T1: basal diet (BD: negative control); T2: BD + 1 g/kg diet of oxytetracycline (positive control); T3: BD + 2 g SB/kg diet; T4: BD + 4 g SB/kg diet; T5: BD + 2.5 g RM/kg diet; T6: BD + 5.0 g RM/kg diet; T7: BD +2 g SB + 2.5 g RM/kg diet; T8: BD + 2 g SB + 5.0 g RM/kg diet; T9: BD + 4 g SB + 2.5 g RM/kg diet and T10: BD + 4 g SB + 5.0 g RM/kg diet.
FCR: feed conversion ratio.
The means within the same row with at least one common letter, do not have significant difference (P>0.05).
SEM: standard error of the means.

The highest (P<0.05) daily feed intake was seen in birds fed T3, T6, and T10, even though they are statistically similar to those that received T2, T5, T7, T8 and T9. The daily weight gain was highest (P<0.05) for birds fed T3, T4, T5, and T10. During the starter phase, feed intake values was highest (P<0.05) for birds fed T2, T3, T5, and T6, while, birds fed T1 recorded the lowest feed intake. The lowest (P<0.05) body weight gain value was seen in birds fed T1, while, the highest (P<0.05) value was observed in birds fed T5 and T6, though, statistically similar with those that received dietary T3, T4, and T7. Feed conversion ratio was better (P<0.05) for birds fed T5, compared with birds that received other treatment diets.

The last phase of the feeding trial (finisher phase) showed that, birds fed T1 consumed less (P<0.05) feed with a poor body weight gain, while, those fed T10 had the highest feed intake. The body weight gain was highest (P<0.05) for birds fed T3 and T10, though, statistically the same with those that received dietary T2, T4, T5, and T8. A better (P<0.05) FCR value was seen in birds fed T4 compared with those in other treatments. The overall phase presents a higher (P<0.05) body weight gain recorded for birds fed T3, T4, T5, T6, T8, and T10, while a better (P<0.05) feed conversion to meat ratio was seen in birds fed T4, and T5. Birds fed T1 had the least (P<0.05) feed intake as well as body weight gain.

Table 5 shows the carcass characteristics of broiler birds fed different supplemental levels of sodium butyrate and rosemary leaf meal. Birds fed sodium butyrate and rosemary leaf meal showed significant differences (P<0.05) in all the carcass traits measured in both starter and finisher phases. During the starter phase, the highest (P<0.05) live weight was recorded for birds fed T5 and T6 although the results were statistically similar with those fed T3 and T4. The dressed weight was higher (P<0.05) for birds fed T6 compared with those fed other treatments. Birds fed T4, T5, and T6 had the highest (P<0.05) wing weight but was statistically similar with those fed T3 and T7. The drum stick/thigh weight was higher (P<0.05) for birds fed T6 compared with those fed other treatments. The neck weight showed the highest (P<0.05) value for birds fed T10, although statistically similar with birds fed T5 and T6, while birds fed T1 and T9 showed the lowest (P<0.05) values. Breast-meat weight was lowest (P<0.05) for birds fed T1. Birds fed T3 and T6 had the highest (P<0.05) breast-meat weight, although, they were statistically similar with those fed T5. The back cut weight was higher (P<0.05) for birds fed T4 and T6, but was statistically the same with birds fed T5 and T10. The shank weight was lowest (P<0.05) for birds fed T1. Birds fed T10 had the highest shank weight value although statistically similar with birds fed T2, T5 and T7.

During the finisher phase, the live weight, dressed weight, wings and drumstick/thigh were higher (P<0.05) for birds fed T3 compared with those fed other dietary treatments, while birds fed T1 (control) had the lowest (P<0.05) live weight, dressed weight, wings and drumstick/thigh weight values. Birds fed T2, T3, T7 and T10 had the highest (P<0.05) neck weight values compared with those fed other treatments. Breast-meat, back cut and shank weight was lowest (P<0.05) for birds fed T1, while birds fed T3 had the highest (P<0.05) breast-meat, back cut and shank weight.

Table 6 shows the size of visceral organs of broiler birds fed different supplemental levels of sodium butyrate and rosemary leaf meal. All the parameters measured in this study at both starter and finisher phases were all affected (P<0.05) significantly. The data for the visceral organ sizes of the birds at the end of the starter phase showed that the liver weight was highest (P<0.05) for birds fed T4, though statistically similar with those fed T3, T5, T6, T7, T8 and T10. Birds fed T1 had the lowest (P<0.05) values for liver, gizzard and spleen.

The weight of gizzard was highest (P<0.05) for birds fed T2, T3, T4, T6, T7, and T10. The highest (P<0.05) spleen weight value was seen in birds fed T4, and T6, though, statistically the same with those fed T3. Birds fed T5 recorded the highest (P<0.05) heart weight, the height (P<0.05) while, large intestine weight was recorded for birds fed T8, but they are similar with those that received dietary T1, T3, and T5.

The weight of small intestine was higher (P<0.05) for birds fed T2, and T8, though, statistically the same with those fed T3, T4, T5, and T6. Birds fed T6 and T9 had the highest (P<0.05) length value of the large intestine, while the small intestine length was higher for birds fed T8, and T9. The kidney weight was higher (P<0.05) for birds fed T8 while T1 had the lowest (P<0.05) values for both small intestine length and kidney weight. Birds fed T6 had the highest (P<0.05) weight of proventriculus, with T1 having the lowest (P<0.05) weight of the proventriculus. Birds fed T3 recorded the highest weight (P<0.05) of lungs compared with other treatments.

At the end of the finisher phase, the data collected on the sizes of the visceral organs showed that, birds fed T3 had the highest (P<0.05) liver and gizzard weight when compared with the birds fed dietary T1 (control). The highest (P<0.05) spleen weight was recorded for birds fed T6 and T7. Birds fed T3 had the highest (P<0.05) values for heart and large intestine weight, while birds on T4 and T6 recorded the highest (P<0.05) value for small intestine weight. Birds fed T2, T6, and T8 recorded the highest (P<0.05) large intestine length (P<0.05), although they were similar statistically with birds fed T7 and T10.

Table 5 The effect of sodium butyrate and rosemary meal on carcass characteristics of broiler chicks (n=12 per treatment)

Item	Diets										SEM
	T1	T2	T3	T4	T5	T6	T7	T8	T9	T10	
Starter											
Live weight (g)	730.00^{d}	887.00^{b}	951.00^{ab}	958.00^{ab}	978.00^{a}	1005.00^{a}	889.00^{b}	827.00^{c}	862.00^{b}	907.00^{b}	13.75
Dressed weight (g)	502.00^{d}	570.20^{c}	658.00^{b}	649.30^{b}	661.30^{b}	719.80^{a}	594.08^{c}	540.40^{c}	557.10^{c}	594.60^{c}	10.96
Wings (g)	84.20^{c}	100.30^{b}	117.50^{ab}	121.80^{a}	124.10^{a}	129.00^{a}	113.00^{ab}	95.40^{b}	99.30^{b}	95.40^{b}	2.66
Drumstick/thigh (g)	149.00^{d}	175.30^{b}	185.00^{b}	181.50^{b}	182.10^{b}	205.50^{a}	183.50^{b}	161.80^{c}	156.00^{c}	178.40^{b}	2.74
Neck (g)	31.10^{c}	40.60^{b}	39.50^{b}	42.52^{b}	43.10^{ab}	46.50^{ab}	39.60^{b}	37.93^{b}	29.50^{c}	57.40^{a}	2.12
Breast-meat (g)	125.90^{d}	140.60^{c}	182.30^{a}	147.70^{b}	170.85^{ab}	186.60^{a}	143.20^{c}	148.20^{b}	158.40^{b}	134.80^{ef}	3.23
Back cut (g)	111.60^{c}	111.30^{c}	131.00^{b}	155.40^{a}	140.10^{ab}	153.70^{a}	116.50^{c}	111.40^{c}	115.00^{c}	143.80^{ab}	3.07
Shank (g)	21.70^{d}	31.50^{ab}	25.80^{c}	25.30^{c}	30.80^{ab}	29.90^{b}	31.40^{ab}	27.10^{b}	29.30^{b}	33.40^{a}	0.70
Finisher											
Live weight (g)	1930.00^{d}	2725.00^{bc}	3710.00^{a}	2850.00^{b}	2825.00^{b}	2751.11^{bc}	2800.00^{b}	2300.00^{c}	2350.00^{c}	2400.00^{c}	80.40
Dressed weight (g)	1366.00^{e}	2124.00^{bc}	2948.00^{a}	2217.00^{b}	2304.00^{b}	2065.00^{c}	2244.00^{b}	1705.00^{d}	1829.00^{d}	2023.00^{c}	64.53
Wings (g)	169.00^{e}	208.00^{c}	269.00^{a}	211.00^{c}	207.00^{c}	229.00^{b}	219.00^{bc}	170.00^{e}	183.00^{d}	211.00^{c}	4.64
Drumstick/thigh (g)	384.00^{e}	576.00^{c}	816.00^{a}	577.00^{c}	607.00^{c}	610.00^{bc}	648.00^{b}	469.00^{d}	502.00^{d}	577.00^{c}	17.84
Neck (g)	52.00^{d}	84.00^{a}	84.00^{a}	76.25^{b}	73.00^{b}	66.00^{c}	89.00^{a}	68.00^{c}	63.00^{c}	84.00^{a}	1.79
Breast-meat (g)	337.00^{e}	655.00^{c}	929.00^{a}	697.00^{b}	732.25^{b}	558.00^{d}	652.00^{c}	491.00^{d}	555.00^{d}	613.00^{c}	23.84
Back cut (g)	303.00^{e}	419.00^{c}	584.00^{a}	508.20^{b}	494.00^{b}	409.00^{c}	430.00^{c}	369.00^{d}	389.00^{d}	364.00^{d}	12.46
Shank (g)	48.00^{d}	57.00^{c}	105.00^{a}	57.00^{c}	59.00^{c}	78.00^{b}	88.00^{b}	55.00^{c}	57.00^{c}	58.00^{c}	2.85

T1: basal diet (BD: negative control); T2: BD + 1 g/kg diet of oxytetracycline (positive control); T3: BD + 2 g SB/kg diet; T4: BD + 4 g SB/kg diet; T5: BD + 2.5 g RM/kg diet; T6: BD + 5.0 g RM/kg diet; T7: BD +2 g SB + 2.5 g RM/kg diet; T8: BD + 2 g SB + 5.0 g RM/kg diet; T9: BD + 4 g SB + 2.5 g RM/kg diet and T10: BD + 4 g SB + 5.0 g RM/kg diet.
The means within the same row with at least one common letter, do not have significant difference (P>0.05).
SEM: standard error of the means.

Table 6 The effect of supplemental levels of sodium butyrate and rosemary meal on sizes of visceral organs of broiler chicks (n=12 per treatment)

Item	Diets										SEM
	T1	T2	T3	T4	T5	T6	T7	T8	T9	T10	
Starter											
Liver (g)	19.00^{c}	21.90^{b}	24.07^{ab}	25.00^{a}	24.22^{ab}	22.80^{ab}	22.70^{ab}	22.20^{ab}	21.50^{b}	22.70^{ab}	0.36
Gizzard (g)	19.00^{c}	26.40^{a}	27.00^{a}	26.10^{a}	22.70^{b}	25.20^{a}	26.40^{a}	22.15^{b}	22.40^{b}	27.20^{a}	0.47
Spleen (g)	1.10^{c}	1.20^{b}	1.41^{ab}	1.61^{a}	1.20^{b}	1.70^{a}	1.31^{b}	1.31^{b}	0.99^{c}	1.12^{b}	0.03
Heart (g)	5.00^{d}	5.00^{d}	5.70^{c}	6.70^{b}	8.10^{a}	6.30^{b}	5.30^{c}	5.50^{c}	5.60^{c}	6.20^{b}	0.16
Large Intestine weight (g)	2.00^{ab}	1.40^{bc}	2.20^{ab}	1.30^{bc}	2.30^{ab}	1.70^{b}	1.31^{bc}	2.40^{a}	1.90^{b}	1.70^{b}	0.07
Small Intestine weight (g)	43.10^{c}	67.90^{a}	61.50^{ab}	63.58^{ab}	63.60^{ab}	62.20^{ab}	58.50^{b}	67.30^{a}	53.40^{b}	56.00^{b}	1.28
Large Intestine length (cm)	7.70^{d}	8.40^{c}	9.60^{ab}	9.00^{b}	9.80^{ab}	10.00^{a}	9.00^{b}	9.00^{b}	10.50^{a}	8.70^{c}	0.16
Small Intestine length (cm)	139.00^{e}	174.00^{b}	150.00^{d}	173.23^{b}	171.90^{b}	164.40^{c}	146.00^{d}	200.50^{a}	194.00^{a}	160.00^{c}	3.17
Kidney (g)	0.80^{e}	1.20^{c}	1.90^{ab}	1.10^{d}	1.60^{bc}	1.50^{b}	1.40^{c}	2.10^{a}	1.70^{b}	1.00^{d}	0.07
Proventriculus (g)	5.80^{c}	10.50^{ab}	8.60^{b}	9.30^{b}	8.40^{bc}	11.70^{a}	5.40^{c}	7.20^{c}	7.40^{c}	5.40^{d}	0.33
Lungs (g)	4.30^{f}	7.50^{c}	14.49^{a}	9.70^{b}	6.40^{d}	8.40^{c}	6.90^{d}	6.40^{d}	3.90^{f}	5.10^{e}	0.47
Finisher											
Liver (g)	44.30^{e}	66.40^{c}	96.47^{a}	68.30^{c}	77.20^{b}	73.00^{b}	58.90^{d}	36.17^{f}	49.50^{d}	63.90^{c}	2.69
Gizzard (g)	34.00^{d}	43.20^{b}	68.70^{a}	35.06^{d}	47.20^{b}	36.50^{d}	40.80^{c}	34.50^{d}	39.50^{c}	30.10^{e}	1.75
Spleen (g)	3.10^{b}	2.50^{b}	3.30^{b}	3.00^{b}	3.20^{b}	5.20^{a}	5.20^{a}	2.70^{b}	3.00^{b}	2.20^{b}	0.18
Heart (g)	8.20^{e}	12.70^{bc}	21.70^{a}	10.60^{c}	9.10^{d}	11.20^{c}	11.65^{c}	14.20^{b}	10.50^{c}	10.10^{c}	0.63
Large Intestine weight (g)	4.20^{d}	9.50^{b}	11.70^{a}	5.30^{c}	3.10^{d}	3.70^{d}	4.70^{d}	6.30^{c}	4.50^{d}	2.70^{e}	0.44
Small Intestine weight (g)	67.70^{d}	77.60^{c}	94.70^{b}	123.30^{a}	83.10^{c}	113.50^{a}	75.30^{c}	106.50^{b}	105.60^{b}	62.90^{d}	3.30
Large Intestine length (cm)	11.50^{b}	13.00^{a}	7.20^{c}	10.50^{b}	10.00^{b}	14.00^{a}	12.00^{ab}	13.00^{a}	9.75^{b}	12.00^{ab}	0.37
Large Intestine length (cm)	279.00^{c}	311.10^{a}	247.50^{d}	282.00^{c}	225.00^{d}	291.50^{bc}	184.00^{f}	252.00^{d}	299.00^{ab}	256.00^{d}	5.94
Kidney (g)	9.80^{d}	11.70^{c}	19.15^{a}	15.10^{b}	14.50^{b}	12.80^{c}	10.30^{c}	9.00^{d}	10.00^{c}	11.20^{c}	0.53
Proventriculus (g)	11.80^{c}	15.40^{a}	13.60^{b}	14.30^{ab}	13.50^{ab}	16.80^{a}	10.40^{c}	12.20^{b}	12.30^{b}	10.40^{c}	0.40
Lungs (g)	8.40^{d}	12.50^{bc}	19.60^{a}	14.60^{b}	11.30^{c}	13.50^{b}	11.90^{c}	11.30^{c}	8.50^{d}	10.00^{c}	0.54

T1: basal diet (BD: negative control); T2: BD + 1 g/kg diet of oxytetracycline (positive control); T3: BD + 2 g SB/kg diet; T4: BD + 4 g SB/kg diet; T5: BD + 2.5 g RM/kg diet; T6: BD + 5.0 g RM/kg diet; T7: BD +2 g SB + 2.5 g RM/kg diet; T8: BD + 2 g SB + 5.0 g RM/kg diet; T9: BD + 4 g SB + 2.5 g RM/kg diet and T10: BD + 4 g SB + 5.0 g RM/kg diet.
The means within the same row with at least one common letter, do not have significant difference (P>0.05).
SEM: standard error of the means.

The lowest (P<0.05) value for small intestine length was seen in birds fed T7, while the highest values were recorded for birds fed T2, although this value was statistically similar with birds fed T9. The kidney and lungs weight were highest (P<0.05) for birds fed T3. The highest (P<0.05) proventriculus weight was recorded for birds fed T2 and T6, but this was statistically the same with those that received dietary treatments T4 and T5.

The apparent nutrient digestibility data for birds fed different inclusion levels of sodium butyrate and rosemary leaf meal is presented in Table 7. All the nutrient digestibility traits (crude fiber, crude protein, crude fat and dry matter) measured in this study for both starter and finisher phases were affected (P<0.05). The digestibility of crude fiber, crude protein, crude fat and dry matter for starter and finisher phases were higher (P<0.05) for birds fed T5 and these were statistically similar with birds fed dietary T3 and T4.

The dietary treatment and week interaction effect on BWG showed that T3, T4, and T5 promoted the highest BWG only at week 7 and 8. This is similar to the findings of Jackson *et al.* (2004), Lee *et al.* (2008) and Jia *et al.* (2009), they suggested that the BWG was better in the finishing phase more than the starter phase. These outcomes demonstrated that some of the anti-nutrients (NSPs) including glucans, phytates, and mannans may not be adequately digested and absorbed by the villi of young birds. Olukosi *et al.* (2007) and Wyatt *et al.* (2008) suggested that younger animals were hampered in their growth since they cannot secrete a sufficient number of endogenous digestive compounds because their body systems cannot efficiently manage external compounds that can complement the endogenous digestive compounds. This could clearly be the reason why we see an enhanced performance with mature or finisher birds. Some authors have reported the presence of relatively shorter villi in younger birds which resulted in reduced endogenous digestive compound secretions at the tip of the villi, thereby resulting in poor digestion and absorption of nutrients in addition to an unhealthy gut (Zhang *et al.* 2005; Abudabos and Yehia. 2013).

The dietary inclusion of sodium butyrate (2 g SB/kg feed=T3), 4 g SB/kg feed=T4) and rosemary leaf meal (2.5 g RM/kg feed=T5) at single levels improved the BWG and FCR of birds compared with the negative (no additive) control and the positive (antibiotic) control diets as well as the combination of sodium butyrate and rosemary leaf meal. The results of the present study suggested that sodium butyrate (organic acid) and rosemary leaf meal could replace antibiotics in broiler chicken's diet for a better growth performance. Dibner and Buttin (2002) and Panda *et al.* (2009) suggested that organic acids improved protein and energy digestibility by reducing microbial competition with the host for nutrients and endogenous nitrogen losses, by lowering the incidence of sub-clinical infections and secretion of immune mediators, by reducing the production of ammonia and other growth depressing microbial metabolites. Probably these could be the reasons that butyrate improved feed utilization leading to better performance in the birds. The results of this study is in agreement with the findings of Panda *et al.* (2009) and Sikandar *et al.* (2017) who reported that the inclusion of sodium butyrate (SB) at 4 g/kg in the diet of broiler chicken performed better than antibiotics in improving BWG of birds with a superior feed efficiency. According to Chamba *et al.* (2014), sodium butyrate improved the body weight of broilers, and they attributed it to the beneficial effect of sodium butyrate in promoting the intestinal epithelium cell development and modulating intestinal symbiotic growth. The improved feed conversion ratio for birds fed 2 g SB/kg feed (T3), and 4 g SB/kg feed (T4) may be due to the effect of sodium butyrate as it increases the absorption of nutrients as well as the exclusion of harmful microbial load (Raza *et al.* 2019). Contrary to the results of this study, Wu *et al.* (2016), reported that sodium butyrate addition did not influence the body weight gain, feed intake or feed to gain ratio. These variable results may be attributed to the available contents of the sodium butyrate SB addition and the type of microbial environment to which the chicks were exposed. It is important to note that the available content of the tested organic acid used in this study is made up of mono and diglycerides with approximately 80% by weight of butyrate. According to Zhang *et al.* (2011) and Chamba *et al.* (2014), the improved performance of broiler chickens fed dietary sodium butyrate may be attributed to better feed utilization through improved villus height. The improved villus height enhanced the villus function which leads to a better growth performance of the birds (Shaaban *et al.* 2020). Arbab *et al.* (2017) opined that better performance may be due to the creation of the acidic environment in the gut after SB consumption, which in turns minimizes the load of pathogens (Arbab *et al.* 2017).

The in-feed SB may improve the intraluminal digestibility of minerals and proteins which may result in improved weight gain in SB offered groups as mentioned by Zhang *et al.* (2011). The result of the present study agreed with the findings of Adil *et al.* (2011) who reported that the supplementation of organic acids improved the FCR in broilers chicken. The study showed that 2 g/kg feed (T3), and 4 g/kg feed (T4) of microencapsulated sodium butyrate reduced feed intake with a positive body weight gain and feed conversion ratio all through the feeding trial. Namkung *et al.* (2011) opined that, butyric acid and its glyceride forms could cause feed intake depression, unlike propionates and acetates.

Table 7 The effect of sodium butyrate and rosemary powder supplementation on apparent digestibility (%) of dry matter, crude fibre, crude protein and crude fat in broiler chicks (n = 1 per replicate)

Item	Diets										SEM
	T1	T2	T3	T4	T5	T6	T7	T8	T9	T10	
Starter											
Crude fibre	14.06^{b}	12.87^{b}	17.74^{ab}	17.51^{ab}	19.32^{a}	18.19^{a}	17.56^{ab}	13.49^{b}	11.01^{bc}	12.56^{b}	0.51
Crude protein	76.01^{b}	71.69^{b}	81.21^{ab}	81.63^{ab}	89.76^{a}	86.91^{a}	85.29^{a}	75.46^{b}	69.25^{b}	78.50^{b}	1.07
Crude fat	55.29^{a}	53.91^{b}	71.94^{a}	70.46^{a}	78.81^{a}	77.81^{a}	78.23^{a}	55.01^{b}	51.99^{b}	67.09^{ab}	1.27
Dry matter	75.03^{ab}	70.56^{b}	82.67^{a}	78.14^{a}	83.36^{a}	76.39^{ab}	80.79^{a}	72.39^{b}	70.43^{b}	80.01^{a}	0.92
Finisher											
Crude fibre	18.41^{c}	25.87^{b}	32.18^{a}	30.54^{a}	33.46^{a}	19.89^{c}	21.81^{c}	26.54^{b}	19.94^{c}	30.52^{a}	1.20
Crude protein	70.52^{b}	78.04^{ab}	85.61^{a}	87.14^{a}	89.87^{a}	78.61^{ab}	72.01^{b}	80.45^{ab}	71.62^{b}	86.94^{a}	0.99
Crude fat	62.81^{c}	70.92^{b}	77.01^{a}	79.81^{a}	80.48^{a}	64.73^{d}	69.34^{b}	74.63^{ab}	61.89^{c}	78.74^{a}	1.44
Dry matter	70.37^{b}	69.89^{b}	83.16^{a}	80.84^{a}	85.27^{a}	72.46^{b}	71.86^{b}	77.85^{ab}	70.02^{b}	80.96^{a}	0.96

T1: basal diet (BD: negative control); T2: BD + 1 g/kg diet of oxytetracycline (positive control); T3: BD + 2 g SB/kg diet; T4: BD + 4 g SB/kg diet; T5: BD + 2.5 g RM/kg diet; T6: BD + 5.0 g RM/kg diet; T7: BD +2 g SB + 2.5 g RM/kg diet; T8: BD + 2 g SB + 5.0 g RM/kg diet; T9: BD + 4 g SB + 2.5 g RM/kg diet and T10: BD + 4 g SB + 5.0 g RM/kg diet.
The means within the same row with at least one common letter, do not have significant difference (P>0.05).
SEM: standard error of the means**.**

The microencapsulation of sodium butyrate allowed for the targeted release of this compound at the ileum level and it directly affected the intestinal morphology, potentially the micro-biota, and digestive processes in this section of the intestinal tract. As reported by Kaczmarek *et al.* (2016), unprotected or un-encapsulated butyric acid salts (butyrates) are also rapidly absorbed in the upper parts of the GIT, thus, the protection of the active ingredient is crucial for these to have a positive effect in the animal's intestinal digestive and absorptive capacity. Contrary to the results of the present study, Chamba *et al.* (2014) reported that Sodium butyrate or colistin sulphate supplementation did not affect the birds during the starter phase with regards to weight gain, feed intake and feed conversion ratio. The opined that such discrepancies may be due to differences in the age of the birds or health status, feed composition and digestibility, housing conditions, experimental infection models, and the concentration of butyrate in the feed.

Also the dietary inclusion of rosemary leaf meal at 2.5 g/kg (T5) had a positive effect on the feed intake and body weight gain (BWG) of the broiler birds and also improved the FCR at starter and overall phase of the feeding trial. This result is in line with the findings of Ghazalah and Ali (2008) who reported a positive increase in BWG and performance of broilers at lower inclusion (2.0 g/kg) level of Rosemary leaf meal. They attributed the improvement to the presence of essential oil in rosemary leaf meal and its active constituents (phenolic compounds) rich in antibacterial, antifungal and antioxidant activities (Gema *et al.* 2018). Alternatively, the combination of sodium butyrate and rosemary leaf meal had an adverse effect on the feed intake of broiler birds which affected the performance. At the starter phase, feed intake was reduced; this may be due to low palatability in young chicks, although this effect disappeared during finishing phase.

This may be attributed to the capacity of broiler birds to adapt with the cellulose content in the diets at older age. The reducing gastric pH can stimulate favourable micro-organism and the catabolic enzymes synthesis that can help in the digestion and absorption of amino acids, sugars and fatty acids for an improved performance (Yang and Liao 2019).

The cooking convenient of whole chicken carcass and cut yield determines the purchasing decision of the consumers. An improved carcass yield is closely linked with adequate food and nutrition of broilers (Oyeagu *et al.* 2019b). After all, animals with adequate supply of nutrients will deposit more tissue (muscle). The increased proportional weights of retail cuts from broiler chickens fed single levels sodium butyrate and rosemary leaf meal may be due to the potency of the feed additives which provides a better digestibility of the ingredients and, therefore, increased the amount of nutrients available for improved muscles (tissue) development and breast growth, since the breast cutting represent about 40% of the total carcass yield (Dalòlio *et al.* 2015). The highest carcass weight was recorded for birds fed 2.5 g RM/kg (T5) diet and 5 g RM/kg (T6) diet at single level of inclusion. The carcass from these treatments (T5 and T6) also produced the highest breast-meat at the starter phase. The live weight, wings, drumstick, neck, breast-meat and back-cut showed a positive response to the rosemary leaf meal supplementation especially at 5 g RM/kg diet during the starter phase. In contrast, Ghazalah and Ali (2008), Adil *et al.* (2010), Norouzi *et al.* (2015) and Veselin *et al.* (2018) observed that the supplementation of rosemary meal in broiler diets did not affect carcass yield, but could, to some extent, improve carcass quality. Also Azza and Naele (2014) observed no significant differences in the carcass characteristics measured. Birds fed butyrate at 2 g/kg (T3) diet had a better carcass weight and breast-meat at starter;

they also had an improved carcass and cut yield traits measured at finisher phase. The improvements in the cut yield could be very important to the poultry industry because there is a tendency to sell cuts than the whole carcass due to the increase in aggregate value (Oyeagu *et al.* 2019c). The results of the present study are in line with the findings of Leeson *et al.* (2005), Panda *et al.* (2009) and Raza *et al.* (2019) who reported higher carcass yield, dressed weight and breast-meat in broilers fed 0.2% butyrate in the diet. They attributed the increase to better feed absorption and utilization which resulted to an improved performance and increased carcass yield. Sodium butyrate increases blood flow to the intestine and this may lead to better tissue oxygenation and growth (Chamba *et al.* 2014). Contrary to the current result, Raza *et al.* (2019) revealed that none of the carcass traits was influenced by the dietary supplementation of butyrate in the diet of broiler chicken. These variations in results may be due to the type or form of butyric acid used and it may also be linked with the genetic differences of the experimental birds used, along with other possible differences on other environmental conditions.

The result of this study showed that dietary treatments, significantly improved the visceral organs of broiler birds. Sodium butyrate (2 g/kg feed=T3) increased the relative weight of gizzard. A large, well-developed gizzard improves gut motility and may increase cholecystokinin release, which in turn stimulates the secretion of pancreatic enzymes (Rui *et al.* 2020). The decreased gizzard weight recorded in the other treatments could be explained in part by the decrease in microbial population of the upper parts of the guts (Dehghani-Tafti and Jahanian, 2016). According to (Aghazadeh and Taha, 2012), butyrate inclusion increased the relative weights of liver and intestine, but, it had no effects on the relative weight of gizzard. However, other studies did not found any effects of butyrate on relative weight of liver or gizzard (Antongiovanni *et al.* 2007; Panda *et al.* 2009). The liver and to some extent the heart play a major role in detoxification of toxin, their similarity in weight for sodium butyrate inclusion supplemented birds, rosemary leaf meal and their combinations tend to suggest that the different dietary treatments did not have any toxic effect on these organs. This is in line with the findings of (Rui *et al.* 2020). The spleen is one of the key players of the immune system. The dietary inclusion of sodium butyrate and rosemary leaf meal in the present study increased the weight of the spleen, which may suggest that sodium butyrate and rosemary leaf meal accelerated the development of an immune-related organ. The spleen produces antibodies and it serves as a reservoir that contains over half of the body's monocytes (Oyeagu *et al.* 2019a). This showed that these additives positively influenced the immune capacity of the birds. The relative weight of the large and small intestine was higher for birds fed sodium butyrate supplementation and this is in line with the results of Chamba *et al.* (2014) and Rui *et al.* (2020) who reported higher weight of the small intestine with SB supplementation. The small intestine is the site for absorption and the improved weight and length indicates better absorption and utilization of nutrient. Sodium butyrate produces gut epithelial cells with energy and it increases the epithelial cell proliferation, differentiation and improve colonic barrier function (Guilloteau *et al.* 2010). The observed decrease in relative length of the small and large intestine was probably caused by a decrease in the thickness (viscosity) of the contents of the small intestine and a reduction in the crypt cell proliferation rate (Oyeagu *et al.* 2019a). Some authors maintained that the reduction in the length of the gut may be associated with a decrease in the viscosity of the gut contents and the concentration of volatile fatty acids in the ceca as well as rapid passage rate of the digesta and its greater dilution with water (Afsharmanesh *et al.* 2016; Oyeagu *et al.* 2019c). The results of the present study agree with the findings of Yakhkeshi *et al.* (2012), Sharifi *et al.* (2013) and Behzad *et al.* (2015) who observed an improvement on broiler chickens fed rosemary leaf and yarrow powder, but disagree with the findings of Cabuk *et al.* (2006) who did not find any changes in the gastrointestinal tract weight in response to the inclusion of rosemary essential oil mixtures in broiler diets. The improved kidney observed in the study maybe due to the ability of the sodium butyrate to reduce the pH of the intestine, and this helps in the proliferation of positive bacteria that reduce the pressure of the kidney in the removal of waste. The inclusion of rosemary leaf meal at single level and their combination with sodium butyrate improved some of the visceral organs such as, liver, gizzard, spleen, length of large intestine, and proventriculus. The observed changes on the visceral organs in this study could be attributed to the effect of the rosemary meal supplementation. Rosemary have some important traits that may improve the visceral organs of broiler birds such as antimicrobial, hypoglycemic, hypolipidemic, cytotoxic, hepatoprotective and anti-inflammatory properties (Gema *et al.* 2018). However, the high crude fibre content in the rosemary leaf meal used in this study might have caused an expansion of the gastrointestinal tract (Jorgensen *et al.* 1996). Sodium butyrate increased the gizzard weight at the starter phase, however it was observed that the gizzard weight of the birds was decreased at finisher phase. In healthy animals the increase in weight of immune organs is correlated with improved immune responses of the body. The observed increase in the visceral organs of birds fed 2 g/kg diet suggest that sodium butyrate inclusion alters gut physiology and could influence the digestion and absorption of nutrient in broilers. Small intestine is the site for absorption in which the available nutrients are taken up through epithelial cells and drained into the general circulation. Architectural modulation of the small intestine is assumed to have a relationship with the production performance of animals. We noted that small intestine length and weight improved significantly in sodium and rosemary leaf meal offered groups. Butyrate acts as a rich source of energy for the enterocytes (Arbab *et al.* 2017), and it may possibly increase the cell mitosis in the crypts.

The inclusion of sodium butyrate and rosemary leaf meal in the diets of broilers enhanced the digestibility of crude fibre, crude protein and crude fat at both phases. This could be due to their intrinsic (antimicrobial, antioxidant, anti-inflammatory, and hepatoprotective) qualities (Veselin *et al.* 2018) that improved the villi height which promoted the activities of the digestive enzymes at the tip of the villi which will increase nutrient digestion and absorption for enhanced muscles (tissue) development (Oyeagu *et al.* 2019a). The higher efficiency of nutrient utilization for birds fed sodium butyrate and rosemary leaf meal may be the reason for the observed improvement in the performance. This improvement could be attributed to better health status of the GIT or larger villi surface area which improved nutrient digestion and absorption (Mansoub, 2011). They also improved the pancreatic enzyme secretion, intestinal mucosa, and their antimicrobial action (Adil *et al.* 2010). The result of the present study is similar with the results of Qaisrani *et al.* (2015) who reported that sodium as a feed additive in poultry diets may be an approach to improve protein digestibility of poorly digestible protein sources. The use of protected butyrate increased the ileal digestibility of thrionine, serine and proline (Kaczmarek *et al.* 2016). Sodium butyrate improved the ileal digestibility energy on d 42 compared to the control (Liu *et al.* 2017).

However, the present result was probably achieved because of the level of fibre contents in the mixture, which did not interfere with the utilization of nutrients (Rostami *et al.* 2015). Also the supplementation of sodium butyrate in the diet of the broiler birds increased the digestibility of crude fibre, crude protein and crude fat. This may be due to the ability of the organic acid to reduce gut pH. The pH reduction prevents the intestinal bacteria from stepping down the metabolic needs of the animal, hence, increasing the availability of nutrients to the host (Azza and Naela, 2014). These also decreased bacterial fermentation, as it improved the digestibility of protein and fibre (Thirumeignanam *et al.* 2006; Sheikh *et al.* 2010). According to Dibner and Butin (2002) the organic acids improved the digestibility of protein and energy by reducing the microbial competition with the host for nutrient and endogenous nitrogen losses. This helps to reduce the incidence of sub-clinical infections and secretion of immune mediators, by reducing the production of ammonia and other growth depressing microbial metabolites.

CONCLUSION

In conclusion, up to 2 g/kg sodium butyrate, 4 g/kg sodium butyrate, or 2.5 g/kg rosemary leaf meal can be supplemented in the chicken diets for improved digestibility and absorption of nutrients, growth traits and better cut yields. Moreover, sodium butyrate and rosemary leaf meal inclusion at single levels accelerated the development of immune organs (spleen) and improved the health promoting organs (heart, kidney, and liver). This showed that these additives can be used successfully as a potent alternative to antibiotics without any deleterious effect on the animal and consumers.

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