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Research Article

Sodium Formate, Acetate, and Propionate as Effective Feed Additives in Broiler Diets to Enhance Productive Performance, Blood Biochemical, Immunological Status and Gut Integrity

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Abstract | This study focused on the impact of sodium formate, acetate, and propionate as feed additives on broiler chicken performance, carcass characteristics, blood biochemical parameters, immunological condition, and gastrointestinal health. Total of 240 male Arbor Acres broiler chicks were randomly divided into four groups, each with six replicates of 10 chicks. Group I fed diet consisted of a basic diet with no additives (control). Groups II, III, and IV fed diets consisted of a control diet supplemented with 1.5g sodium formate/Kg (SF), 1.5g sodium acetate/Kg (SA), and 1.5g sodium propionate/Kg (SP), respectively. When compared to the control, the addition of organic acid salts (OAS's) significantly (*P<0.05*) enhanced weight gain and feed efficiency. Dietary supplementation with OAS's enhanced significantly (P<0.01) the weight of carcass and dressing percentages of birds. The liver, heart, gizzard, and spleen were unchanged (% of body weight). Birds fed diets enriched with SF or SP had considerably (*P<0.05*) longer and wider guts than the control group, and scored zero in intestinal lesions scale. The addition of SF or SP were significantly enhanced (*P<0.05*) the *lactobacillus* count when compared to the control, while the quantity of *Clostridium perfringens* intestinal colonization was not exist. When OAS's were introduced to broiler diets, total protein, globulin, albumin/globulin, T3, T4, and total antioxidant capacity levels were dramatically increased, while alanine aminotransferase (ALT), aspartate aminotransferase (AST), and urea levels remained not affected. Adding SF, SA, or SP to broiler diets significantly improved immunological state (*P<0.05*) via enhancing avian influenza (H5) and Newcastle disease (ND) titers. Accordingly, OAS's as natural feed additives could improve broiler performance and immunological state. Chicks fed SF or SP had the best productive performance, immunological status, digestive parameters, and microbiota.

Keywords | Blood parameters, Broiler chicks, Gut health, Immune status, Organic acids salts, Productive performance

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INTRODUCTION

Adding feed additives to a chicken's diet is critical to its development and productivity (Abd-Elsamee et al., 2012; Hassan et al., 2016, 2018; Mohamed et al., 2016; Elsherif et al., 2021). Antibiotic as promoters for growth in feeding of animal and poultry have been used for many years to boost health and productivity (Huyghebaert et al., 2011). For a long time, antibiotics have been utilized as growth promoters, resulting in an increase in disease and bacterial resistance, as well as significant health risks (Qiao et al., 2018). As a result, in 2006, the EU outlawed the use of antibiotic growth promoters in chicken feed. Antibiotics are no longer utilized as growth enhancers in chicken feed, prompting a wider search for new solutions (Elsherif et al., 2021). Many of natural feed additives such as organic acids and their salts, extracts and metabolites of plants used as scavenge free radicals, antibacterial, antifungal, and growth enhancers in poultry nutrition (Ragaa and Korany, 2016; Elsherif et al., 2021). Organic acids are safe and therefore recommended for use as an alternative to antibiotics in poultry nutrition (Baaboua et al., 2018). Organic acids should now be used in broilers as a safe alternative to anti-biotics to boost immunity, antibacterial and growth promoter (Khan et al., 2022). Salts of organic acids are easily used and mixed well in feed, this is due to its properties not liquid or volatile and odorless (Huyghebaert et al., 2011). Furthermore, organic acids can be utilized to reduced intestinal pathogenic bacteria (Wolfenden et al., 2007). Christian and Mellor (2011) found that using potassium di-formate and sodium di-formate in animal diet significantly increased nutritive value. Furthermore, Tohru et al. (2011) concluded that adding 1% potassium di-formate to broiler feed increased significantly (*P<0.05*) body weight. Increases in broiler body weight, feed efficiency, and gut health were achieved by adding 0.5 % sodium butyrate or 1.0 % calcium propionate to their diets (Akbar et al., 2017). Sodium acetate (4g/Kg) added to broilers feed resulted in greater weight gain than that of control (Agboola et al., 2018). Organic acids and salts have been used in poultry feed to improve intestinal health, immunological condition, nutritional digestibility, and productivity (Yadav and Jha, 2019; Wu et al., 2020; Gao et al., 2021). Therefore, the purpose of this research was to see how sodium formate, sodium acetate, and sodium propionate affected productive performance, carcass traits, immunological condition, blood parameters, and intestinal microbiota in broiler chicks.

MATERIALS AND METHODS

Diets, housing, and management of birds

The farm experiment was done at Cairo University's Faculty of Agriculture's Poultry Nutrition Research Unit in Giza, Egypt. In three-layer batteries, 240 male Arbor acres broiler chicks weighing average 41 g at one day of age were randomly divided into four groups, each with six replicates of 10 chicks. Chicks were reared in a warm housing for the starter stage (1-14 days), then gradually lowered the temperature to fulfil the needs of the grower (14-28 days) and finisher (28-35 days). During the experiment, the light was on for 23 hours a day. Feed and water were continuous available. Avian influenza and New Castle vaccine protocols as well as Infectious Bronchitis (IB) and infectious bursal disease (IBD) immunization protocols were strictly adhered to throughout the trial. Four different experimental diets were established. Diet one consisted of a basal diet with no additives (control). Diets 2, 3, and 4 consisted of a basal diet supplemented with 1.5g sodium formate/Kg (SF), 1.5g sodium acetate/Kg (SA), and 1.5g sodium propionate/Kg (SP), respectively. Using the Arbor Acres guide, Table 1 depicts the formulation and nutrient composition of the diets.

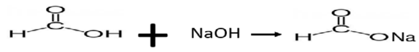
Table 1: Starter, grower, and finisher diet formulation and nutrient composition.

Ingredients %	Starter (1-14 days)	Grower (14-28 days)	Finisher (28-35 days)
Yellow maize	55.50	58.70	62.81
Soybean meal (44%)	34.00	30.00	25.85
Corn gluten meal (60%)	4.60	4.41	4.50
Soybean oil	1.50	2.81	3.00
Monocalcium phosphate	1.00	0.90	0.86
Limestone	1.80	1.58	1.45
Vitamin & Mineral mix(1)	0.30	0.30	0.30
Nacl	0.30	0.30	0.30
L-lysine HCl	0.30	0.33	0.33
DL-methionine	0.25	0.25	0.20
Threonine	0.16	0.13	0.11
$NaHCO_3$	0.17	0.17	0.17
Choline chloride	0.10	0.1	0.1
Phytase	0.01	0.01	0.01
Energy enzymes	0.01	0.01	0.01
Total	100	100	100
Calculated composition (2)			
Crude protein %	23.02	21.47	20.01
ME (Kcal/Kg)	2949	3076	3138
Ether extract%	3.99	5.38	5.71
Crude fiber%	3.66	3.45	3.25
Lysine %	1.34	1.26	1.16
Methionine %	0.64	0.61	0.54
Methionine + Cystine %	1.01	0.97	0.87
Threonine %	0.97	0.88	0.81
Calcium %	0.98	1.00	0.81
Nonphytate P %	0.38	0.35	0.33
Sodium%	0.18	0.18	0.18
Chlorine%	0.22	0.22	0.22

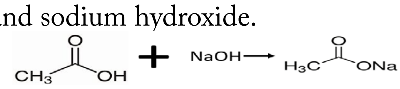
(1) Vitamin and mineral mix supplied/ Kg of diet: Vit D_3, 2200 IU; Vit A, 12000 IU; Vit K_3, 2 mg; Vit E, 10 mg; Vit B_1, 1mg; Niacin, 20 mg; Vit B_2, 4mg; Vit B_{12}, 10µg; Vit B_6, 1.5mg; Folic acid, 1 mg; Pantothenic acid, 10 mg; Choline chloride, 500 mg; I, 1mg; Biotin, 50 µg; Fe, 30 mg; Cu, 10 mg; Mn, 55 mg; Se, 0.1 mg and Zn, 50 mg. (2) According to NRC 1994.

Preparation of salts of organic acids

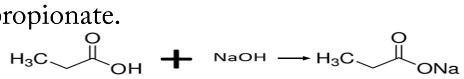
Formic acid and sodium hydroxide were used to make sodium formate.



Sodium acetate was synthesized by the reaction between acetic acid and sodium hydroxide.



Propionic acid and sodium hydroxide reacted to form sodium propionate.



Make sure the sodium hydroxide is completely dissolved by vigorously stirring it. Then stoichiometric moles of acids were added to start the reaction and stirring was continued for one hour, after reaching the neutralization of each solution, crystallization was done (Ouellette and Rawn, 2018).

Growth performance parameters

To determine feed conversion ratio (FCR) and weight gain (WG), the birds were weighed and feed consumption were recorded per replicate three times: at 14 days, 28 days and 35 days of age (Abd-Elsamee et al., 2012; Hassan et al., 2016; Mohamed et al., 2016; Elsherif at al., 2021). The carcass characteristics determined as following; each treatment included five birds of a similar weight taken at 35 days of age for carcass characteristics and intestinal measures to be analyzed. Before slaughter and feather removal, a percentage of a bird's live body weight was recorded for the carcass weight, liver, heart, spleen and gizzard.

Gut integrity analysis

At 35 days of age, five birds from each group were inspected to assess the length and diameter of their small intestines (in the middle of the ileum) (Dahiya et al., 2005; Elsherif et al., 2021).

While for determination the lesion score appearance: Five birds from each group had their small intestines opened and graded from zero to four. There are no lesions in the serosa and mesentery when the score is 0, but there are numerous serosal and mesentery swellings when the score is 0.5. A thin-walled and friable intestine with few red petechial when the score is 1, The presence of a necrotic area in the score of 2, necrotic spots on the skin (1 to 2 cm long) when the score is 3, and Four is necrosis that is common in field cases (Dahiya et al., 2005; Elsherif et al., 2021).

For count of *lactobacillus* spp., Fresh digesta (1 g) was taken from the caecum and diluted in 9 mL of MRS broth. Micro aerobic incubation at 39°C for 48 hours resulted in the plating of three diluted samples on Oxoid MRS agar (CM0361) (Dahiya et al., 2005; Elsherif et al., 2021). While the count of *Clostridium perfringens* screened through, around 0.2 g of intestinal fresh digesta was applied to sheep blood agar plates and TSC (supplemented with D-cycloserine) agar (emulsified with egg yolk) with each dilution being serially diluted in sterile PBS to 1:100, 1:1000, and 1:10000. TSC agar or big dome-shaped colonies on blood agar plates with a twofold zone of hemolysis were counted as colony-forming units (CFUs) per g after 24 hours of anaerobic incubation at 37°C (Carrido et al., 2004; Elsherif et al., 2021).

Blood biochemical parameters

Five birds from each treatment had blood samples taken at 35 days of age during slaughter. A centrifuge at 1000 g for 10 minutes was used to separate the blood serum samples, which were then stored at -20°C until chemical analysis. Analysis of each individual serum sample for total protein (g/dL), albumin (g/dL) and from them calculated globulin (g/dl), urea (mol/L), aspartate aminotransferase (AST) (U/L), alanine aminotransferase (ALT)(U/L) and total antioxidant capacity (TAC) using biodiagnostic commercial kites. Commercial ELISA kits were used to quantify total T3 and T4 levels in the blood (My Bio Source, Inc., San Diego, CA). By dividing the T3 value by the T4 value, the T4/T3 ratio was determined.

Immune status assessment

At 35 days of age, serum from the five birds from each treatment used to investigate the impact on immunity. Blood serum samples were tested for antibody titers against ND and H5 vaccinations using haemagglutinating (HA) units in a haemagglutination inhibition (HI) test. The log of the reciprocal of the greatest haemagglutination dilution was used to determine all titers (Swayne et al., 1998).

Statistical analysis

SAS's General Linear Model (one-way analysis of variance) was used to analyze the data (SAS, 2004). Duncan's new multiple range test ($P<0.05$) was used to differentiate the treatments with the most significant variations in means (Duncan, 1955).

RESULTS

For the starter, grower, finisher, and the overall period, the effects of various nutritional treatments are shown in Table 2. At starting phase, all treatments significantly ($P<0.05$) outperformed the control in weight gain (WG) and feed conversion ratio (FCR). For grower phase, the WG was significantly boosted ($P<0.05$) with chicks fed a feed enriched with sodium propionate (SP) or sodium formate (SF). In comparison to the control, adding SF, SA, or SP to the finisher phase enhanced FCR considerably. As compared to the control at overall period, adding SF, SA, or SP significantly ($P<0.05$) enhanced total WG and FCR. Birds provided a feed containing SF gained the most weight and had the highest FCR, followed by those fed a diet supplemented with SP. Treatments and the control group had no significant differences in the amount of feed consumed at any given time. According to these findings, the addition of SF and SP had a greatest effect than the addition of SA. In order to increase the productivity of broilers as measured by WG or FCR, sodium formate or sodium propionate were utilized. Feed utilization was higher in broiler chicks fed such additive diets than in those on a control diet.

Carcass characteristics

Table 3 illustrates the impacts of SF, SA, and SP on carcass characteristics. Carcass weight was significantly enhanced ($p<0.01$) for birds fed a diet enriched with OAS's. The dressing% were slightly improved ($p>0.05$) with OAS's addition compared to control. No significant effect in the liver, heart, gizzard, and spleen percentages of live body weight were recorded due to the different treatments.

Intestinal length, diameter, and lesion score

At 35 days of age, chick's intestinal length, width, and lesions shown in Figure 1. The effects of adding SF and SP to the diet on intestinal length, diameter, and lesion score were significant ($P<0.05$). The length of the intestines of birds fed diets enriched with SF or SP were significantly ($P<0.05$) increased (170 and 171 cm, respectively) compared to the control group (145 cm). While, chicks fed a meal supplemented with SA had comparable results to the control group (145 cm). The width of the gut was considerably increased ($P<0.05$) when SF or SP were added to the feed. Normal intestinal appearance without any lesion recorded for birds in treatments fed diets containing propionate and formate while the control group take one on this scale which refer to the intestinal is thin-walled and fragile intestines accompanied by small red petechiae.

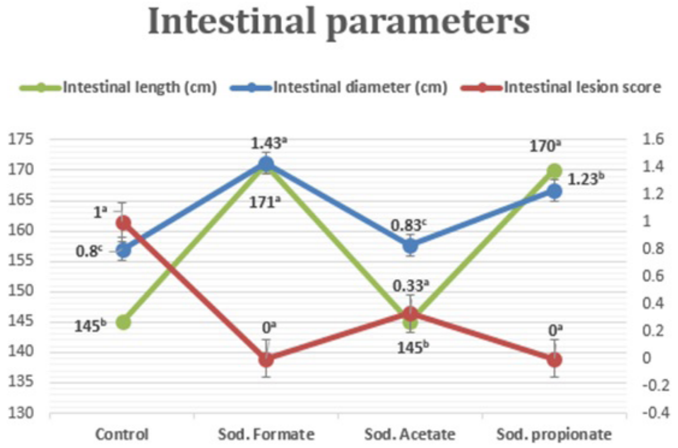


Figure 1: At 35 days of age, the effect of dietary interventions on intestine length, diameter, and lesion score in broiler chicks.

Intestinal microbiota count

As broilers reached 35 days of age, Figure 2 shows the impact of dietary treatments on the intestinal microbiota (*Lactobacillus* and *Clostridium perfringens*). When compared to the control (4 log10 CFU/g), the number of *Lactobacillus* in the birds fed meals supplemented with SF or SP was significantly ($P<0.05$) increased (6.93 and 6.27 log10 CFU/g, respectively). The amount of intestinal colonization of *C. perfringens* was zero for chicks fed diets enriched with SP and SF, compared to the control (2 log10 CFU/g). The small intestine is an important element of the digestive system that aids in feed absorption, and its proper development is essential for bird health and performance.

Table 2: Growth performance of broiler chicks as a result of food treatments.

Item	Starter (1-14)			Grower (14-28)			Finisher (28-35)			Overall period (1-35)		
	WG	FI	FCR	WG	FI	FCR	WG	FI	FCR	WG	FI	FCR
Control	299^{b}	395	1.33^{a}	893^{b}	1149	1.29	497	981	1.97^{a}	1689^{b}	2525	1.49^{a}
Sod.formate	324^{a}	360	1.11^{b}	960^{a}	1150	1.20	598	972	1.63^{b}	1882^{a}	2482	1.32^{b}
Sod. Acetate	334^{a}	383	1.15^{b}	907^{b}	1145	1.27	574	1000	1.74^{b}	1815^{a}	2528	1.39^{b}
Sod.propionate	339^{a}	370	1.09^{b}	948^{a}	1155	1.22	557	991	1.78^{b}	1844^{a}	2516	1.36^{b}
SE of means	±4.80	±6.54	±0.03	±8.57	±11.33	±0.01	±7.38	±8.99	±0.03	±16.70	±20.08	±0.02
Significances	***	NS	**	***	NS	NS	NS	NS	***	***	NS	**

$^{a-b}$Means assigned with the same letter within the same column are not significantly different at 0.05 probability level, **P<0.01), ***P<0.001, NS: Not significant (P>0.05).

Table 3: Nutritional treatment effects on carcass traits at 35 days of age.

Item	Carcass weight (g)	Dressing %	Giblets % (of LBW)			Spleen %
			Liver	Heart	Gizzard	
Control	1289^{b}	74.24	2.30	0.61	2.16	1.04
Sod.formate	1470^{a}	76.62	2.19	0.60	2.40	1.27
Sod. Acetate	1398^{a}	75.04	2.29	0.58	2.43	1.15
Sod.propionate	1420^{a}	75.61	2.36	0.59	2.55	1.11
SE of means	±24.11	±0.66	±0.03	±0.01	±0.07	±0.07
Significances	**	NS	NS	NS	NS	NS

$^{a-b}$Means assigned with the same letter within the same column are not significantly different at 0.05 probability level, **P<0.01, NS: Not significant (P>0.05).

Table 4: Effects of feed interventions on various blood biochemical markers in 35-day-old broiler chicks.

Item	Total protein (g/L)	Albumin (g/L)	Globulin (g/L)	Albumin/ Globulin	Urea (µmol/L)	ALT (U/L)	AST (U/L)
Control	2.64^{b}	1.39	1.25^{c}	1.12^{a}	2.67	13.97	207.66
Sod. formate	2.83^{a}	1.30	1.53^{ab}	0.85^{b}	2.46	13.60	207.00
Sod. Acetate	2.67^{a}	1.36	1.40^{bc}	0.98^{ab}	2.66	13.93	206.65
Sod.propionate	2.85^{a}	1.30	1.55^{a}	0.84^{b}	2.53	13.63	205.67
SE of means	±0.03	±0.02	±0.04	±0.04	±0.05	±0.18	±1.58
Significances	*	NS	**	**	NS	NS	NS

$^{a-c}$Means assigned with the same letter within the same column are not significantly different at 0.05 probability level, NS: not significant, *(p<0.05), **(P<0.001). Aspartate aminotransferase (AST), alanine aminotransferase (ALT), uric acid (µmol/L).

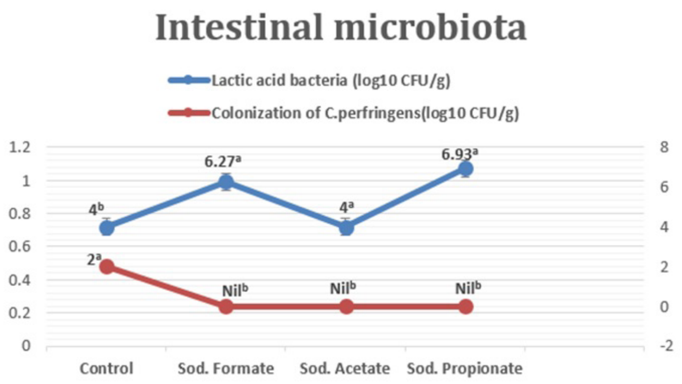


Figure 2: Effect of feed interventions on intestinal microbiota of broiler chicks a 35 days of age.

Blood biochemical parameters

Table 4 shows the effects of several dietary treatments on blood biochemical. Adding OAS's to broiler diets resulted in significant (*P<0.05*) improvements in total protein, globulin, and albumin/globulin ratio than the control. When SP or SF was added to the diets, blood total protein and globulin levels were improved compared to SA addition. While no significant difference in blood albumin levels. The additives did not adversely affect both liver and kidney functions, no influence on the levels of ALT, AST, or urea. Figure 3 shows the effects of several dietary treatments on total antioxidants capacity (TAC). Supplementation with SF or SP were significantly (*P<0.05*) increased TAC than control. Furthermore, broilers administered OAS's showed a stronger immune response than control broilers, as demonstrated by higher blood globulin levels.

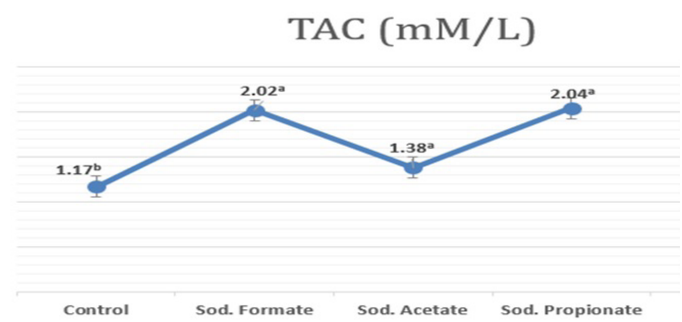


Figure 3: At 35 days of age, the effect of dietary interventions on broiler chicks total antioxidant capacity.

Thyroid hormones

Figure 4 shows the effects of OAS's on thyroid hormones. The addition of OAS's raised T3 and T4 levels considerably (*P<0.05*). Despite this, the T4/T3 ratio did not affect. Adding SF and SP to broiler diets enhanced metabolic and growth rates, according to these findings. In broilers, elevated thyroid hormone levels have been linked to feed changes that included the addition of salts of organic acids (SF, SA, and SP).

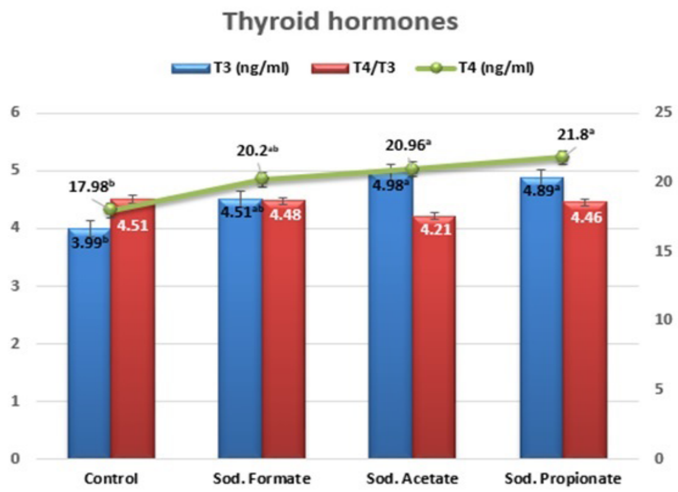


Figure 4: Effect of dietary interventions on broiler chicks thyroid hormones at 35 days.

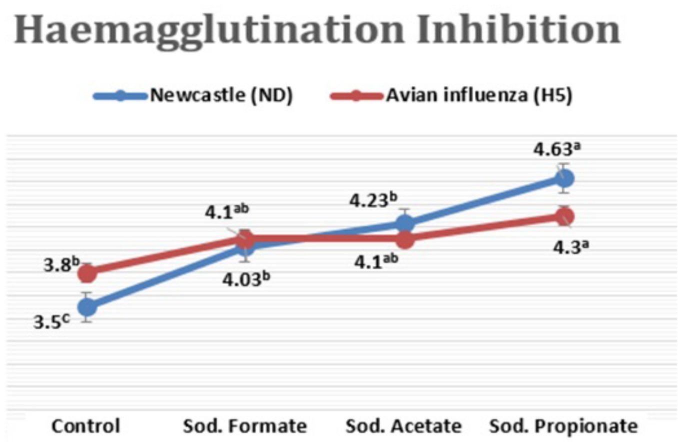


Figure 5: The Effect of treatments on the immunological state of 35 days old broiler chicks.

Links Researchers

Immune status

The effects of OAS's on immunological status are shown in Figure 5. A haemagglutination inhibition tests were used to assess antibody titer against avian influenza (H5) and Newcastle disease (ND) vaccinations. Against both the ND and H5 vaccines, the immunological status of the birds fed diets supplemented with SF, SA, or SP salts were significantly ($P<0.05$) improved. When SP was added to broiler, the immune response against the ND and H5 vaccination was improved.

DISCUSSION

Growth performance

According to the current study, the addition of salts of organic acid in broiler feed boosted weight gain and feed conversion ratio by 7.5-11.5 and 7-11 %, respectively. The results of this study are in agreement with previous studies. Body weight gain and FCR were increased by 5.5 and 12 %, respectively, when the broiler feed was supplemented with a mixture of organic acids (Hassan et al., 2010). Helen and Christian (2010) found that introducing diformate to broiler chickens at concentrations of 0.1, 0.3 and 0.5% improved WG and FCR. Addition of sodium butyrate to broiler chicks increased their performance by improving WG and FCR (Sikandar et al., 2017). Adding 0.5 % sodium butyrate or 1.0 % calcium propionate to broiler diets enhanced significantly ($P<0.05$) the productive performance and gut morphology, decreased Coliform bacteria (log10 CFU/g.), and increased *Lactobacilli* count when compared to the control group. According to Sabour et al. (2019) adding a mixture of organic acids (lactic acid, citric acid, formic acid, phosphoric acid, acetic acid, sodium butyrate and propionic acid) to a broiler diet improved growth performance. Improved gut microbiota, nutrient digestion, and broiler development performance can be achieved by the use of acidifiers (Wu et al., 2020). Gao et al. (2021) studied that adding phosphoric acid (0.1 and 0.2 g/kg) as acidifiers to broiler feed enhanced productive performance, intestinal parameters and meat analysis compared to the birds fed the basal diets. Organic acids or their salts may improve broiler performance by improving feed digestibility, reducing microbial infections, enhancing immunity, and lowering the production of gases (ammonia) (Khan et al., 2016). As a result of better utilization of nutrients, broilers treated with organic acid salts (OAS's) gained more weight and less FCR.

Carcass characteristics

The results obtained are consistent with the results of Leeson et al. (2005), who found that birds given 0.2 % butyrate supplements significantly increased in carcass weight. Adding organic acids to broiler meals, according to Hassan et al. (2010), raised the dressing percentage, although liver, spleen, and thymus (% body weight) did not differ significantly across treatments.

Intestinal length, diameter, and lesion score

The results obtained were in line with the results of previous studies. Broilers fed diets containing organic acid had longer intestinal villi than those fed a control diet (Khatun et al., 2010). Could be owing to its role as a natural barrier against pathogenic bacteria and harmful compounds in the intestinal lumen, resulting in an increased villus height (Khan, 2013). Increased weight and length of the gastrointestinal tract and response to the ND vaccine were two benefits of feeding broilers sodium butyrate in their diet (Lan et al., 2020).

Intestinal microbiota count

The findings were consistent with those of prior research. The small intestine is an important element of the digestive system that aids in feed absorption, and its proper development is essential for bird health and performance. As a result, in order to maximize feed utilization and growth rate, gut health is the most critical aspect in broiler production. It is possible that altering the microbiota to reduce pathogenic bacteria may have a positive impact on the creation of the intestinal wall (Cengiz et al., 2012). Reduced intestinal mucosal permeability is a result of organic acids in broiler feed protecting epithelial cells from disturbance (Kumar et al., 2021). One theory is that, in addition to decreasing dangerous bacteria, organic acids may also regulate the bacteria that compete with birds for food resources (Lee, 2005). Dietary salts of organic acids reduce bacterial metabolites and prevent competing between microorganisms and their host on nutrients, allowing birds to gain weight and feed more efficiently. Salmonella typhimurium colonization was reduced in broiler chicks given a 0.9 % organic acid (mostly SF) (Adhikari et al., 2020). Organic acids appear to be more effective at preventing *C. perfringens* colonization in broilers than antibiotics (Kumar et al., 2021). Organic acids were added to broilers, which enhanced beneficial bacteria while reduced pathogenic bacteria (Rodjan et al., 2017; Sureshkumar et al., 2021). Different organic acids have antibacterial activity (Aljumaah et al., 2020). Most organic acids salts have different physical and chemical properties. Some organic acids have a narrow antibacterial spectrum (lactic acid is good for bacteria), while others have a broad spectrum (formic and propionic acids are more effective against pathogenic bacteria and fungal infections (Galli et al., 2021).

Blood biochemical parameters

The findings were in line with those of previous studies. Organic acid-fed broilers had higher globulin levels than those in the control group (Kamal and Ragaa 2014).

Because of their inhibitory effects on harmful microbes in the stomach, dietary organic acids may enhance the immune system (Kim et al., 2015).

Thyroid hormones

The results of this study are in agreement with previous studies. Thyroid hormones, particularly T3, which regulate all major metabolic pathways, could be manipulated physiologically to enhance BW and FCR. Another reason for the enhanced in weight gain could be a rise in thyroid gland function, as demonstrated by the elevated T3 and T4 levels. In addition, thyroid hormones promote the protein synthesis (McAninch and Bianco, 2014; Cicatiello et al., 2018).

Immune status

The results obtained were in line with the results of previous studies. Antibody titers of ND were considerably ($P<0.05$) higher in broilers fed diets enriched with organic acid than in control (Houshmand et al., 2012). The immune systems of broilers are impaired as a result of their rapid growth. Organic acids boost the immune systems of broilers by reducing pathogenic microbes and increasing *Lactobacillus* in the intestine (Yang et al., 2018; Scicutella et al., 2021).

CONCLUSIONS

It could be concluded that Organic acid salts (OAS's) have a great impact on broiler chick's performance, carcass weight, and immunological state. In addition, dietary SF and SP supplementation improved gut microbiota by lowering pathogenic microorganisms. Not all OAS's had the same impact on gut bacterial populations or performance. Based on these findings and previous discussion, salts of organic acids can be used as a powerful tool for gut microbiota in broiler diets, improving performance and immune status. The best results of productive performance, immunological state, intestinal parameters and microbiota recorded for birds fed SF or SP.

NOVELTY STATEMENT

Sodium formate, acetate, and propionate were chemically synthesized to use them as effective feed additives to improve intestinal microbiota, immunological condition, and productive performance without causing any side effects.

AUTHOR'S CONTRIBUTION

All authors contributed equally to study design, methodology, interpretation of results, and writing of the manuscript.

Conflict of interest

The authors have declared no conflict of interest.

REFERENCES

Abd-Elsamee, M.O., El-Sherbiny, A.E., Hassan, H.M.A., Samy, A., and Mohamed, M.A. (2012). Adding phytase enzyme to low phosphorus broiler diets and its effect upon performance, bone parameters and phosphorus excretion. Asian J. Poultry Sci., 6(4): 129-137.

Adhikari P, Yadav S, Cosby DE, Cox NA, Jendza JA, Kim WK (2020). Research Note: Efect of organic acid mixture on growth performance and Salmonella typhimurium colonization in broiler chickens. Poult. Sci., 99: 2645–2649. https://doi.org/10.1016/j.psj.2019.12.037

Agboola AF, Omidiwura BRO, Osakue PO, Ogunbiyi KO (2018). Effects of sodium acetate and sodium propionate supplemented diets on growth performance and gut histomorphology of broiler starters. Niger. J. Anim. Sci., 20: 183-196.

Akbar MA, Tewatia BS, Kumar S (2017). Effect of dietary supplementation of salts of organic acids on gut morphology and meat quality of broilers. Indian J. Anim. Res., 52: 1727-1731. https://arccjournals.com/journal/indian-journal-of-animal-research/B-3448

Aljumaah MR, Alkhulaifi MM, Abudabos AM, Alabdullatifb A, El-Mubarak AH, Al-Suliman AR, Stanley D (2020). Organic acid blend supplementation increases butyrate and acetate production in Salmonella enterica serovar Typhimurium challenged broilers. PLoS One, 15: e0232831–e0232831. https://doi.org/10.1371/journal.pone.0232831

Baaboua AE, El-Maadoudi A, Bouyahya A, Belmehdi O, Kounnoun A, Zahli R, Abrini J (2018). Evaluation of antimicrobial activity of four organic acids used in chicks feed to control *Salmonella typhimurium*: suggestion of amendment in the search standard. Int. J. Microbiol., 2018: 9 pages. https://doi.org/10.1155/2018/7352593

Carrido, MN, Skjerheim, M, Oppegaard, H and Sqrum, H (2004). Acidified litter benefits the intestinal flora balance of broiler chickens. Appl. Environ. Microbiol., 70: 52085215. https://doi.org/10.1128/AEM.70.9.5208-5213.2004

Cengiz, O, Koksal, BH, Tatli, O, Sevim, O, Avci, H, Epikmen, T, Beyaz, D, Buyukyoruk, S, Boyacioglu, M, Uner, A and Onol, AG (2012). Influence of dietary organic acid blend supplementation and interaction with delayed feed access after hatch on broiler growth performance and intestinal health. Vet. Fac., Adnan Menderes Univ, Aydin, Turkey. Vet. Med., 57: 515-528. https://doi.org/10.17221/6363-VETMED

Christian L, Mellor S (2011). The use of organic acids in animal nutrition, with special focus on dietary potassium diformate under European and Austral-Asian conditions. Recent Adv. Anim. Nutr. Aust., 18: 123-130.

Cicatiello AG, Di Girolamo D, Dentice M (2018). Metabolic effects of the intracellular regulation of thyroid hormone: old players, new concepts. Front. Endocrinol., 9: 474. https://doi.org/10.3389/fendo.2018.00474

Dahiya JP, Hoehler D, Wilkie DC, Van Kessel AG, Drew MD (2005). Dietary glycine concentration affects intestinal *Clostridium perfringens* and Lactobacilli populations in broiler chickens. Poult. Sci., 84: 1875–1885. https://doi.

org/10.1093/ps/84.12.1875

Duncan DB (1955). Multiple range and multiple F tests. Biometrics, 11: 1-42. https://doi.org/10.2307/3001478

Elsherif HMR, Orabi A, Ali AS, Samy A (2021). Castor and propolis extracts as antibiotic alternatives to enhance broiler performance, intestinal microbiota and humoral immunity. Adv. Anim. Vet. Sci., 9(5): 734-742.

Galli GM, Aniecevski E, Petrolli TG, Da Rosa G, Boiago MM, Simões CA, Wagner R, Copetti PM, Morsch VM, Araujo DN (2021). Growth performance and meat quality of broilers fed with microencapsulated organic acids. Anim. Feed Sci. Technol., 271: 114706. https://doi.org/10.1016/j.anifeedsci.2020.114706

Gao CQ, HQ Shi, WY Xie, LH Zhao, JY Zhang, CJi and Ma QG (2021). Dietary supplementation with acidifiers improves the growth performance, meat quality and intestinal health of broiler chickens. Anim. Nutr., 7: 762-769. https://doi.org/10.1016/j.aninu.2021.01.005

Hassan HMA, Samy A, El-Sherbiny AE, Mohamed MA, Abd-Elsamee MO (2016). Application of nano-dicalcium phosphate in broiler nutrition: Performance and impact on environmental pollution. Asian J. Anim. Vet. Adv., 11(8): 477-483. https://doi.org/10.3923/ajava.2016.477.483

Hassan HMA, MA Mohamed, Amani W Youssef, Eman R Hassan (2010). Effect of using organic acids to substitute antibiotic growth promoters on performance and intestinal microflora of broilers. Asian Aust. J. Anim. Sci., 23: 1348-1353. https://doi.org/10.5713/ajas.2010.10085

Hassan HM, Samy A, Youssef AW, Mohamed MA (2018). Research article using different feed additives as alternative to antibiotic growth promoter to improve growth performance and carcass traits of broilers. Int. J. Poult. Sci., 17: 255-261. https://doi.org/10.3923/ijps.2018.255.261

Helen B, Christian L (2010). Performance enhancement through the use of diformates in broiler. ADDCON Co Ger, Porsgrunn publication.

Houshmand M, Azhar K, Zulkifi I, Bejo MH, Kamyab A (2012). Effects of nonantibiotic feed additives on performance, immunity and intestinal morphology of broilers fed different levels of protein. South Afr. J. Anim. Sci., 42: 22–32. https://doi.org/10.4314/sajas.v42i1.3

Huyghebaert G, Ducatelle R, Van Immerseel F (2011). An update on alternatives to antimicrobial growth promoters for broilers. Vet. J., 187: 182-188. https://doi.org/10.1016/j.tvjl.2010.03.003

Kamal AM, Ragaa NM (2014). Effect of dietary supplementation of organic acids on performance and serum biochemistry of broiler chicken. Nat. Sci., 12: 38-45.

Khan RU, Chand N, Ali A (2016). Effect of organic acids on the performance of Japanese quails. Pak. J. Zool., 48: 1799–1803.

Khan SH (2013). Probiotic microorganisms-identification, metabolic and physiological impact on poultry. World's Poult. Sci. J., 69: 601e12. https://doi.org/10.1017/S0043933913000603

Khan RU, Naz S, Raziq F, Qudratullah Q, Khan NA, Laudadio V, Ragni M (2022). Prospects of organic acids as safe alternative to antibiotics in broiler chickens diet. Environ. Sci. Pollut. Res., pp. 1-11. https://doi.org/10.1007/s11356-022-19241-8

Khatun M, Islam KMS, Howleder MAR, Haque MN, Chowdhury R, Karim MR (2010). Effects of dietary citric acid, probiotic and their combination on the performance, tibia ash and non-specific immune status of broiler. Indian J. Anim. Sci., 80: 813e6.

Kim JW, Kim JH, Kil DY (2015). Dietary organic acids for broiler chickens: A review. Rev. Colombiana Ciencias Pecuarias, 28: 109-123. https://doi.org/10.17533/udea.rccp.v28n2a01

Kumar A, Toghyani M, Kheravii SK, Pineda L, Han Y, Swick RA, Wu SB (2021). Organic acid blends improve intestinal integrity, modulate short-chain fatty acids profiles and alter microbiota of broilers under necrotic enteritis challenge. Anim. Nutr., https://doi.org/10.1016/j.aninu.2021.04.003

Lan RX, Li SQ, Zhao Z, Li LA (2020). Sodium butyrate as an effective feed additive to improve growth performance and gastrointestinal development in broilers. Vet. Med. Sci., 6: 491-499. https://doi.org/10.1002/vms3.250

Lee KH, Jung S, Kim HJ, Kim IS, Lee JH, CJo (2012). Effect of dietary supplementation of the combination of gallic and linoleic acid in thigh meat of broilers. Asian-Austral. J. Anim. Sci., 25: 1641-1648. https://doi.org/10.5713/ajas.2012.12260

Lee MD (2005). Molecular basis for AGP effects in animals. Antimicrobial growth promoters: Worldwide Ban on the Horizon. Noordwijk and Zee, the Netherlands, pp. 37-38.

Leeson S, Namkung H, Antongiovanni M, Lee EH (2005). Effect of butyric acid on the performance and carcass yield of broiler chickens. Poult. Sci., 84: 1418-1422. https://doi.org/10.1093/ps/84.9.1418

McAninch EA, Bianco AC (2014). Thyroid hormone signaling in energy homeostasis and energy metabolism. Ann. N. Y. Acad. Sci., 1311: 77-87. https://doi.org/10.1111/nyas.12374

Mohamed MA, Hassan HMA, Samy A, Abd-Elsamee MO, El-Sherbiny AE (2016). Carcass characteristics and bone measurements of broilers fed nanodicalcium phosphate containing diets. Asian J. Anim. Vet. Adv., 11(8): 484-490. https://doi.org/10.3923/ajava.2016.484.490

National Research Council (1994). Nutrient requirements of poultry. 9th. Washington, DC: Natl. Acad. Sci.,

Ouellette RJ, Rawn JD (2018). Organic chemistry: structure, mechanism, synthesis. Academic Press.

Qiao M, Ying GG, Singer AC, Zhu YG (2018). Review of antibiotic resistance in China and its environment. Environ. Int., 110: 160-172. https://doi.org/10.1016/j.envint.2017.10.016

Ragaa NM, Korany RM (2016). Studying the effect of formic acid and potassium diformate on performance, immunity and gut health of broiler chickens Anim. Nutr., 2: 296-302. https://doi.org/10.1016/j.aninu.2016.08.003

Rodjan P, Soisuwan K, Thongprajukaew K, Theapparat Y, Khongthong S, Jeenkeawpieam JT, Salaeharae (2017). Efect of organic acids or probiotics alone or in combination on growth performance, nutrient digestibility, enzyme activities, intestinal morphology and gut microfora in broiler chickens. J. Anim. Physiol. Anim. Nutr., 102(2): 931–940. https://doi.org/10.1111/jpn.12858

Sabour S, Tabeidian SA, Sadeghi G (2019). Dietary organic acid and fiber sources affect performance, intestinal morphology, immune responses and gut microflora in broilers. Anim. Nutr., 5: 156–162. https://doi.org/10.1016/j.aninu.2018.07.004

SAS (2004). SAS/STAT user's guide. Release 8.1, SAS Institute Inc., Cary, NC. USA, pp. 554.

Scicutella F, Mannelli F, Daghio M, Viti C, Buccioni A (2021). Polyphenols and organic acids as alternatives to antimicrobials in poultry rearing: A review. Antibiotics, 10: 1010. https://doi.org/10.3390/antibiotics10081010

Sikandar A, Zaneb H, Younus M, Masood S, Aslam A, Khattak F, Ashraf K, Yousaf MS, Rehman H (2017). Effect of sodium butyrate on performance, immune status, microarchitecture of small intestinal mucosa and lymphoid organs in broiler chickens. Asian-Australas. J. Anim. Sci., 30: 690-699. https://doi.org/10.5713/ajas.16.0824

Sureshkumar S, Park JH, Kim IH (2021). Effects of the inclusion of dietary organic acid supplementation with anti-coccidium vaccine on growth performance, digestibility, fecal microbial, and chicken fecal noxious gas emissions. Braz. J. Poult. Sci., 23. https://doi.org/10.1590/1806-9061-2020-1425

Swayne DE, Glisson JR, Jackwood MW, Pearson JE, Reed WM (1998). A laboratory manual for the isolation and identification of avian pathogens. 4th Ed, American Association of Avian Pathologist Inc., Kennett Square, Pennsylvania, USA. pp. 156-163.

Tohru M, Kamisoyama H, Honda K, Hasegawa S (2011). Effect of dietary potassium diformate on the growth of growing broiler chickens. J. Poult. Sci., 48: 247-253. https://doi.org/10.2141/jpsa.011037

Wolfenden AD, Vicente JL, Higgins JP, Andreatti RL, Filho SE, Higgins B, Hargis M (2007). Effect of organic acids and probiotics on Salmonella enteritidis infection in broiler chickens. Int. J. Poult. Sci., 6: 403-405. https://doi.org/10.3923/ijps.2007.403.405

Wu Y, Yin X, Wang Y, Mahmood T, Shahid M, Yin D, Yuan J (2020). Effect of 2-hydroxy-4-(methylthio) butanoic acid and acidifier on the performance, chyme pH, and microbiota of broilers. Anim. Sci. J., 91: e13409. https://doi.org/10.1111/asj.13409

Yadav S, Jha R (2019). Strategies to modulate the intestinal microbiota and their effects on nutrient utilization, performance, and health of poultry. J. Anim. Sci. Biotechnol., 10: 2-11. https://doi.org/10.1186/s40104-018-0310-9

Yang X, Xin H, Yang C, Yang X (2018). Impact of essential oils and organic acids on the growth performance, digestive functions and immunity of broiler chickens. Anim. Nutr., 4(4): 388–393. https://doi.org/10.1016/j.aninu.2018.04.005