Effect of Butyric Acid on the Performance and Carcass Yield of Broiler Chickens

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ABSTRACT Short-chain fatty acids such as butyrate are considered potential alternatives to antibiotic growth promoters. The efficacy of butyric acid on performance and carcass characteristics of broiler chickens was tested in two studies. The effect of dietary butyrate on the ability to withstand coccidial oocyte challenge also was investigated. In experiment 1, male broiler chickens were fed diets supplemented with 0 or 11 ppm virginiamycin or 0.2 or 0.4% butyric acid (as mono-, di-, and triglyceride). In experiment 2, broilers were fed bacitracin methylene disalicylate or 0.1 or 0.2% butyric acid. In another trial, birds vaccinated against coccidiosis were challenged with oocytes at 21 d and examined 6 d later. In experiment 1, diet treatments had no effect on body weight gain. Feed intake of the birds fed 0.4% butyric acid was decreased ($P < 0.01$) compared with birds fed the nonmedicated diet during the starter period, whereas birds fed 0.2% butyric acid had similar feed intake to the control birds. In experiment 2, diet treatments did not affect the performance of broiler chicks while carcass weight and breast meat yield increased ($P < 0.01$) in birds fed 0.2% butyric acid. With oocyte challenge, birds that had received butyric acid before challenge showed higher growth rate following the challenge compared with birds that received nonmedicated feed. Bacitracin decreased ($P < 0.05\%$) duodenal villi crypt depth, whereas villus length was similar in birds fed butyric acid or the nonmedicated control diet. These results show that 0.2% butyric acid can help to maintain the performance and carcass quality of broilers, especially in vaccinated birds challenged with coccidiosis.

(*Key words*: butyric acid, coccidiosis, broiler, growth promoter)

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INTRODUCTION

Medium-chain fatty acids have been considered a potential alternative for antibiotics in pig diets (Dierick et al., 2002). Bacterial cells take up undissociated fatty acids, and once these dissociate, the change in intracellular pH is usually bactericidal (van der Wielen et al., 2002). In testing the survival of *Salmonella enterica* serovar typhimurium during exposure to short-chain fatty acids, Kwan and Ricke (1998) showed butyrate and valerate to have the greatest efficacy.

The levels of short-chain fatty acids are quite low in the distal small intestine and ceca of the young chick, but then increase and plateau by approximately 15 d of age (van der Wielen et al., 2000). These authors showed a correlation between pathogen control and the presence of undissociated, but not total, levels of acetate, propionate, and butyrate in the ceca. In addition to its bactericidal activity, butyrate appears to play a role in development of the intestinal epithelium. Butyrate, which is a by-product of microbial fermentation of products such as resistant starch, is considered to be important for normal development of epithelial cells (Pryde et al., 2002). Brons et al. (2002) credit butyrate derived from the fermentation of nonstarch polysaccharides with improved gastrointestinal health in humans and reduced incidence of colon cancer.

Butyric acid therefore appears to be both bactericidal and a stimulant of villi growth. As with any short-chain fatty acid, bactericidal activity of butyric acid is greatest when the acid is undissociated. Bolton and Dewar (1965) indicated that free butyrate quickly disappeared in the upper digestive tract, and whereas almost 60% of the feed source was intact in the crop, less than 1% was recovered from the upper small intestine. The efficacy of butyrate likely will be improved if it is protected from immediate absorption in the upper tract. In this study, we tested butyrate in the form of a mixture of mono-, di-, and triglycerides for its potential in sustaining broiler health and performance.

MATERIALS AND METHODS

Experiment 1

Eight hundred forty commercial-strain, 1-d-old male broiler chickens (Ross × Ross) were obtained from a

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TABLE 1. Diet composition (%)

Item	Diet	
	Starter	Grower/finisher
Corn[2]	52.31	59.75
Wheat shorts	5.00	5.00
Soybean meal	34.80	26.75
Animal-vegetable fat	3.50	4.10
DL-Methionine	0.24	0.25
L-Lysine	—	0.22
Salt	0.41	0.37
Limestone	1.60	1.63
Dicalcium phosphate	1.14	0.93
Premix[1]	1.00	1.00
Total	100.00	100.00
Calculated analyses		
Metabolizable energy (kcal/kg)	3,000	3,090
Crude protein (%)	21.85	19.0
Sodium (%)	0.19	0.18
Calcium (%)	0.98	0.90
Average phosphorus (%)	0.44	0.38
Lysine (%)	1.20	1.11
Methionine (%)	0.58	0.53
Methionine + cystine (%)	0.94	0.85

[1]Supplied per kg diet: *trans*-retinol, 2.4 mg; cholecalciferol, 40 μg; α-tocopherol acetate, 11.0 mg; riboflavin, 7.0 mg; pantothenic acid, 7.0 mg; cobalamin, 8 μg; niacin, 20 mg; choline, 900 mg; menadione, 1.5 mg; folic acid, 1.5 mg; biotin, 0.25 mg; ethoxyquin, 125 mg; manganese, 50 mg; zinc, 50 mg; copper, 5.0 mg; iron, 30 mg; selenium, 0.3 mg.

[2]Butyric acid (0.1, 0.2 or 0.4% as a mixture of mono-, di-, and triglycerides), virginiamycin (11 ppm) and bacitracin MD (550 ppm) were added to the basal diet substituting for corn.

commercial hatchery. Birds were randomly assigned to 1 of 4 treatment groups: nonmedicated control (Table 1), 11 ppm virginiamycin, 0.2% butyric acid, or 0.4% butyric acid, respectively, both as a mixture of glycerides.[2] The product contains 25 to 30% monoglycerides in the 1 or 3 position, 50 to 55% diglycerides in the 1 or 3 position, and 15 to 25% triglyceride. There were 35 birds per pen and 6 replicate pens per treatment. Butyric acid and antibiotics were added to the basal diet by substituting at the expense of corn. Birds were maintained at a brooding temperature of 32°C for 5 d, and then the environmental temperature was gradually reduced to 22°C in keeping with normal brooding practice. The lighting schedule was 23 h/d from d 0 to 4; 12 h/d from d 4 to 14; 15 h/d from d 14 to 18; 18 h/d from d 18 to 25; and 23 h/d from d 25 to 42. Birds were vaccinated against coccidiosis at 1 d of age using gel-spray coccidiosis vaccine.[3] Birds were managed under the guidelines of the Canadian Council on Animal Care (1993) and with the approval of the University of Guelph Animal Care Committee. Feed and water were available ad libitum. Birds were individually weighed on d 20 and 42. The starter diet (crumble) was fed until d 20. The grower/finisher diet (pellet) was fed from d 20 to 42. On d 42 of the trial, 8 birds from each treatment were selected at random for estimation of carcass characteristics. Birds were processed at the University facilities. Carcasses were water chilled overnight at 4°C and weighed. The left and right breast muscles were then dissected and weighed.

Experiment 2

General experimental design, bird numbers and management were as described in experiment 1. Birds were randomly assigned to 1 of 4 treatment groups (Table 3). The treatments were nonmedicated control, 50 ppm bacitracin (bacitracin methylene disalicylate),[4] 0.1% butyric acid or 0.2% butyric acid as a mixture of glycerides as described in experiment 1. Birds were weighed individually on d 21 and 42. Starter diet (crumble) was fed until d 21, and grower/finisher pellets fed from d 21 to 42. Duodenal samples were collected 5 cm posterior to the gizzard from 21-d-old birds from control, bacitracin, and 0.2% butyric acid treated birds, and fixed in 10% buffered formalin solution. Ten birds per treatment were sampled. These birds were maintained in the same rooms as those in the growth study, but were not part of the larger study and their feed intake and growth characteristics were not part of the statistical design for these parameters. Serial sections (5 μm) were cut and stained with hematoxylin/eosin to evaluate villus length and crypt depth. Villus height was represented by the distance from the crypt opening to the tip of the villus, whereas crypt depth was determined from the base of the crypt to the level of the opening (Kik et al., 1990).

Experiment 3

Forty 21-d-old birds were used for a coccidial challenge study. The 40 birds were vaccinated against coccidosis at d 1 of age and fed nonmedicated feed or 0.2% butyric acid to 21 d. At 21 d, birds were challenged with a mixture of 5×10^5, 8×10^4, 1×10^5 and 6×10^4 of *Eimeria acervulina*, *E. maxima*, *E. tenella*, and *E. necatrix*, respectively. Birds were weighed at time of challenge and again 6 d later. All birds were fed the nonmedicated control diet from 21 to 27 d of age. Mortality and cecal lesions were observed.

Statistical Analysis

The experiment was a completely randomized design with pen as the experimental unit. For carcass parameters, the individual randomly selected bird was the experimental unit, and results were analyzed by a one-way ANOVA using the GLM procedure of SAS.[5] The other response variables considered were body weight, body weight gain, feed intake, feed intake to body weight gain, carcass weight, breast meat yield, breast meat yield as a percentage of carcass weight, and percentage of mortality between 0 to 42 d. Means were separated by using Tukey's test when the *F*-test was significant ($P < 0.05$).

[2]SILO, Industria Zootecnica, Florence, Italy.
[3]Vetech Laboratories Inc., Guelph ON.
[4]BMD-50, Alpharma, Fort Lee, NJ.
[5]SAS Institute, Inc., Cary, NC.

TABLE 2. Performance of broiler chickens fed diets containing butyric acid or virginiamycin (experiment 1)

Treatment	Weight gain[1] (g)			Mortality[2] (%)
	0 to 20 d	20 to 42 d	0 to 42 d	0 to 42 d
Control	660	1,886	2,546	3.8
Virginiamycin	650	1,866	2,515	8.1
0.2% butyric acid	659	1,946	2,605	3.9
0.4% butyric acid	630	1,924	2,554	4.8
SD	25.5	121.7	133.4	3.1

	Feed intake (g/bird)			Feed intake:gain			Carcass weight	Breast meat	
	0 to 20 d	20 to 42 d	0 to 42 d	0 to 20 d	20 to 42 d	0 to 42 d		(g)	% Carcass
Control	986[c]	3,673	4,659	1.49[a]	1.95	1.83	1,997	464	23.2
Virginiamycin	920[d]	3,632	4,551	1.42[b]	1.95	1.81	1,972	466	23.4
0.2% butyric acid	946[cd]	3,743	4,690	1.44[ab]	1.93	1.80	2,013	475	23.6
0.4% butyric acid	910[d]	3,678	4,588	1.45[ab]	1.91	1.80	2,012	473	23.5
SD	25.9	167.7	176.3	0.04	0.06	0.04	177.2	59.6	1.8

[a,b]Means followed by different letters are significantly different ($P < 0.05$).

[c,d]Means followed by different letters are significantly different ($P < 0.01$).

[1]Day-old chick weight averaged 37 g.

[2]Not transformed.

RESULTS

Performance data for birds fed virginiamycin or butyrate in experiment 1 are detailed in Table 2. Diet treatment generally had no effect on body weight or weight gain in either the starter or grower/finisher periods. Birds consumed less starter feed when diets were supplemented with virginiamycin or 0.4% butyrate relative to the control birds ($P < 0.01$, Table 2). The reduction in intake resulted in superior feed efficiency for birds fed virginiamycin. The eviscerated carcasses from birds randomly selected from within each treatment group were consistently heavier compared with other treatments, although this effect was not statistically significant. Breast meat yield, both absolute weight and percentage yield, was unaffected by diet treatment (Table 2).

Results from experiment 2, in which bacitracin was used for comparative purposes, are shown in Table 3. Birds fed bacitracin were consistently heavier than those from all other treatments, although differences were not significant. The heaviest carcass weight was recorded for birds fed 0.2% butyrate with this effect significant ($P < 0.01$) relative to birds fed 0.1% butyrate (Table 3). The carcasses from birds fed 0.2% butyrate also produced the most breast meat (Table 3).

The results of duodenal morphology are shown in Table 4. Bacitracin reduced villi crypt depth compared with control birds or those fed 0.2% butyrate. When birds were challenged with a mixed culture of oocysts, subsequent weight gain was improved for birds previously fed 0.2% butyrate vs. the unmedicated control birds (Table 4). One bird in the butyrate treatment group

TABLE 3. Performance of broiler chickens fed diets containing butyric acid or bacitracin (experiment 2)

Treatment	Weight gain[1] (g)			Mortality[2] (%)
	0 to 21 d	21 to 42 d	0 to 42 d	0 to 42 d
Control	764	1,887	2,651	4.29
Bacitracin	790	2,017	2,808	2.38
0.1% butyric acid	771	1,894	2,666	10.5
0.2% butyric acid	773	1,895	2,667	8.1
SD	21.4	88.3	101.5	7.5

	Feed intake (g/bird)			Feed intake:gain			Carcass weight	Breast meat	
	0 to 21 d	21 to 42 d	0 to 42 d	0 to 21 d	21 to 42 d	0 to 42 d		(g)	% Carcass
Control	1,027	3,522	4,549	1.35	1.87	1.72	2,097[ab]	466[b]	22.2
Bacitracin	1,050	3,647	4,697	1.33	1.81	1.67	2,146[ab]	486[ab]	22.6
0.1% butyric acid	1,040	3,308	4,347	1.35	1.74	1.63	2,063[b]	465[b]	22.5
0.2% butyric acid	1,045	3,427	4,471	1.35	1.81	1.68	2,185[a]	506[a]	23.2
SD	38.2	230.6	242.3	0.05	0.10	0.02	166.1	57.9	1.97

[a,b]Means followed by different superscripts are significantly different ($P < 0.01$).

[1]Day-old chick weight averaged 37 g.

[2]Not transformed.

TABLE 4. Duodenal morphology (experiment 2) and weight gain from 21 to 27 d following challenge with coccidial oocyts (experiment 3)

Treatments	Duodenum (nm)		21 to 27 d weight gain (g)
	Villus length	Crypt depth	
Control	1,428	270[a]	252[b]
Bacitracin	1,595	203[b]	—
0.2% butyric acid	1,562	266[a]	316[a]
SD	70.0	17.9	65

[a,b]Means followed by different superscripts are significantly different.

died in the 21- to 27-d test period, compared with no mortality in the control group. Mortality was 70% in unvaccinated Leghorn chicks used to monitor efficacy of the oocyst preparation. Butyrate had no effect on the minimal coccidial lesion scores noted in the vaccinated birds at 27 d.

DISCUSSION

Although short-chain fatty acids such as acetate and propionate have been successfully used as water sanitizers, there is little information available on butyrate metabolism by poultry. Bolton and Dewar (1965) indicate that free butyric acid is absorbed very quickly in the upper digestive tract, and will likely be of limited use other than as a feed sanitizer. By inference, butyrate needs to be stabilized, and hence the testing of butyrate glycerides used in this study. This butyrate is composed of mono- and diglycerides with approximately 75% by weight of butyric acid. Unlike butyric acid, the butyrate glycerides used in this study had only a mild buttery type odor and not the rancid odor often associated with butyric acid.

Pinchasov and Jensen (1989) reported that butyric acid, unlike other acids such as propionate, did not depress feed intake. In the current studies, adding up to 0.2% butyrate glycerides had no detrimental effect on feed intake. There is an indication from the present study of modification to villi development relative to birds fed bacitracin. Sakata (1987) showed that infusion of butyrate into fistulated rats increased the proliferation of crypt cells in both the small and large intestines. Sharma et al. (1995) suggested that the effect on crypt cell growth may reflect changes in the gut microflora, which is known to be a major modulator of epithelial cell activity. Further studies are warranted on the effects of graded levels of butyrate on epithelial cell development in the small intestine of young broilers. The levels of short-chain fatty acids are quite low in the intestine and ceca of young chicks (van der Wielen et al., 2000) and so the neonate may be the best candidate for diet supplementation.

Birds previously fed butyrate can better withstand the stress of coccidial challenge at 21 d of age (Table 4). van der Wielen et al. (2000) showed a correlation between the presence of undissociated butyrate (and acetate and propionate) and pathogen control in the ceca of young birds. van Immerseel et al. (2004a,b) have indicated significantly reduced levels of *Salmonella* in the ceca of birds fed organic acids, whereas Cox et al. (1994) showed butyric acid in particular was effective in reducing *Salmonella* colonization of the intestine. Chaveerach et al. (2002) indicate that this efficacy of organic acids in controlling microbes such as *Campylobacter* is influenced by concentration, form of the acid, and the degree of any dissociation. Our preliminary studies with cocci-vaccinated birds confirm the additional benefit of butyrate in terms of growth rate after coccidiosis challenge, which is a common occurrence under commercial conditions.

The results of these studies indicate no negative effect of feeding up to 0.4% butyrate glycerides throughout the 42-d broiler growth period. There is an indication that unlike antibiotics, butyrate helps in the maintenance of intestinal villi structure, compared with the negative effect of antibiotics, and that prior treatment reduces the devastating effects of coccidial challenge. Further studies are warranted to study the dose response to butyric acid, and the specific time needed to feed this product. A mixture of butyrate mono-, di-, and triglyerides seems to provide an alternative route for administering butyric acid via the feed of broiler chickens.

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