

Influence of Dietary Supplementation of Coated Sodium Butyrate and/or Synbiotic on Growth Performances, Caecal Fermentation, Intestinal Morphometry and Metabolic Profile of Growing Rabbits

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Abstract

The aim of the present experiment was to study the synergistic effects of dietary supplementation with coated slow released sodium butyrate (CM3000[®]) and a commercial synbiotic (Poultry-Star[®]) on the productive performance and intestinal morphometry of the growing rabbits. Thirty two apparently healthy male New Zealand rabbits with average body weight of 544 ± 9 g were divided randomly into four dietary treatments at weaning (28th day of age). The control group (C) was fed on standard basal diet with no supplementation. Rabbits in the second group (T1) received the same basal diet supplemented with CM3000[®] 500 g/ton feed. Animals in the third group (T2) consumed the basal diet containing Poultry-Star[®] 500 g/ton feed. Rabbits in the fourth group (T3) were fed on the basal diet enriched with mixture of CM3000[®] and Poultry-Star[®], 250 g/ton feed for each. Feed and water were offered *ad-libitum* during 70 days experimental period. Body weight and feed consumption were recorded biweekly to calculate body weight gain and feed conversion. At the end of the experimental period blood and caecal content samples were collected from all animals. Duodinal tissue samples were collected for histomorphometry. The results revealed that additives used improved significantly live body weight compared to the control group. Rabbits in T3 group showed the highest body weight gain. In addition, supplementation of the basal diet with a mixture of additives revealed significant increase of feed intake. The blood urea level was reduced significantly in bucks of T1. The rabbits in T3 group recorded the highest level of blood glucose. Caecal pH revealed a significant decrease in T1 and T3. The mixture of additives has positive results on the intestinal morphometry. Coated butyrate and synbiotic are capable of improving performance, enhancing intestinal health.

Keywords: rabbits, sodium butyrate, synbiotic, zootechnical performance, intestinal morphology

1. Introduction

Rabbit meat for its dietetic and nutritional characteristics is accepted by the consumer as a product of high quality meat. Rabbit meat is lean and its lipids are highly unsaturated (60% of the total fatty acids), rich in protein (20-21%) with high biological values, very low in cholesterol and sodium and rich in potassium and magnesium (Dalle Zotte, 2000). Under intensive production conditions (high genetic makeup breeds, high density of breeding unit, developing feeding mills, early weaning, etc), multi-factorial stressors (environmental, nutritional, managerial, etc) affects and suppress the health and production of all rabbit breeds. Improvement of the rabbit health and productive performance are very important to maximize the production at low cost. Recently using of growth promoters and feed additives to maintain rabbit health and maximize economics of rabbit meat production has increased.

Short review of European Union (2003) recorded that the rabbit's gut microflora are the key factors to maintain rabbit's health, zootechnical performance and reproduction. This review pay attention to feed additives that favour better rabbit gut microbiota with special emphasize on their effects on growth performance and health status as safe, reliable and efficacious alternatives to antibiotics in rabbit nutrition.

It is reported that butyrate derived from the fermentation of non-starch polysaccharides is considered to be important for normal development of epithelial cells with improved gastrointestinal health and reduced incidence of enteric diseases (Bron et al., 2002). Sakata (1987) reported 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 might reflect changes in the gut microflora, which is known to be a major modulator of epithelial cell activity. It has been demonstrated that short chain organic acids produced from fibre fermentation can inhibit the growth of bacteria of the group Enterobacteriaceae. Hume et al. (1993) showed that butyric acid has a higher diffusion coefficient through the pathogenic cell wall than other acids with shorter chains, which allows it to pass through the bacterial membrane more easily. Furthermore, in a recent work by Sunkara et al. (2011), the hypothesis that sodium butyrate is capable of inducing host defence peptides (HDPs) and enhancing disease resistance. Host defence peptides are natural broad spectrum antimicrobials and an important first line of defence in almost all forms of life.

Unfortunately, the natural levels of butyrate from fibre fermentation are quite low in the intestine and caeca (van der Wielen, 2000). Moreover, uncoated butyrate feed additive is immediately absorbed in the first part of the digestive tract before reaching the large intestine. In order to exert the influence in the large intestine, dietary butyrate should slowly be released over the gastrointestinal tract (Hu & Guo, 2007).

Probiotics, prebiotics and synbiotics have proven to be effective in reducing mortality in domestic animals (Collier et al., 2010) by maintaining the microbial balance in the digestive tract and reducing potentially pathogenic bacteria (Corcionivoschi et al., 2010). Several strains of probiotic bacteria and yeast have reduced mortality in various species of animals (Collier et al., 2010; Peret et al., 1998), and beneficial effects are more pronounced in conditions of stress or in herds with high mortality (Ewing, 2008). However, few studies have evaluated the effectiveness of synbiotics in rabbits.

Low information is available regarding the effect of adding coated or slowly released butyrate products with or without combination with synbiotic in rabbit diets. Based on this concept, the goal of the present study was to investigate the synergistic effects of dietary supplementation with coated slow released sodium butyrate (CM3000[®]) and a commercial synbiotic (Poultry-Star[®]) on the productive performance and intestinal morphometry of the postweaning growing rabbits.

2. Materials and Methods

2.1 Feed Additives Used

1) CM3000[®] is a commercial 30% microencapsulated sodium butyrate. CM3000[®] keeps releasing slowly and continuously in both small and large intestine. CM3000[®] is manufactured by Hangzhou King Techina Feed Co., Ltd, China.

2) Poultry-Star[®] is a microencapsulated synbiotic product for feed application. Poultry-Star[®] contains multi-species probiotic microorganisms (*Enterococcus faecium*, *Pediococcus acidilactici*, *Bifidobacterium animalis*, *Lactobacillus reuteri* and *Lactobacillus salivarius*) combined with prebiotic fructo-oligosaccharide (FOS). Poultry-Star[®] produced by BIOMIN America, Inc, USA.

2.2 Experimental Animals, Housing and Diets

Thirty two apparent healthy, weaned male New Zealand white bucks 35 day age and average body weight of 544 ± 9 g were used. The rabbits were weighed individually and randomly allocated to four dietary treatments (8 animals/group). The rabbits were housed individually in commercial cages (55 × 60 × 34 cm), equipped with automatic drinkers and j-feeders. Daily lighting regime was 10-12 hour photoperiod/day through both natural and fluorescent lighting. The study was conducted in the experimental rabbitry of Physiology Department, Faculty of Veterinary Medicine Cairo University, Egypt.

Basal diet was formulated and analysed to cover the nutrient requirements of growing rabbits as recommended in NRC (1977) (Table 1).

Feed and water were provided *ad-libitum* for 70 days experimental period. Rabbits in the first group were offered non-supplemented basal diet and served as a control group (C). Animals in the second group were reared on the basal diet supplemented with CM3000[®] 500 g/ton feed (T1). Rabbits in the third group consumed the basal diet containing Poultry-Star[®] 500 g/ton feed (T2). While rabbits in the fourth group were fed on the basal diet enriched with both CM3000[®] and Poultry-Star[®], 250 g/ton feed for each additive (T3). Individual body weights for all animals as well as the rest of feeds were recorded biweekly. Body weight gain and feed conversion were calculated.

Table 1. Composition percentage, calculated nutrients profile and chemical analyses of the basal diet

Ingredients (%)	%	Calculated analysis (%)**	
		Crude protein	17.5
		Crude fiber	14.0
Berseem hay	30.0	Ether extract	2.7
Barley grain	21.0	Nitrogen free extract	56.4
Yellow corn	5.0	Digestible energy (kcal/kg)	2600
Wheat bran	21.1	<u>Chemical analysis (%)***</u>	
Soybean meal	17.5	DM	90.1
Molasses	3.0	Moisture	9.9
CaCl ₂	1.5	Crude protein	17.7
NaCl	0.4	Crude fiber	13.8
Vit.&Min. Premix*	0.3	Total ash	3.5
DL-Methionine	0.2	Ether extract	2.3
		Nitrogen free extract	52.8

Note. * The Rabbit's vitamin and mineral premix/kg contained the following IU/g for vitamins or minerals: A-4,000,000, D3-5000,000, E-16,7 g, K-0.67 g, B1-0.67 g, B2-2 g, B6-0.67 g, B12-0.004 g, B5-16.7 g, Pantothenic acid-6.67 g, Biotein-0.07 g, Folic acid-1.67 g, Choline chloride-400 g, Zn-23.3 g, Mn-10 g, Fe-25 g, Cu-1.67 g, I-0.25 g, Se-0.033 g, and Mg-133.4 g (Rabbit premix); ** Based on NRC (1977); *** According to AOAC (1999).

2.3 Blood and Caecal Content Samples

Blood samples were collected at the end of the experimental period (at 105 days of age) from the ear vein of all animals at the morning before accesses to feed and water. Citrated plasma (in a ratio of 1 volume sodium citrate (3.8%): 9 volumes blood) Serum was obtained for determination of certain haematological metabolic parameters namely, glucose (Trinder, 1969), triglycerides (Wahlefeld, 1974), total cholesterol (Allian, 1974), total protein (Henry, 1964), albumen and urea (Fawcett & Scott, 1960).

Caecal content samples were collected at the end of the experimental period post slaughtering for determination of caecal fermentation pattern namely, pH, total short chain fatty acids (Eadie et al., 1967), individual volatile fatty acids (Samuel et al., 1997) and ammonia concentration (Chaney & Marbach, 1962; Abdl-Rahman et al., 2010).

2.4 Histological Investigation of the Intestinal Wall

At the end of the experimental period rabbits were slaughtered. Tissue samples were collected from the duodenum, 10 cm from the pyloric junction, flushed with physiological saline and fixed in 10% buffered neutral formaldehyde solution for 48 hr, dehydrated in a graded series of ethanol, cleared in xylene and embedded in paraffin. Cross sections 5 µm thickness were cut and mounted on slides and stained with hematoxylin and eosin.

2.5 Histomorphometry

Villus height was measured by averaging the height of 10 intact villi, from the tip of the villus to the end of the crypt depth. The duodenal gland length was determined as the distance between the lamina muscularis mucosa and the tunica muscularis externa, while the villus width was measured as the distance between the epithelium at the middle of the villus. Morphological indices were measured using image processing and analysis system (Version 1, Leica Imaging System Ltd., Cambridge, UK).

2.6 Statistical Analysis

All data were statistically analysed using IBM SPSS® version 19 software for personal computer (2010). Means were compared by one way ANOVA ($p < 0.05$) using Post Hoc test according to Snedecor and Cochran (1980).

3. Results

3.1 Zootechnical Performance

The live body weight and body weight gain in the treated groups were significantly improved ($p < 0.05$) in comparison with the control group (Tables 2 and 3).

Table 2. Effects of sodium butyrate and/or synbiotic on live body weight of growing male rabbit (g/rabbit) raised to 70 days of age (means \pm SE)

Age (day)	Control	T1 Sod. butyrate	T2 Synbiotic	T3 Mixture
35	544.37 \pm 6.3 ^a	544.38 \pm 6.3 ^a	544.37 \pm 6.3 ^a	539.38 \pm 8.6 ^a
49	656.25 \pm 22.0 ^a	800.00 \pm 23.1 ^{bc}	768.75 \pm 33.9 ^b	850.00 \pm 16.3 ^c
63	875.00 \pm 19.41 ^a	1325.00 \pm 21.1 ^c	1181.25 \pm 16.2 ^b	1378.12 \pm 24.7 ^c
77	1387.50 \pm 18.2 ^a	1643.75 \pm 17.5 ^c	1568.75 \pm 24.8 ^b	1708.75 \pm 19.4 ^d
91	1671.87 \pm 17.5 ^a	2030.62 \pm 17.5 ^b	2000.00 \pm 17.5 ^b	2184.37 \pm 17.5 ^c
105	2011.87 \pm 20.6 ^a	2350.00 \pm 13.3 ^c	2300.00 \pm 13.4 ^b	2468.75 \pm 13.1 ^d

Note. Different superscripts within a row indicate a significant treatment effect ($p < 0.05$).

Table 3. Effects of sodium butyrate and/or synbiotic on body weight gain of growing male rabbit (g/rabbit) raised to 70 days of age (means \pm SE)

Age (day)	Control	T1 Sod. butyrate	T2 Synbiotic	T3 Mixture
49	111.88 \pm 4.5 ^a	255.62 \pm 4.2 ^b	224.38 \pm 3.3 ^b	310.62 \pm 5.2 ^c
63	218.75 \pm 4.7 ^a	525.00 \pm 7.5 ^c	412.50 \pm 9.8 ^b	528.12 \pm 6.3 ^c
77	512.50 \pm 12.3 ^c	318.75 \pm 11.2 ^a	387.50 \pm 13.4 ^b	330.63 \pm 16.5 ^a
91	284.37 \pm 17.3 ^a	386.87 \pm 19.5 ^c	431.25 \pm 20.0 ^b	475.62 \pm 18.2 ^c
105	340.00 \pm 18.1 ^c	319.38 \pm 15.6 ^b	300.00 \pm 17.8 ^a	284.38 \pm 18.6 ^a
Total	1467.50 \pm 21.8 ^a	1805.62 \pm 18.3 ^c	1755.63 \pm 17.5 ^b	1929.37 \pm 19.3 ^d

Note. Different superscripts within a row indicate a significant treatment effect ($p < 0.05$).

Live body weight showed significant differences ($p < 0.05$) at the end of the experiment in the following order: T3 > T1 > T2 > C (2468.75 \pm 13.1, 2350.00 \pm 13.3, 2300.00 \pm 13.4 and 2011.87 \pm 20.6 g/rabbit respectively). Both additives CM3000[®] (T1) and Poultry-Star[®] (T2) significantly improved live body weight. The highest body weight was shown in rabbits fed on the mixture of CM3000[®] and Poultry-Star[®] (T3) group. In the same way body weight gain showed significant differences at the end of the experiment in the following order: T3 > T1 > T2 > control group.

Tables 4 and 5 show the feed consumed and feed conversion in the different groups. Rabbits reared on the diet containing mixture of CM3000[®] and Poultry-Star[®] (T3) consumed more feed than the control and the other treated groups. In addition, feed conversion was improved by the additives used to record 3.30 in T3 and T2 versus 3.53 in the control group.

Table 4. Effects of sodium butyrate and/or synbiotic on feed intake of growing male rabbit (g/rabbit) raised to 70 days of age (means±SE)

Age (day)	Control	T1 Sod. butyrate	T2 Synbiotic	T3 Mixture
49	381.06 ± 16.8 ^a	381.10 ± 15.5 ^a	381.06 ± 12.3 ^a	377.57 ± 11.6 ^a
63	643.13 ± 21.0 ^a	784.00 ± 25.3 ^c	753.38 ± 24.9 ^b	833.00 ± 22.4 ^d
77	1157.50 ± 19.41 ^a	1298.50 ± 27.2 ^b	1157.63 ± 23.6 ^a	1350.56 ± 21.7 ^c
91	1359.75 ± 28.9 ^a	1610.88 ± 35.1 ^c	1537.38 ± 33.6 ^b	1674.58 ± 30.2 ^c
105	1638.43 ± 28.2 ^a	1990.00 ± 25.3 ^b	1960.00 ± 21.4 ^b	2140.68 ± 20.5 ^c
Total	5179.87 ± 20.6 ^a	6064.48 ± 13.3 ^c	5789.45 ± 13.4 ^b	6376.39 ± 13.1 ^d

Note. Different superscripts within a row indicate a significant treatment effect ($p < 0.05$).

Table 5. Effects of sodium butyrate and/or synbiotic on feed conversion (FCR) of growing male rabbit raised to 70 days of age (means±SE)

Age (day)	Control	T1 Sod. butyrate	T2 Synbiotic	T3 Mixture
49	3.41	1.49	1.70	1.22
63	2.94	1.49	1.83	1.58
77	2.26	4.07	2.99	4.08
91	4.78	4.16	3.56	3.52
105	4.82	6.23	6.54	7.53
Total	3.53	3.36	3.30	3.30

3.2 Caecal Fermentation Parameters

The results clearly demonstrate decrease in the pH in groups T1 and T3 compared to the control group ($p < 0.05$) (Table 6).

Table 6. Effects of sodium butyrate and/or synbiotic on caecal fermentation of growing male rabbit raised to 70 days of age (means±SE)

Parameter	Control	T1 Sod. butyrate	T2 Synbiotic	T3 Mixture
pH	6.79 ± 0.12 ^a	6.32 ± 0.03 ^b	6.92 ± 0.07 ^a	6.29 ± 0.03 ^b
Ammonia	17.35 ± 1.11 ^c	14.58 ± 0.96 ^b	17.32 ± 0.33 ^c	13.87 ± 0.81 ^a
TVFA	64.0 ± 6.11 ^a	126.67 ± 4.81 ^a	46.0 ± 1.15 ^a	124.67 ± 3.71 ^a
Acetic acid mol%	55.17 ± 0.93 ^a	58.56 ± 1.96 ^c	62.35 ± 0.22 ^d	56.98 ± 1.82 ^b
Propionic acid mole%	26.56 ± 1.14 ^c	14.81 ± 2.10 ^a	14.34 ± 0.57 ^a	21.31 ± 0.34 ^b
butyric mol%	7.78 ± 0.71 ^a	26.09 ± 0.33 ^c	22.56 ± 0.54 ^b	20.70 ± 0.21 ^b

Note. Different superscripts within a row indicate a significant treatment effect ($p < 0.05$).

Each treatment modified the VFAs profile within the caecum in a particular fashion. As for acetic acid proportion, the highest percent was recorded in T2 group compared to the C group, while all supplements lowered propionic acid molar proportion compared to C group. Regarding caecal NH₃-N concentrations, both T1 and T3 groups demonstrated a decrease significantly ($p < 0.05$) with reference to control group.

3.3 Blood Parameters

The results obtained from serum analyses are shown in table 7. An increase in the glucose concentration was reported in all treated groups and the highest was recorded in T3 group. Serum triglycerides showed highest values in the treated group (T1). Ammonia concentration recorded low values in T1 and T3 groups compared with the control one ($p < 0.05$).

Table 7. Effects of sodium butyrate and/or synbiotic on some blood parameters of growing male rabbit raised to 70 days of age (means±SE)

Parameter	Control	T1 Sod. butyrate	T2 Synbiotic	T3 Mixture
Albumin	3.72 ± 0.28 ^a	4.42 ± 0.34 ^b	3.15 ± 0.23 ^a	4.80 ± 0.27 ^c
Total protein	6.04 ± 0.20 ^a	6.25 ± 0.28 ^a	5.67 ± 0.40 ^a	6.53 ± 0.38 ^a
Urea	35.14 ± 4.27 ^b	30.61 ± 3.75 ^a	63.29 ± 5.18 ^d	37.49 ± 4.60 ^c
Triglycerides	122.03 ± 19.20 ^b	288.28 ± 49.52 ^c	36.68 ± 5.83 ^a	119.68 ± 17.56 ^b
Cholesterol	127.03 ± 20.27 ^a	96.73 ± 13.72 ^a	109.00 ± 9.70 ^a	81.38 ± 12.67 ^a
Glucose	137.64 ± 4.95 ^a	139.02 ± 5.37 ^b	139.85 ± 6.48 ^b	179.74 ± 14.24 ^c

Note. Different superscripts within a row indicate a significant treatment effect ($p < 0.05$).

3.4 Histological Investigation of the Intestinal Wall

The effect of dietary treatments on the duodenal morphology (villus height, villus width and duodenal gland length) is shown in Table 8 and Figure 1. Dietary supplementations influenced the histomorphological measurements of duodenal villi and gland length comparing with the control. Feed additives increased significantly ($p < 0.05$) the villus and gland lengths in all treated groups when compared with the control. Furthermore, the mixture of sodium butyrate and synbiotic (T3) supplementation increased the gland length and villus width numerically compared with other additives.

Table 8. Effects of feed additive supplementations on the histomorphological parameters of the rabbit intestine (means±SE)

Parameter	Control	T1 Sod. butyrate	T2 Symbiotic	T3 Mixture
Villus height (µm)	349±11 ^a	395±12 ^b	378±12 ^b	389±13 ^b
Villus width (µm)	43±1.4 ^a	44±1.9 ^{ab}	49±2.3 ^{bc}	51±1.7 ^c
Gland length (µm)	177±10 ^a	250±20 ^b	236±14 ^b	286±19 ^b

Note. Different superscripts within a row indicate a significant treatment effect ($p < 0.05$).

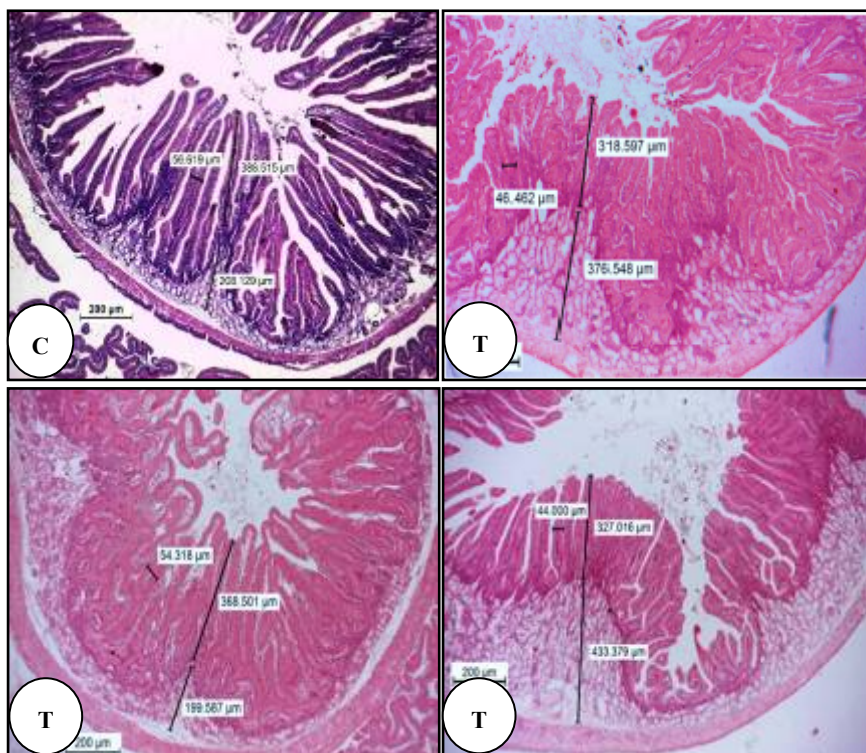


Figure 1. Photomicrographs of the small intestine (duodenum) from male New Zealand white rabbits showing the intestinal villi and duodenal glands. (C) Control group; (T1) Sodium butyrate supplemented group; (T2) Symbiotic supplemented group; (T3) Mixture of butyrate and symbiotic group, (H&E) staining

4. Discussion

From the obtained results it is clear that rabbits performance was enhanced by the additive used. These findings can be explained in the light of that short chain fatty acids (SCFA) produced by microbial fermentation from dietary fibre stimulate epithelial cell proliferation resulting in a larger absorptive surface (Sakata, 1988; Leeson et al., 2005; Hu & Guo, 2007; Panda et al., 2009). Moreover, normal colonic epithelia derive 60 to 70% of their energy supply from SCFA, particularly from butyric acid (Scheppach et al., 1992). Butyric acid induces cell differentiation and regulates the growth and the proliferation of normal colonic mucosa (Treem et al., 1994) while suppressing the growth of cancer cells (Clausen et al., 1991). Synbiotic products contain viable bacterial cultures that establish early in the gut while the prebiotic present in them serve as a source of nutrients for the probiotics in addition to dietary sources (Mohnl et al., 2007; Zhang et al., 2006). Probiotics and/or synbiotics could have positive effects on bacterial population in the gastrointestinal tract (Smirnov et al., 2005), and the addition of probiotic to diets has been found to improve growth performance (Jin et al., 1997; Wenk, 2000). Gut microflora changes actively by adding prebiotics and significantly reduces gut pH which improve rabbit's performance through influencing gut microbial population (Rahmani & Speer, 2005). Hooze (2004) reported that positive effects of mannan oligosaccharides on animal performance could be more visible during stressful, high temperature as that situation in Egypt, high density and weak management conditions. Prebiotics are potential alimentary supplements which reduce harmful effects of putrefactive factors and increases nutrition output (Fooks & Gibson, 2002). Also it has been reported that using prebiotics increases nutrient absorbance area via increasing gut length and thus improves bird performance (Santin et al., 2001). In the present study butyrate and synbiotic mixture used affected the productive performance of rabbits synergistically and revealed positive results on rabbit growth and zootechnical performance.

The obtained results of feed conversion reflect the efficient utilization of feed by the additives used. These results coincide with Tony et al. (2014), who concluded that coated and slowly released sodium butyrate (CM3000[®]) could significantly improve broiler performance and feed conversion. They mentioned that the oral administration of CM3000[®] enhances resistance to *Salmonella* Enteritidis challenge and markedly reduce *Salmonella* shedding. In the present study butyrate and synbiotic mixture used affected the productive performance of rabbits synergistically and revealed positive results on rabbit growth and zootechnical

performance.

The analyses of caecal contents revealed significant decrease in the pH in T1 and T3 compared with C group. This observation may be due to an increase in TVFA concentration reported in former groups. These short-chain carboxylic acids in the gastrointestinal tract of non-ruminants reflect the amount consumed and the rate of intraluminal production by anaerobic microorganisms from fermentable substrate (Smulikowska et al., 2009). These acids have a number of important regulatory functions related to gastrointestinal functionality, among others mucosal development, proliferation, differentiation, maturation and apoptosis of enterocytes and colonocytes (Mroz et al., 2006).

Propionic acid is a valuable substrate in glucose synthesis in many species (Bergman, 1990) as it contributes in gluconeogenesis and formation of long-chain fatty acids in the liver and its intermediate products change and participate in regulation of a series of processes, including ketogenesis, gluconeogenesis and ureogenesis (Remesy et al., 1995). Despite lower propionic acid molar proportion, the present study failed to demonstrate a decrease in serum glucose concentration in the experimental groups, but rather an increase in the glucose concentration was reported in T3 group which may be due to better digestibility and absorption of carbohydrates, secondary to the improvement in intestinal morphometry. Concerning butyrate, all experimental groups showed higher concentrations compared to C group with highest % recorded for T1 group. As butyrate is an essential precursor in lipogenesis (Remesy et al., 1995), serum triglycerides showed highest values in the former group (T1). Moreover, butyrate is recognized as the most effective source of energy for epithelial cells proliferation (Mroz et al., 2006), where sodium butyrate has been reported to be helpful in maintenance of intestinal villi structure after coccidial challenge (Leeson et al., 2005).

According to Macfarlane and Gibson (1995) a series of factors could influence NH₃-N concentrations within the caecum, including H₂ pressure, chyme reaction, and carbohydrates availability. In comparison with ruminants, proteolytic activity in the rabbit caecum is relatively higher (Gidenne, 1997). The lower recorded ammonia concentration in T1 and T3 group could be attributed to either increased nitrogen retention by enterocytes and colonocytes in these groups which may be connected with greater epithelial cell proliferation in gastrointestinal tract as suggested by Smulikowska et al. (2009) or better ammonia utilization in liver for protein production, this seems true since albumen concentrations were increased in T1 and T3 groups. The decreased in caecal pH, the decreased in ammonia-N concentration and the higher VFA concentration suggest high fermentation activity, caecal microbial synthesis, gut health and high nitrogen retention. This observation is consistent with the growth performance result discussed above, and is also in agreement with the results of Garcia et al. (2000).

Concerning serum total proteins all supplements did not alter serum values reflecting that the experimental animals were in a good nutritional status and liver has no pathological lesions (Abdl-Rahman et al., 2010).

The histomorphological changes in the intestine of growing rabbit reported in the present study provide new information regarding the potential for using synbiotics and probiotics in rabbit feed. Increasing the villus height suggests an increased surface area capable of greater absorption of available nutrients (Caspary, 1992). Feeding of probiotics has been shown to induce gut epithelial cell proliferation in rats (Ichikawa et al., 1999). The intestinal epithelial cells originating in the crypt migrate along the villus surface upward to the villus tip and are extruded into the intestinal lumen within 48 to 96 h (Imondi and Bird, 1966; Potten, 1998). A shortening of the villi may lead to poor nutrient absorption, increased secretion in the gastrointestinal tract, and lower performance (Xu et al., 2003). In contrast, increases in the villus height and villus height: crypt depth ratio are directly correlated with increased epithelial cell turnover (Fan et al., 1997). It is understood that greater villus height is an indicator that the function of intestinal villi is activated (Langhout et al., 1999; Shamoto & Yamauchi, 2000). This fact suggests that the villus function is activated after feeding of dietary probiotic and synbiotic.

In the present study, coated sodium butyrate supplementation was associated with increased intestinal morphological parameters compared with the control (Table 8 and Figure 1). Sodium butyrate has been reported to be helpful in maintenance of intestinal villi structure after coccidial challenge (Leeson et al., 2005). Moreover, Mroz et al. (2006) reported that butyrate is recognized as the most effective source of energy for epithelial cells proliferation. Per contrary, in pigs and chickens, the effect of sodium butyrate on small intestinal epithelium is often insignificant (Biagi et al., 2007; Hu & Guo, 2007).

5. Conclusion

Exogenous administration of coated, slow-release butyrate (CM3000[®]) combined with synbiotic (Poultry-Star[®]) is capable of improving zootechnical performance, enhancing intestinal health. Butyrate with synbiotic mixture may be used as alternatives for antibiotics in rabbit nutrition to improve growth performance that would be a valuable feeding strategy in developing countries.

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