Review Article

Butyric Acid as an Antibiotic Substitute for Broiler Chicken–A Review

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Abstract | In modern commercial broiler chicken production, the birds are inevitably exposed to various stress due to rapid growth, intensive poultry rearing, high stock density resulting in diminishing immune competence, gut health etc. This paves way to greater susceptibility of the birds to illness, infection and mortality. To overcome these losses, mostly antibiotics are being incorporated in feed. These antibiotics have possible lead to the emergence and dissemination of multiple antibiotic resistant pathogens and reduction in response to human and animal infections. The ban of antibiotic growth promoters in many countries necessitates to find an alternative to suppress microbial load particularly the gut. Probiotics, prebiotics or organic acids have being included to replace antibiotics. Of which, prebiotics are costlier affecting economics in poultry production, while probiotics have different degrees of survivability in feed and in the gut environment. Organic acids could be the possible choice as alternative to antibiotics. In poultry production, organic acids have not gained as much attention as in swine production (Langhout, 2000).Generally, short chain fatty acids (formic acid, acetic acid, butyric acid) are preferred acidifiers, among which, butyric acid (BA) is considered as the prime enterocyte energy source, necessary for development of Gut Associated Lymphoid Tissue (GALT) (Friedman and Bar-Shira, 2005) and has the highest bactericidal efficacy against the acid-intolerant species such as *Escherichia coli* and *Salmonella sp.* (Kwan and Ricke, 2005) with selective stimulation of beneficial gut bacteria.

Keywords | Broiler chicken, Antibiotic substitute, Organic acid, Butyric acid

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Butyric Acid and its Forms

Butyric acid (or butanoic acid or 1-Propanecarboxylic acid or Propanecarboxylic acid,) is a carboxylic acid containing four carbon atoms. BA is available as Na, K, Mg and Ca salts which can used as feed additive,. The advantage of salts over free acids is that, they are generally odour-less and easier to handle the feed manufacturing process owing to their solid and less volatile form. Sodium butyrate (SB) is the most commonly available form.BA has a pKa (4.81) that dissociates in crop.Hence, 90-99 % of the short chain fatty acids are present in the gastrointestinal tract as anions rather than free acids.However, the fat coated BA salts may overcome this problem as it is available even in the lower part of the small intestine (Ashan et al., 2016). Protection can be made either by esterification of BA with glyceride, known as Butyric Acid Glycerides (BAG), or by encapsulation of butyric acid or its salts. These encapsulated products are also referred to as coated butyric acid or coated salts. Of which, encapsulated salts reach the distal sections of gastrointestinal tract at higher concentration (Mallo et al., 2012).

Benefits of Butyric Acid

Antimicrobial effect

Inhibition of pathogenic bacteria by organic acids is by penetration (non-ionized) into lipophilic bacterial cell wall, dissociation at neutral cytosolic pH and releases anions and protons causing lethal accumulation of anions that affects purine bases (Choi et al., 2000), denatures essential enzymes (Roe et al., 2002) and results in bacterial

Table 1: Effect of various forms of butyric acid supplemented at different levels in broiler chicken diet on microbial count of intestinal digesta

Forms of butyric acid	Level of inclusion (%)	Site of intestine where digesta collected	Type of count studied (Result: Reduced (-), Not influenced (NI))	Reference
Butyric acid (BA)	0.156	Caecum	Salmonella (-)	Van Immerseel et al. (2004)
Sodium Butyrate(SB)	0.06	Caecum	*Salmonella*(NI)	Van Immerseel et al. (2005)
CSB (Coated sodium butyrate)	0.25	Caecum	Salmonella (-)	Van Immerseel et al. (2005)
CSB and UCSB (Uncoated sodium butyrate)	0.125 and 0.0315 respectively		Salmonella (-)	
SB	0.2	Jejunum	Escherichia coli (NI)	Hu and Guo (2007)
			Lactobacillus (-)	
UCSB	0.092	Crop	Salmonella (-)	Fernandez-Rubio et al. (2009)
		Caecum	Salmonella (-)	
CSB	0.092	Crop	Salmonella (-)	
		Caecum	Salmonella (-)	
BA	0.1 % + Essential oil	Caecum	Salmonella (-)	Cerisuelo et al. (2014)
Protected SB	0.07	Jejunum	*Escherichia coli* (NI)	Chamba et al. (2014)

cell death. The *in vitro* study of microbial count influenced due to organic acid is presented in Table 1. The different forms of butyric acid at various levels studied by several authors showed divergent results of body weight gain, feed intake and feed efficiency (Table 2).Table 3 shows that coated sodium butyrate (CSB), butyric acid glycerides (BAG) or butyric acid (BA) supplementation produces performance similar to antibiotic supplemented group indicating the ability to replace various feed antibiotics.

by supplementation of coated (0.09% and 0.18%) and uncoated sodium butyrate (0.03% and 0.06%), showed performance in terms of body weight gain, feed intake and FCR comparable to Oxytetracycline (50 ppm) supplemented group suggesting the capability to replace the antibiotic. Further, 0.18% coated sodium butyrate (CSB) reduced serum total cholesterol, LDL cholesterol and uric acid, increased serum sodium level, villi height, villi height to crypt depth ratio, villi height to villi width ratio of jejunum. In addition, both levels of CSB reduced duodenal pH, caecal *Escherichia coli* and *Clostridium perfringens* count determining that CSB can be a better antimicrobial agent than uncoated sodium butyrate.

Effect on PH of Intestinal Digesta

Supplementation of 0.6% BA reduces the pH of gastrointestinal segments such as crop, proventriculus, gizzard and duodenum (Panda et al., 2009), whereas, ileal pH was not altered by addition of 0.3 % BAG (Mahdavi and Torki, 2009) and 0.03% coated SB (Czerwinski et al., 2012) in broiler ration. Similar comparable caecal pH was also recorded when 0.03 % fat coated SB (Smulikowska et al., 2009) and 0.1 % SB together with essential oil (Cerisuelo et al., 2014) were used in broiler ration.

Effect on Immunity

During the process pathogenesis, an interaction occurs between bacteria and host cells, where, butyrate down regulates expression of invasion genes and decreases the virulence of bacteria. (Van Immerseel et al., 2004). In addition to that, butyrate produces mucin glycoproteins in the intestinal epithelium and increase the defence barrier of colon mucosa (Leonel and Alvarez-Leite, 2012).Butyrate increases serum globulin concentrations and lowers albumin to globulin ratio (Griminger, 1986).Studies showed that, BAG at 0.4 % in broiler ration increased serum total protein, albumin and globulin (Ali et al., 2014) in normal and *Eimeria maxima* challenged-birds.SB at 0.1 % in broiler ration had no influence of serum total protein in healthy birds but in *E.coli* LPS challenged birds BA prevented the elevation of the serum total protein (Zhang et al., 2011a).Unlike the above results, BAG supplementation at 0.3 (Mahdavi and Torki, 2009) and BA at 3.0 % (Kamal and Ragaa, 2014) did not influence serum total protein, but in the latter study, serum globulin level was significantly higher.

Effect on Serum Protein and Lipids

BAG at 0.4 per cent in broiler ration significantly increased serum total protein, albumin and globulin (Ali et al., 2014) in normal and *Eimeria maxima* challenged-birds while SB at 0.1 per cent in broiler ration had no influence of serum total protein in healthy birds but in *E.coli* LPS challenged birds BA prevented the elevation of the serum total protein (Zhang et al., 2011a). Unlike the above studies, BAG supplementation at 0.3 (Mahdavi and Torki, 2009) and BA at 3.0 per cent (Kamal and Ragaa, 2014) did not influence serum total protein, but in the latter study, serum globulin level was significantly higher.

Table 2: Performance of various forms of butyric acid supplementation at different levels in broiler diet when compared to unsupplemented group

Level of inclusion (%)	Body weight gain	Feed intake	Feed Efficiency	Reference
COATED SODIUM BUTYRATE				
0.1	NI	NI	Better(4.2)	Smulikowska etal.(2009)
0.15	+	NA	NA	Jerzsele et al. (2012)
0.15 + 0.15 % essential oil (ginger and carvacrol oils)				
0.03	- (1.1)	NI	NI	Czerwinski et al. (2012)
0.03 + 0.06 % salinomycin	+ (2.5)	-(1.9)	NI	
0.07	+ (5.7)	NI	Better (3.8)	Chamba et al. (2014)
0.1 in starter phase	- (7.8)	NA	NI	El-Ghany et al. (2016)
0.05 in grower phase	- (3.9)	+(6.2)	Poor (9.4)	
0.025 in finisher	+ (0.7)	NI	Poor (3.3)	
BUTYRIC ACID GLYCERIDES				
0.2	NI	NI	NI	Leeson et al. (2005)
0.2	+ (3.13)	NI	NI	Antongiovanni et al. (2007)
0.35	NI			
0.5 and 1.0	NI			
0.3 in starter and 0.2 in grower phase	+ (7.41)	-(10.98)	Better (17.5)	Taherpour et al. (2009)
0.3	NI	NI	NI	Mahdavi and Torki (2009)
0.2	- (9.11)	- (10.74)	Better (2.65)	Mansoub (2011a)
0.2	+ (9.9)	- (7.2)	Better (19.1)	Mansoub (2011b)
0.2	NI	NI	NI	Jang (2011)
0.3 in 1st week and 0.2 up to 25 days				Sayrafi et al. (2011)
0.3				Irani et al. (2011)
0.4	+ (15.14)	- (6.31)	Better (20.7)	Ali et al. (2014)
COATED BUTYRIC ACID				
0.09 in starter and 0.045 in grower -finisher phase	+ (8.05)	+ (6.73)	NI	Edmonds et al. (2014)
(0.05 in starter and 0.025 in grower -finisher phase) + Humic acid	NI	NI	NI	
0.05	+ (2.00)	NI	Better (1.9)	Levy et al. (2015)
UNCOATED SODIUM BUTYRATE				
0.2	NI	NI	NI	Hu and Guo (2007)
0.1	NI	NI	NI	Zhang et al. (2011a)
0.2	NI	+ (1.18)	NI	Shahir et al. (2013)
0.1 UCSB + Essential oil (Cinnamaldehyde and thymol)	NI	NI	NI	Cerisuelo et al. (2014)
BUTYRIC ACID				
0.6	+ (3.31)	NI	Better (4.8)	Panda et al. (2009)
3.0	+ (8.47)		Better (8.4)	Adil et al. (2010)
0.5	NI	NI	NI	Rahmatian et al. (2010)
0.25				Aghazadeh and Yazdi (2012)

3.0	+ (8.55)	NI	Better (8.84)	Kamal and Ragaa (2014)
0.3	+ (8.19)	NA	Better (11.5)	Lakshmi and Sunder (2015)
0.25 (starter & grower phase)	NI	NI	NI	Dehghani-Tafti and Jahanian (2016)
0.25 (finisher phase)	+ (5.29)	+ (2.32)	Better (3.0)	

Values in parenthesis for body weight gain, feed intake and feed efficiency indicateper cent increase (+) or decrease (-); Not influenced (NI); Not applicable (NA)

Table 3: Performance of various forms of butyric acid supplemented at different levels in broiler diet when compared to antibiotic supplemented group

Level of inclusion	Antibiotics	Body weight gain	Feed intake	FCR	Reference
CSB (Coated sodium butyrate) 0.03 %	Salinomycin (60 ppm)	NI	- (6.31)	NI	Czerwinski et al. (2012)
CSB - 0.07 %	Colistin	+ (2.63)	NI	Better (1.70)	Chamba et al.(2014)
Butyric acid glycerides (BAG) 0.4 %	Virginiamycin (11 ppm)	NI	NI	NI	Leeson et al.(2005)
BAG -0.2 %	Bacitracin methylene disalicyate (50 ppm)				
BAG -0.3 %	Salinomycin (50 %)	NI	NI	NI	Irani et al.(2011)
0.3 % in first week and 0.2 % up to 25 days of age (BAG)	Bacitracin methylene disalicyate (50 ppm in grower and 25 ppm in finisher phase)				Sayrafi et al. (2011)
Butyric acid (BA) - 0.6 %	Furazolidone (0.05 %)	NI	NI	NI	Panda et al.(2009)
BA-0.5 %	Salinomycin (0.5 %)	NI	NI	NI	Rahmatian et al. (2010)
BA- 0.3 %	Virginiamycin (11 ppm)	+ (6.55)	-	Poor (7.6)	Lakshmi and Sunder (2015)

It is well known that acidifiers improve gut health by promoting the growth of beneficial bacteria while inhibiting the pathogenic bacteria. Beneficial bacteria like *Lactobacillus sp.* havehigh bile salt hydrolytic activity which is responsible for deconjugation of bile salts (Sarono, 2003). Deconjugated bile acids are less soluble, hence less absorbed in the intestine and are more likely to excrete cholesterol and its fractionin faeces (Klaver and Van der meer, 1993) thus reduction of cholesterol accretion in the body. Previous work done by Taherpour et al. (2009), Jang (2011), Mansoub (2011a), Kamal and Ragaa (2014) and Deepa et al. (2017) showed reduced levels of serum total and LDL cholesterol without affecting HDL cholesterol level due to addition of various forms of BA. Similarly, serum triglyceride level was also found to be reduced when BAG was supplemented in broiler ration at 0.2 (Jang, 2011; Mansoub, 2011a) and BA at 0.25 % (Dehghani-Tafti and Jahanian, 2016). Addition of 0.6 (Panda et al., 2009), 0.3 % BA (Lakshmi and Sunder, 2015) in broiler chicken reduced the abdominal fat. While, it was not influenced by inclusion of 0.04 % microencapsulated SB (Zhang et al., 2011b), 0.3 % protected BA (Mahdavi and Torki, 2009), 0.25 (Aghazadeh and Yazdi, 2012) and 0.2 % BAG (Jang, 2011).

Effect on Mineral Absorption

In general, acidification of feed increases calcium absorption in intestine by decreasing the pH of digesta, in turn inhibiting phytic acid from formation of calcium-phytate complex (Boling et al., 2000; Rafacz-Livingston et al., 2005). Butyrate induces absorption of water and sodium (Friedel and Levine, 1992). Earlier works with BAG supplemented at 0.3 (Mahdavi and Torki, 2009) and BA at 3.0 % (Adil et al., 2010; Kamal and Ragaa, 2014) in broiler ration increased serum calcium level. The latter authors also documented increased serum phosphorus (Adil et al., 2010; Kamal and Ragaa, 2014) and magnesium levels (Kamal and Ragaa, 2014).

Anticatabolic Effect

Elevated levels of serum ALT and AST indicates the deleterious effects of liver functions. BA supplementation at 3.0 % (Kamal and Ragaa, 2014; Adil et al., 2010) did not influence the serum Alanine Transaminase (ALT) and Aspartate Transaminase (AST) levels in broilers. In *Eimeria maxima* challenged-birds, inclusion of BAG at 0.4 % prevented the elevation of serum ALT and AST levels as found in positive control indicating that butyric acid, at times, have the protective effect over hepatocytes (Ali et al., 2014).

Antioxidant Effect

Dietary inclusion of various forms of butyric acid increases serum superoxide dismutase(SOD) activity and decrease malanoldehyde (MDA) content suggesting enhanced the capacity of scavenging free radicals and decreased damage of tissues or cells. Catalase is one of the key defence systems against oxidative stress which is also found to be elevated due to inclusion of various forms of butyric acid. In a study by Zhang et al. (2011a), at day 21, broiler birds supplemented with SB up to 0.1 % elevated serum SOD and catalase, while reduced serum MDA levels. Similarly, supplementation of 0.04 % microencapsulated SB inhibited stress due to corticosterone injection by enhanced catalase activity and decreased MDA level in breast muscle of broiler birds (Zhang et al., 2011b).

Effect on Intestinal Integrity

Frankiel et al. (1994) have shown that short chain fatty acid mixture infusions into the rat isolated caecum caused trophic effects in the jejunum mucosa. Further, an increase in the villus height and villus height to crypt depth ratio are directly correlated with increased epithelial cell turnover (Fan et al., 1997) and an indicator of activated intestinal villi function (Langhout et al., 1999; Shamoto and Yamauchi, 2000) and it also stimulates intestinal blood flow. In addition, butyrate of stimulates cell growth and differentiation of normal cells and apoptosis (early cell death) of tumour cells which represents'butyrate paradox' (Canani et al., 2011).Previous studies showed increased jejunum villi height (Adil et al., 2010; Jerzsele et al., 2012; Chamba et al., 2014), villi height to crypt depth ratio (Hu and Guo, 2007; Shahir et al., 2013) and comparable crypt depth (Hu and Guo, 2007; Adil et al., 2010; Smulikowska et al., 2009; Chamba et al., 2014; Sayrafi et al., 2011; Antongiovanni et al., 2007) by supplementation of different forms of butyric acid.

Table 4: Effect of butyric acid oncarcass characteristics in broilers

Inclusion of Butyric acid (%)	Parameter influenced	Increase (+) or Decrease (-)	Reference
0.25	Dressed carcass weight	+	Aghazadeh and Yazdi (2012), Dehghani-Tafti and Jahanian (2016)
0.6		+	Panda et al.(2009)
3.0		+	Adil et al.(2010)
0.3	Breast meat	+	Lakshmi and Sunder (2015)
0.25	Liver weight	+	Aghazadeh and Yazdi (2012)

It is clear from the Table 4 that inclusion of BA in broiler diet improves the weight of carcass indicating anabolic effect in broiler chicken.

CONCLUSION

Butyric acid is thus known to have antimicrobial, anticatabolic and antioxidant effect together improving the lipid metabolism, mineral absorption and immune status of birds. It is also known to improve the carcass characteristics and overall performance of broiler birds. Among various sources of butyric acid, coated form of butyric acid overcomes the odour problems and produces desired outcome by enabling the butyric acid to reach entire gastrointestinal tract effectively.

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CONFLICT OF INTEREST

We don't have any conflict of interest

AUTHORS CONTRIBUTION

All authors contributed equally.

REFERENCES

- Abdel -Fattah SA, MH El -Sanhoury, NM El -Mednay, F Abdel -Azeem (2008). Thyroid activity, some blood constituents, organs morphology and performance of broiler chicks fed supplemental organic acids. Int. J. Poult. Sci. 7(13) : 215 – 222.
- Adil S, T Banday, GA Bhat, MS Mir, M Rehman (2010). Effect of dietary supplementation of organic acids on performance, intestinal histomorphology, and serum biochemistry of broiler chicken. Vet. Med. Int. 1-7. https://doi.org/10.4061/2010/479485
- Aghazadeh AM, MT Yazdi (2012). Effect of butyric acid supplementation and whole wheat inclusion on the performance and carcass traits of broilers. S. Afr. J. Anim. Sci. 42(3) : 241-248. https://doi.org/10.4314/sajas.v42i3.5
- Ali AM, SA Seddiek, HF Khater (2014). Effect of butyrate, clopidol and their combination on the performance of broilers infected with Eimeria maxima. Br. Poult. Sci. 55 (4) : 474-482. https://doi.org/10.1080/00071668.2014.920488
- Antongiovanni M, A Buccioni, F Petacchi, S Leeson, S Minieri, A Martini, R Cecchi (2007). Butyric acid glycerides in the diet of broiler chickens:effects on gut histology and carcass composition. Ital. J. Anim. Sci. 6(1) : 19-25. https://doi.org/10.4081/ijas.2007.19
- Ashan U, O Cengiz, I Raza, E Kuter, MFA Chacher, Z Iqbal, S Umar, S Cakir (2016). Sodium butyrate in chicken nutrition: the dynamics of performance, gut microbiota, gut morphology and immunity. Worlds Poult. Sci. J. 72(2) : 265 -275. https://doi.org/10.1017/S0043933916000210
- Boling SD, DM Webel, I Mavromichalis, CM Parsons, DH Baker (2000). The effect of citric acid on phytate phosphorus utilization in young chicks and pigs. J. Anim. Sci. 78(3): 682-689. https://doi.org/10.2527/2000.783682x

- Canani RB, M Di Costanzo, L Leone, M Pedata, R Meli, en A Calignano (2011). Potential beneficial effects of butyrate in intestinal and extraintestinal diseases. World J. Gastroenterol. march 28; 17 (12): 1519-1528.
- Cerisuelo A, C Marin, F Sanchez-Vizcaino, EA Gomez, JM de la Fuente, R Duran, C Fernandez (2014). The impact of a specific blend of essential oil components and sodium butyrate in feed on growth performance andSalmonella counts in experimentally challenged broilers. Poult. Sci. 93(3): 599-606. https://doi.org/10.3382/ps.2013-03528
- Chamba F, M Puyalto, A Ortiz, H Torrealba, JJ Mallo, R Riboty (2014). Effect of partially protected sodium butyrate on performance, digestive organs, intestinal villi and E. coli development in broilers chickens. Int. J. Poult. Sci. 13(7): 390-396. https://doi.org/10.3923/ijps.2014.390.396
- Choi SH, DJ Baumler, CW Kaspar (2000). Contribution of dps to acid stress tolerance and oxidative stress tolerance in Escherichia coli O157:H7. Appl. Environ. Microbiol. 66(9): 3911-3916. https://doi.org/10.1128/AEM.66.9.3911-3916.2000
- Czerwiński J, O Hojberg, S Smulikowska, RM Engberg, A Mieczkowska (2012). Effects of sodium butyrate and salinomycin upon intestinal microbiota, mucosal morphology and performance of broiler chickens. Arch. Anim. Nutr. 66(2): 102-116. https://doi.org/10.1080/1745039X.2012.663668
- Deepa K, Purushothaman MR, Vasanthakumar P, Sivakumar K (2017). Serum Biochemical Parameters and Meat Quality Influenced Due to Supplementation of Sodium Butyrate in Broiler Chicken. Int. J. Livestock Res. 7(8): 108-116.
- Dehghani-Tafti N, R Jahanian (2016). Effect of supplemental organic acids on performance, carcass characteristics, and serum biochemical metabolites in broilers fed diets containing different crude protein levels. Anim. Feed Sci. Tech. 211 : 109–116. https://doi.org/10.1016/j.anifeedsci.2015.09.019
- Edmonds MS, S Johal, S Moreland (2014). Effect of supplemental humic and butyric acid on performance and mortality in broilers raised under various environmental conditions. J. Appl. Poult. Res. 23 : 1-8. https://doi.org/10.3382/japr.2013-00901
- El-Ghany WAA, MH Awaad, SA Nasef, AH Gaber (2016). Effect of Sodium butyrate on Salmonella enteritidis infection in broiler chickens. AJPS. 10(2) : 104-110. https://doi.org/10.3923/ajpsaj.2016.104.110
- Fan YK, J Croom, VL Christensen, BL Black, AR Bird, LR Daniel, BW Mcbride, EJ Eisen (1997). Jejunal glucose uptake and oxygen consumption in turkey poults selected for rapid growth. Poult. Sci. 76(12) : 1738-1745. https://doi.org/10.1093/ps/76.12.1738
- Fernandez-Rubio C, C Ordonez, J Abad-Gonzalez, A Garcia-Gallego, M P Honrubia, JJ Mallo, R Balana-Fouce (2009). Butyric acid-based feed additives help protect broiler chickens from Salmonella Enteritidis infection. Poult. Sci. 88(5) : 943-948. https://doi.org/10.3382/ps.2008-00484
- Frankiel WL, W Zhang, A Singh, DM Klurfeld, S Don, T Sakata, I Modlin, JL Rombeau (1994). Mediation of the trophic effects of short-chain fatty acids on the rat jejunum and colon. Gastroenterology. 106(2) : 375-380. https://doi.org/10.1016/0016-5085(94)90595-9
- Friedel D, GM Levine (1992). Effect of short-chain fatty acid on colonic function and structure. J. Parent. Enter. Nutr. 16(1) : 1-4. https://doi.org/10.1177/014860719201600101
- Friedman A, E Bar-Shira (2005). Effect of nutrition on development of immune competence in chickens gut associated lymphoid system. WPSA, Proc. 15thEur. Symp. Poult. Nutr. 247-255.
- Galfi P, S Neogradi, T Sakata (1991). Effects of volatile fatty acids on the epithelial cell proliferation of digestive tract and its hormonal mediation. Physiological aspects of digestion and metabolism in ruminants, Academic Press, Orlando, Florida, 49-59. https://doi.org/10.1016/B978-0-12-702290-1.50010-2
- Griminger P (1986). Lipid Metabolism, in: Sturkie, P.D. (Ed) Avian Physiology. 4th Edn. (New Work, Springer-Verlag, Inc. 345-358. https://doi.org/10.1007/978-1-4612-4862-0_15
- Hu Z, Y Guo (2007). Effects of dietary sodium butyrate supplementation on the intestinal morphological structure, absorptive function and gut flora in chickens. Anim. Feed Sci. Technol. 132(3-4) : 240–249. https://doi.org/10.1016/j.anifeedsci.2006.03.017
- Irani M, S Gharahveysi, M Zamani, R Rahmatian (2011). The effect of butyric acid glycerides on performance and some bone parameters of broiler chickens. Afr. J. Biotechnol. 10(59) : 12812-12818.
- Jang JP (2011). Comparative effect of Achillea and butyric acid on performance, carcass traits and serum composition of broiler chickens. Ann. Biol. Res. 2(6) : 469-473.
- Jerzsele A, K Szeker, R Csizinszky, E Gere, C Jakab, JJ Mallo, P Galfi (2012). Efficacy of protected sodium butyrate, a protected blend of essential oils, their combination, and Bacillus amyloliquefaciens spore suspensionagainst artificially induced necrotic enteritis in broilers. Poult. Sci. 91(4) : 837–843. https://doi.org/10.3382/ps.2011-01853
- Kabir Lutful SM (2009). The Role of Probiotics in the Poultry Industry. Int. J. Mol. Sci. 10(8) : 3531-3546. https://doi.org/10.3390/ijms10083531
- Kamal AM, NM Ragaa (2014). Effect of dietary supplementation of organic acids on performance and serum biochemistry of broiler chicken. Natur. Sci. 12(2) : 38-45.
- Klaver FA, R Van der Meer (1993). The assumed assimilation of cholesterol by *Lactobacillus* and *Bifidobacterium bifidum* is due to their bile salt deconjugating activity. Appl. Enviro. Microbiol.59(4) : 1120-1124.
- Kwan YM, Ricke SC (2005). Induction of acid resistance of Salmonella typhimurium by exposure to short chain fatty acids. Appl. Environ. Microbiol. 64(9) : 3458 – 3463.
- Lakshmi KV, GS Sunder (2015). Supplementation of Propionic Acid (PA), Butyric Acid (BA) or Antibiotic (AB) in diets and their influence on broiler performance, carcass parameters and immune response. IJSR. 4(3) : 1002-1006.
- Langhout DJ, JB Schutte, LP Van, J Wiebenga, S Tamminga (1999). Effect of dietary high and low methylated citrus pectin on the activity of the ileal microflora and morphology of the small intestinal wall of broiler chickens.Br. Poult. Sci. 40(3) : 340-347. https://doi.org/10.1080/00071669987421
- Langhout P (2000). New additives for broiler chickens. World poultry- Elsevier. 16(3) : 22-27.
- Leeson S, H Namkung, M Antongiovanni, EH Lee (2005). Effect of butyric acid on the performance and carcass yield of broiler chickens. Poult. Sci. 84(9) : 1418–1422. https://doi.org/10.1093/ps/84.9.1418
- Leonel AJ, en JI Alvarez-Leite (2012). Butyrate: implications for intestinal function." Curr. Opin. Clin. Nutr. Metab. Care. 15: 474-479. https://doi.org/10.1097/MCO.0b013e32835665fa
- Levy AW, JW Kessler, L Fuller, S Williams, GF Mathis, B Lumpkins, F Valdez (2015). Effect of feeding an encapsulated

source of butyric acid (ButiPEARL) on the performance of male Cobb broilers reared to 42 d of age. Poult. Sci. 94(8) : 1864-1870. https://doi.org/10.3382/ps/pev130

- Mahdavi R, M Torki (2009). Study on usage period of dietary protected butyric acid on performance, carcass characteristics, serum metabolite levels and humoral immune response of broiler chickens. J. Anim. Vet. Adv. 8(9) : 1702-1709.
- Mallo JJ, M Puyalto, SV Rama Rao (2012). Evaluation of the effect of sodium butyrate addition of broiler diet on energy and protein digestibility productive parameters and size of intestinal villi of animals. Feed Livestock. 8 : 26-30.
- Mansoub NH (2011a). Comparitive effect of butyric acid, probiotic and garlic on performance and serum composition of broiler chickens. American-Eurasian J. Agric. Environ. Sci. 11(4) : 507-511.
- Panda AK, SV Rama Rao, MV LN Raju, G Shyam Sunder (2009). Effect of butyric acid on performance, gastrointestinal tract health and carcasscharacteristics in broiler chickens. Asian-Aust. J. Anim. Sci. 22(7) : 1026 – 1031.
- Rafacz-Livingston KA, CM Parsons, RA Jungk (2005). The effects of various organic acids on phytate phosphorus utilization in chicks. Poult. Sci. 84 : 1356-1362. https://doi.org/10.1093/ps/84.9.1356
- Rahmatian R, M Irani, MG Jouybari, VR Pour, Z Rahmani (2010). Investigation of oocyst count and performance affected by butyric acid and salinomycine in broiler. J. Cell Anim. Biol. 4(7) : 103-107.
- Roe AJ, C O'Byrne, D Mclaggan, IR Booth (2002). Inhibition of Escherichia coli growth by acetic acid: a problem with methionine biosynthesis and homocysteine toxicity. Microbiol. 148(pt 7) : 2215-2222. https://doi.org/10.1099/00221287-148-7-2215
- Sarono S (2003). In vitro probiotic properties of indigenous dadih lactic acid bacteria.Asian- Australian J. Ani. Sci. 16(5) : 726-731.
- Sayrafi R, F Soltanalinejad, R Shahrooz, S Rahimi (2011). Effects of butyric acid glycerides and antibiotic growth promoter on the performance and intestinal histomorphometry of broiler chickens. JFAE. 9(3&4) : 285-288.
- Shahir MH, S Moradi, O Afsarian, O Esmaelipour (2013). Effects of cereal type, enzyme and sodium butyrate addition on growth performance, carcass traits and intestinal morphology of broilers. Braz. J. Poult. Sci. 15(3) : 169-286. https://doi.org/10.1590/S1516-635X2013000300003
- Shamoto K, Yamauchi K (2000). Recovery responses of chick intestinal villus morphology to different refeeding procedures. Poult. Sci. 79 : 718-723. https://doi.org/10.1093/ps/79.5.718
- Smulikowska S, J Czerwiński, A Mieczkowska, J Jankowiak (2009). The effect of fat-coated organic acid salts and a feed enzyme on growth performance, nutrientutilization, microflora activity, and morphology of the small intestine in broiler chickens. J. Anim. Feed Sci. 18 : 478–489. https://doi.org/10.22358/jafs/66422/2009
- Taherpour K, H Moravej, M Shivazad, M Adibmoradi, B Yakhchali (2009). Effects of dietary probiotic, prebiotic and butyric acid glycerides on performance and serum composition in broiler chickens. Afr. J. Biotechnol. 8(10) : 2329-2334.
- Van Immerseel F, V Fievez, J de Buck F, Pasmans A, Martel F, Haesebrouck, R Ducatelle (2004). Microencapsulated short-chain fatty acids in feed modify colonization and invasion early after infection with Salmonella enteritidis in young chickens. Poult. Sci. 83 : 69–74. https://doi.org/10.1093/ps/83.1.69
- Van Immerseel F, J De Buck, I De Smet, F Pasmans, F Haesebrouck, en R Ducatelle (2004). Interactions of butyric acid and acetic acid treated salmonella with chicken primary cecal epithelial cells in vitro. Avian Dis. 48: 384-391. https://doi.org/10.1637/7094
- Van Immerseel F, F Boyen, I Gantois, L Timbermont, L Bohez, F Pasmans, F Haesebrouck, R Ducatelle (2005). Supplementation of coated butyric acid in the feed reduces colonization and shedding of Salmonella in poultry. Poult. Sci. 84(12) : 1851–1856. https://doi.org/10.1093/ps/84.12.1851
- Zhang WH, Y Jiang, QF Zhu, F Gao, SF Dai, J Chen,GH Zhou (2011a). Sodium butyrate maintains growth performance by regulating the immune response in broiler chickens. Br. Poult. Sci. 52(3) : 292-301. https://doi.org/10.1080/00071668.2011.578121
- Zhang WH, F Gao, QF Zhu, C Li Y Jiang, SF Dai, GH Zhou (2011b). Dietary sodium butyrate alleviates the oxidative stress induced by corticosterone exposure and improves meat quality in broiler chickens. Poult. Sci. 90(11) : 2592–2599. https://doi.org/10.3382/ps.2011-01446