

Evaluation of the Effect of Organic Acid Blend (Keprofix Oral®) on Hematological and Biochemical Parameters and Histopathological Changes in Dogs

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Abstract— The study has been conducted to evaluate the efficacy of the blend of organic and essential oil in commercial preparation Keprofix® Oral in dogs. Ten male dogs have been divided into two groups; group (A) treated with Keprofix® Oral while group (B) given distal water only. Blood samples were collected from both groups every two weeks until the 12th week. These samples have been used to study blood and serum biochemical analysis which have revealed significant differences in the values of (RBCs count, hemoglobin, PCV, total leukocytes count, neutrophils, lymphocyte, total protein, Albumen, plasma fibrinogen, ALT and serum globulin) at $P \leq 5$. Respectively, after 12th week the challenge dose 1×10^8 CFU of bacteria (*E. coli*) was given orally to both groups and recorded the clinical signs after that sacrifice the animals and study the histopathological change in liver, spleen and intestine which showed characteristic features represented by increased length and width of intestinal villi in treated animals with Keprofix® Oral in contrast to non-treated animals. Also, same changes revealed in liver and spleen represented with infiltration of neutrophils in liver parenchyma with lymphocytic hyperplasia in spleen for treated animals with Keprofix® Oral.

Keywords — Organic Acid Blend, Keprofix Oral®, Dogs, Histopathological Changes.

INTRODUCTION

The phrase organic acid denotes a wide category of substances utilized in essential metabolic activities within the body. Organic acids are weak acids that exhibit partial dissociation (1). The majority of organic acids exhibiting antibacterial properties has a pKa ranging from 3 to 5 (2). A diverse array of organic acids with differing physical and chemical characteristics exists, many of which can serve as drinking water supplements or feed additives. They are also less corrosive and potentially more soluble in water (3).

Organic acids exhibit potent bacteriostatic properties and have been utilized as agents for reducing *Salmonella* and *E. coli* in animal feed and water supplies (4).

Organic acids facilitate the maintenance of an optimal pH in the stomach, thereby ensuring the proper activation and function of proteolytic enzymes and overall protein digestion. They stimulate feed intake, inhibit the proliferation of pathogenic bacteria, energy digestibility and enhance protein by diminishing microbial competition for host nutrients and reducing endogenous nitrogen losses (5).

Formic acid and HMB exhibited the most potent activity in this experiment, leading to complete bacteriolysis within 24 hours. Furthermore, each acid possesses a distinct spectrum of antibacterial activity. Sorbic acid is well recognized for its antimold properties, while lactic acid is more efficacious against bacteria. Certain acids, notably formic, HMB and propionic, exhibit extensive antibacterial properties and can effectively combat fungus and bacteria, including yeast (6).

Keprofix Oral is a composition of precisely prepared organic acids and an essential oil. Sodium propionate inhibits microbial energy production, resulting in a reduction of harmful bacterial proliferation, including *Salmonella* in the intestines. The acids in the formulation maintain a low gut pH, enhancing growth performance in chicken by facilitating endogenous enzymes and suppressing harmful bacterial proliferation (7).

Clove oil serves as a natural growth promoter and modifies enzyme activity in the gastrointestinal tract. This enhances food absorption, digestion and optimizes gut microbiota. The antioxidant action contributes to the fortification of the immune system (8).

MATERIALS AND METHODS

Animals

Ten male dogs aged from (1 years) were conducted in the study in Kerbala province, these dogs divided into two groups (A) and (B) each group consist of 5 dogs, all the animals have been adapted then treated with ant parasite and antibiotic before the study initiated.

Collection of samples

Blood samples were collected from dogs every two weeks by

routine procedures from jugular vein and collected in EDTA tube, these samples used for examination of blood parameter (erythrocytes and leukocytes values) by Hb analyzer in medical city of Imam Hussain and for estimation of serum biochemical profiles.

Preparation of challenge dose of *E.coli*

According to Anderson et al. (9), the challenge inoculum was prepared using a 10 mL overnight culture of *E. coli* obtained from the central health laboratory in Karbala province. The bacteria, cultivated in nutrient broth for 18 hours, were harvested via centrifugation and resuspended in phosphate-buffered saline at an approximate concentration of 1×10^8 colony-forming units, as determined by measuring the absorbance at 600 nm (A600) in a spectrophotometer, with subsequent verification through viable counts on nutrient agar.

Animals sacrificing

The animals from both groups have been sacrificed by administrated (IM) xylazin at dosage (1ml/kg) and ketamine at dosage (5ml/kg) in standing position the autopsy to get the organs for histopathology.

Histopathological examination

Organ samples were promptly immersed in 10% formalin for histological analysis. The histopathological portion was prepared using the methodology of Luna (10). The tissue samples underwent processing in an automated tissue processor for approximately 15 hours, after which the fixed specimens were embedded in paraffin wax. Sections of 3-5 microns in thickness were produced and stained with H&E for histopathological examination (11).

Statistical analyses

Statistical analyses of the results were conducted using the Chi-square test, with $P < 0.01$ as the threshold for significance (12).

RESULT AND DISCUSSION

Results of hematological study

All dogs in the research exhibited evident health throughout the trial period. Neither group of dogs exhibited any abnormalities prior to or following therapy with Keprofix® Oral. The results of hematological values have been showed significant differences between treated and non-treated groups among the weeks of study. The highly significant has been showed in hemoglobin and PCV in all interval of study while in RBCs count revealed significant differences from week 2nd until week 12th respectively.

Table 1. refers to the differences in erythrocyte parameters between group A and group B.

Pre-treatment		Post treatment						
Group A	Weeks	0	2	4	6	8	10	12
Treated	RBC $\times 10^6/\mu\text{L}$	4	5 \pm 1.3 A	5.7 \pm 1.3 A	6.4 \pm 1.7 A	6.8 \pm 1.74A	7.4 \pm 1.7 A	7.8 \pm 2.2 A
	Hb g/dL	9.3	11.6 \pm 2.9A	13.3 \pm 2.1A	15 \pm 3.0 A	16 \pm 3.1 A	17 \pm 3.3A	18 \pm 4.8 A
	PCV%	28	35 \pm 15.5A	40 \pm 16.6A	45 \pm 17.8A	48 \pm 18.4A	52 \pm 18.9A	57 \pm 19.2A
Group B	RBC $\times 10^6/\mu\text{L}$	4	4 \pm 1.3 A	4.1 \pm 1.3B	4.2 \pm 1.5 B	4.3 \pm 1.6 B	4.3 \pm 1.7	4.4 \pm 1.8B
	Hb g/dL	9.3	9.3 \pm 3.3B	9.6 \pm 3.5 B	9.8 \pm 3.8 B	10.06 \pm 4.1B	10.1 \pm 4.3B	10.3 \pm 4.4B
	PCV %	28	28 \pm 13.1 B	29.5 \pm 13.6B	30 \pm 13.9 B	30.2 \pm 14.2 B	30.3 \pm 14.3B	31 \pm 14.4B

The results also have been showed significant differences in the leukocytes parameters, the highly significant revealed in values of total leukocytes count (TLC), Neutrophils, eosinophiles and lymphocytes between group A (treated) and group B (not treated) of among the weeks of study while there are no significant differences in Basophils and monocytes between groups respectively.

Table 2. refers to the differences in leukocytes parameters between group A and group B.

Pre-treatment		Post treatment						
Group A	Weeks	0	2	4	6	8	10	12
Treated	TLC $\times 10^3/\mu\text{L}$	4.5	6.1 \pm 1.3A	9.2 \pm 1.6 A	12 \pm 1.9A	13.8 \pm 2.3A	14.5 \pm 3.1A	15.8 \pm 3.6A
	Neutrophil %	32	40 \pm 12.11A	58 \pm 13.90A	65 \pm 14.7A	70.2 \pm 15.2A	80.4 \pm 16.3A	89 \pm 17.2A
	Eosinophil %	8	9 \pm 1.0 A	13 \pm 1.6A	16 \pm 2.1A	18 \pm 2.8A	20 \pm 3.7A	25 \pm 4.5A
	Basophil %	0	0 \pm 0.0A	0 \pm 0.0A	1 \pm 0.1A	1 \pm 1A	2 \pm 1.1A	2 \pm 1.1A
	Lymphocyte %	7	18 \pm 8.8 A	25.7 \pm 9.8A	30.4 \pm 10.4A	40.2 \pm 12.1A	49.9 \pm 14.3A	58 \pm 15.2A
	Monocyte %	1	3 \pm 1.8 A	5 \pm 2.2A	7 \pm 2.9A	8 \pm 4.1A	9.6 \pm 4.6A	10.2 \pm 5.3A
Group B	TLC $\times 10^3/\mu\text{L}$	4.5	4.5 \pm 0.1B	4.8 \pm 1B	5 \pm 1.3B	5.9 \pm 1.8B	6 \pm 2B	6.2 \pm 2.4B
	Neutrophil %	32	38 \pm 1.30A	40 \pm 1.37B	45 \pm 1.40B	5.4 \pm 1.46B	6.3 \pm 1.51B	6.5 \pm 1.56B
	Eosinophil %	8	8 \pm 1.3 A	8 \pm 1.7B	9 \pm 1.8B	8 \pm 1.7B	9 \pm 1.8B	9 \pm 1.8B
	Basophil %	0	0 \pm 0.0A	0 \pm 0.0A	0 \pm 0.0A	1 \pm 0.1A	0 \pm 0.0A	1 \pm 0.8A
	Lymphocyte %	7	8 \pm 3.1B	8 \pm 4.3B	9 \pm 5.7B	10 \pm 6.4B	12 \pm 6.9B	15 \pm 7.2B
	Monocyte %	00	0 \pm 0.0 A	1 \pm 0.2A	3 \pm 1.0A	4 \pm 1.4A	5 \pm 1.9A	5.4 \pm 2.4A

The results may attributed to ability of organic acid to enhancing the ability to absorption the essential elements which reflected on the increase synthesis of blood components and this agree with (13) who mentioned the used of organic acids Enhance nutritional digestibility and augment mineral absorption, resulting in elevated blood parameters.

smith *et al.* (14) were mention the increase in values of RBC, lymphocytes, monocytes, PLT, eosinophils and neutrophils parameters in mice administrated organic acid (acetic acid) as probiotic.

Conversely, Devi *et al.* (15) investigated the effects of dietary protected organic acid supplementation blends on growth metrics, fecal microbiota, nutritional digestibility, blood contents and gas emissions in pigs. The authors discovered that white blood cells, lymphocyte percentages and immunoglobulin G levels were enhanced with protected organic acid groups (0.2% and 0.1%) in suckling piglets and lactating sows.

Abdel-Fattah *et al.* (16) demonstrated an enhancement in the immunological response of broilers. Moreover, the mass of lymphoid organs was augmented by the influence of acidifiers. The inclusion of propionic acid, butyric acid and acetic acid at a concentration of 1.5% in broiler diets enhances blood biochemical markers and liver enzyme activity without any detrimental effects from butyric acid supplementation (17).

Results of serum biochemical analysis

The results have been revealed significant differences in group A (treated) and group B (not treated) of among the weeks of study. The highly significant has been recorded in total protein, albumin, plasma fibrinogen. Plasma globulins and Alanine aminotransferase (ALT) while there is no significant recorded

in Aspartate aminotransferase (AST) (units/L) and Alkaline phosphatase (ALP) (units/L) respectively.

Table 3. The latter refers to the differences in serum biochemical parameters between group A and group B.

Test	Treated group Mean ± SD	Non treated group Mean ± SD
Total protein (g/dL)	18.35 ± 2.45 A	6.6 ± 1.35 B
Albumen (g/dL)	6.8 ± 1.67 A	0.4 ± 0.095 B
Plasma fibrinogen (g/dL)	305.16 ± 23.88 A	60.20 ± 0.053B
Alanine aminotransferase (ALT) (units/L)	60.47 ± 4.68 A	30 ± 3.36 B
Aspartate aminotransferase(AST) (units/L)	150.35 ± 21.78 A	150 ± 19.67 A
Alkaline phosphatase (ALP) (units/L)	100.72 ± 32.96 A	90 ± 27.89 A
Globulin (g/dL)	6.25 ± 1.30 A	3 ± 1.20 B

The rises of some serum bio chemical values specially (total protein, albumin, plasma fibrinogen and Plasma globulins) may attributed to increase the leukocytes and another plasma protein in animals fed on components contain organic acid these results agree with (18) It was noted that the utilization of acidifiers significantly elevated blood protein and serum albumin levels.

Yan *et al.* (19) observed an elevation in spleen weight in avians administered 0.30 g/kg of fumaric acid, thymol and sorbic acid during the grower and finisher phases. Furthermore, on day 42, elevated levels of immunoglobulin A were seen in the ileal and duodenal mucosa.

Smith *et al.* (14) showed that hematological and serum biochemical indicators generally improved in animals provided meals containing probiotics with organic acids compared to those fed diets without them.

Results of infective study

The animals in both groups (A -treated) and (B- non treated) were infection with E.coli at dosage 1×10^8 reveled differences in clinical signs which have been appeared after infection .the sever systemic illness appeared on animals in group (B) as fever ($40C^\circ$) diarrhea with dehydration (3%) while in group (A) mild clinical signs as mild fever (38.9) with no evidence of diarrhea and dehydration that attributed to the antimicrobial features of organic acid by suppress the pathogenic bacteria in the intestine this agree with (20) It was observed that in pigs, organic acids selectively eliminate target species such as coliform bacteria and E. coli, while sparing Lactobacillus.

Moreover, organic acids in feed suppress the proliferation of harmful bacteria and reduce microbial competition for host resources by altering the pH. The proliferation of most pH-sensitive bacteria (Clostridium perfringens, *Salmonella* and *E. coli*) is inhibited below pH 5, whereas acid-tolerant species endure. The undissociated version of the acid being more lipophilic, penetrates freely over the semi-permeable membrane of the bacterial cell into the cytoplasm at neutral pH, where it subsequently dissociates and releases protons (H^+), leading to a drop in pH within the cell. As a result, the enzymatic operations of nutrient transport, signal transductions and glycolysis, in the microorganisms are hindered, leading to

energy deficiency in their attempts to restore pH to normal levels (21).

Hassan *et al.* (22) observed a decrease in intestinal *Salmonella* spp. and *E. coli* in the intestinal microbiota of broilers through the incorporation of a mixture of salts or organic acids. The probiotics, acidifiers and antibiotics diminished the population of harmful microorganisms, *E. coli*, particularly coliforms and total aerobes (5). Acidifiers have demonstrated antibacterial properties against microorganisms (23,24).

Moreover, probiotics and acidifiers enhanced the Lactobacilli population, since the advantageous impact of these additives can be ascribed to their ability to inhibit pathogenic bacteria while promoting the proliferation of beneficial strains (2,25).

In pigs, dietary supplementation with escalating amounts of protected organic acids resulted in a linear enhancement of faecal Lactobacillus counts, while concurrently reducing the counts of *E. coli* and *Salmonella*, faecal ammonia, diarrhea scores and acetic acid emissions (26).

The acidic environment additionally establishes a barrier against bacterial entry and colonization in the intestine (27).

Histopathological study

The results of histopathological study for organs (liver, intestine and spleen) from sacrificed animals in treated and non-treated group have been showed vary degree of lesions. in liver of treated group with Keprofix oral showed hypertrophy of bile duct with aggregation of neutrophils in liver parenchyma figure(1) while the histopathological section of liver in non-treated group showed sever central vein congestion, marked perivascular mononuclear cells infiltration with fibrosis and significant necrosis of hepatocytes figure (2) .as well as the histopathological section of spleen in treated group showed the significant lymphocytic hyperplasia, proliferation of polymorph nuclear inflammatory cells. figure (3) in contrast to the non-treated group who showed the significant thickness in capsule with fibrous connective tissue fibers (white arrow) , proliferation of fibroblasts figure (4), in another hand the histopathological section for intestine of treated group reveled the massive changes on width and height of intestinal villi characterized by increase on both of them) with hyperplasia of villous mucosal epithelia with lymphocytic infiltration figure (5) while the non-treated group showed the marked and heavy leukocytic inflammatory cells infiltration figure (6).

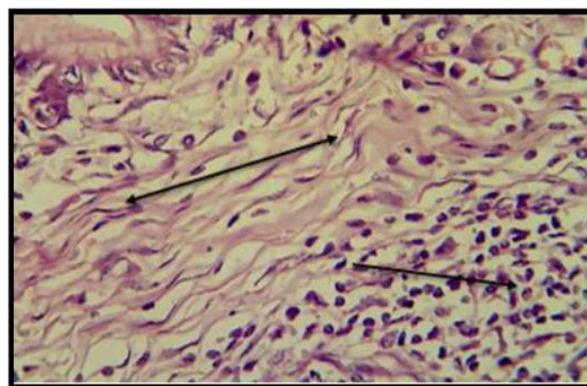


Figure 1. liver section of an animal treated with (Keprofix® Oral) showed hypertrophy of bile duct(black arrow \longleftrightarrow)with

aggregation of neutrophils in liver parenchyma (black arrow) (H and E , 40X).

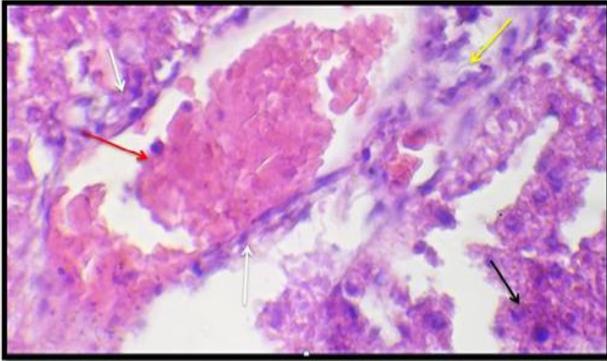


Figure 2. liver section of an animal non treated with (Keprofix® Oral) revealed the sever central vein congestion (red arrow), marked perivascular mononuclear cells infiltration (white arrow) with fibrosis (yellow arrow) and significant necrosis of hepatocytes (black arrow) (H and E, 40X).

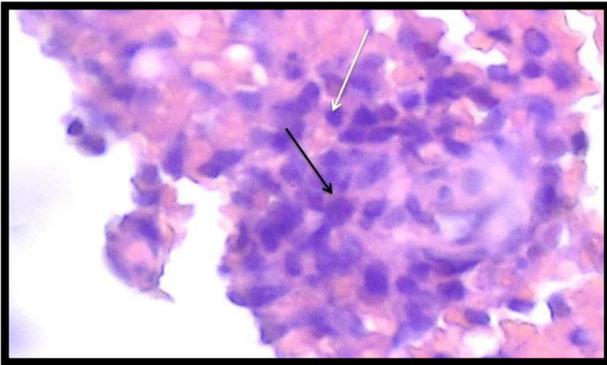


Figure 3. Spleen section of an animal treated with (Keprofix® Oral), revealed the significant lymphocytic hyperplasia (white arrow) , proliferation of polymorph nuclear inflammatory cells (black arrow) (H and E , 40X).

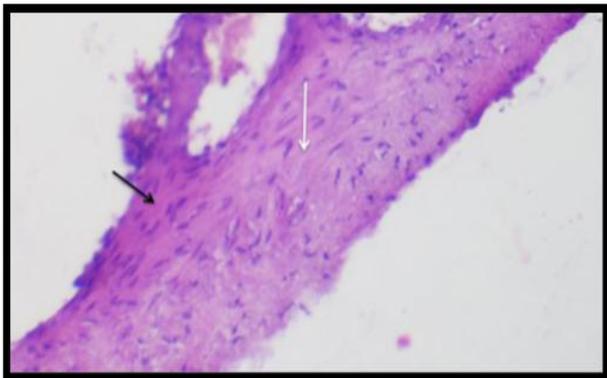


Figure 4. Spleen section of an animal non treated with (Keprofix® Oral) showed the significant thickness in capsule with fibrous connective tissue fibers (white arrow), proliferation of fibroblasts (black arrow) (H and E2 , 40X).

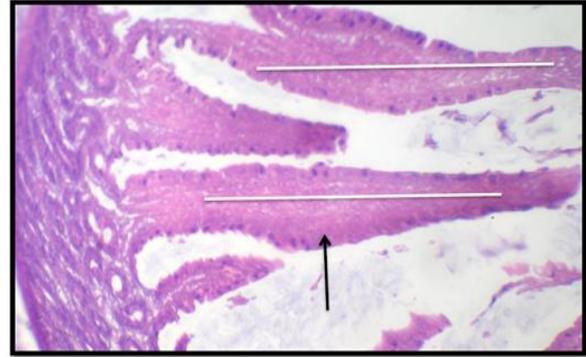


Figure 5. an intestinal section of an animal treated with (Keprofix® Oral) orally, showed the massive changes on width and height of intestinal villi characterized by increase on both of them (white arrow), with hyperplasia of villous mucosal epithelia (black arrow) (H and E , 40X).

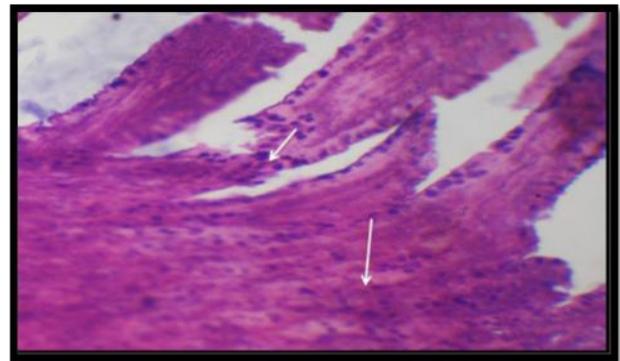


Figure 6. an intestinal section of an animal non treated with (Keprofix® Oral) showed the marked and heavy leukocytic inflammatory cells infiltration (white arrow) (H and E , 40X).

Gut health significantly impacts the growth rate and feed efficiency of poultry and monogastric animals (28).

The most important vital role of organic acid is to increase the growth of intestine which reflected on increase the digestive performance of gut this agree with Adil *et al.*(1) were showed a significant increment in the height of intestinal villi in duodenum (1,410.38 vs. 1,166.88 μm), ileum (876.32 vs. 676.13 μm) and jejunum (1,124.72 vs. 984.05 μm) than the respective control groups when Inclusion of 3% butyric acid in chicken diet.

The present study demonstrated that cecal infusion of propionate increased colonic length and selectively enhanced the levels of tight junction proteins in the jejunal mucosa. The findings highlight the advantageous effects of propionate in the large intestine on intestinal development and epithelial barrier integrity in growing pigs (29).

Short-chain fatty acids (SCFAs)The primary products of microbial fermentation of non-digestible nutrients in the large intestine include acetate, propionate and butyrate. SCFAs, recognized as energy substrates, are efficiently processed by the liver and intestinal epithelium. Moreover, SCFAs function as signaling molecules, crucial for preserving gut barrier integrity. SCFAs, particularly butyrate, are recognized as the primary

energy source for intestinal epithelial cells, supplying 60–70% of the energy necessary for colonic epithelial growth (30). Subsequent research has demonstrated that SCFAs affect biological processes and activities in the colon, including differentiation and cell proliferation (31).

Liu *et al.*(32) reported that the addition of the product enhanced villus height and crypt depth in the jejunum, as well as the spleen index at 42 days, compared to the control group. A prior study demonstrated that intravenous infusion of sodium butyrate enhanced the expression of genes associated with intestinal growth in normally developing pigs (26).

REFERENCES

- 1) Adil, S., Banday, T., Bhat, G. A., Mir, M. S., & Rehman, M. (2010). Effect of dietary supplementation of organic acids on performance, intestinal histomorphology and serum biochemistry of broiler chicken. *Veterinary Medicine International*, 2010, 1–7.
- 2) Mirza, W. M., Rehman, Z. U., & Mukhtar, N. (2016). Use of organic acids as potential feed additives in poultry production. *Journal of World's Poultry Research*, 6(3), 105–116.
- 3) Huyghebaert, G., Richard, D., & van Immerseel, F. (2011). An update on alternatives to antimicrobial growth promoters for broilers. *Veterinary Journal*, 187, 182–188.
- 4) Mohyla, P., Bilgili, S. F., Oyarzabal, O. A., Warf, C. C., & Kemp, G. K. (2007). Application of acidified sodium chlorite in the drinking water to control *Salmonella* serotype *Typhimurium* and *Campylobacter jejuni* in commercial broilers. *Journal of Applied Poultry Research*, 16, 45–51.
- 5) Youssef, I. M. I., Mostafa, A. S., & Abdel-Wahab, M. A. (2017). Effects of dietary inclusion of probiotics and organic acids on performance, intestinal microbiology, serum biochemistry and carcass traits of broiler chickens. *Journal of World Poultry Research*, 7(2), 57–71.
- 6) Regal, B. V. (2014). Scientific opinion on the safety and efficacy of formaldehyde for all animal species. *European Food Safety Authority Journal*, 12, 3561.
- 7) Ndelekwute, E. K., Unah, U. L., & Udoh, U. H. (2019). Effect of dietary organic acids on nutrient digestibility, faecal moisture, digesta pH and viscosity of broiler chickens. *MOJ Anatomy & Physiology*, 6(2), 40–43.
- 8) Yadav, A. S., Kolluri, G., Gopi, M., Karthik, K., Malik, Y. S., & Dhama, K. (2016). Exploring alternatives to antibiotics as health promoting agents in poultry- a review. *Journal of Experimental Biology and Agricultural Sciences*, 4(3s), 368–383.
- 9) Anderson, G.G., Palermo, J.J., Schilling, J.D., Roth, R., Heuser, J., Hultgren, S.J., (2003). Intracellular bacterial biofilm-like pods in urinary tract infections In dogs. *Science* 301, 105-107.
- 10) Luna LG (1968). In Manual of Histological Staining Methods of the Armed Forces Institute of Pathology. (3rd edn), New York: McGraw Hill.
- 11) Sheehan, D.C. and Hrapchak, B.B. (1980) Theory and practice of histotechnology . 2nd Edition, The CV Mosby Company, St Louis
- 12) Al-Mohammed, N.t.; Al-Rawi, Kh. M.; Khames, M.A. and Al-Marani, . (1986). principles of statistics. Ministry of higher education and scientific research. Baghdad university .
- 13) Pearlin.B.V., Muthuvel,Sh., Govidasamy,P., Villavan,M., Alagawany, M., Farag,M.R., Dhama,K., Gopi1,M. (2019) . Role of acidifiers in livestock nutrition and health: A review. *J Anim Physiol Anim Nutr.* 2020;104:558–569.
- 14) Smith, A. L., et al. (2019). "Dietary supplementation of organic acids and their effect on the growth performance, immune organ weight, and intestinal health of broiler chickens." *Poultry Science Journal*, 98(4), 1845-1852.
- 15) Devi, S. M., Lee, K. Y., & Kim, I. H. (2016). Analysis of the effect of dietary protected organic acid blend on lactating sows and their piglets. *Revista Brasileira De Zootecnia*, 45(2), 39–47.
- 16) Abdel-Fattah, S. A., Ei-Sanhoury, M. H., Ei-Mednay, N. M., & Abdul- Azeem, F. (2008). Thyroid activity, some blood constituents, organs morphology and performance of broiler chicks fed supplemental organic acids. *International Journal of Poultry Science*, 7(3), 215–222.
- 17) Tomar, S, Singh, S. K., Singh, R., & Singh, P. (2020). "Effect of butyric acid supplementation on growth performance, blood biochemical parameters and liver enzyme activity in broiler chicken." *International Journal of Chemical Studies*, 8(6), 332-336.
- 18) Yesilbag, D., & Colpan, I. (2006). Effects of organic acid supplemented diets on growth performance, egg production and quality and on serum parameters in laying hens. *Revue De Medecine Veterinaire*, 157, 280–284.
- 19) Yan, X., Zhang, B., Hao, X., Huang, S., Wu, Y., & Tang, J. (2018). "Effects of dietary supplementation with leonurine hydrochloride on growth performance, immune organ weight, and antioxidant capacity in broiler chickens." *Journal of Applied Animal Research*, 46(1), 1461-1465.
- 20) Knarreborg, A., Miquel, N., Granli, T., & Jensen, B. B. (2002). Establishment and application of an *in vitro* methodology to study the effects of organic acids on coliform and lactic acid bacteria in the proximal part of the gastrointestinal tract of piglets. *Animal Feed Science & Technology*, 99, 131–140.
- 21) Mroz, Z., Koopmans, S. J., Bannink, A., Partanen, K., Krasucki, W., Overland, M., & Radcliffe, S. (2006). Carboxylic acids as bioregulators and gut growth promoters in nonruminants. In R. Mosenthin, J. Zentek, & T. Zebrowska (Eds.), *Biology of nutrition in*

- growing animals (pp. 81–133). Edinburgh, UK: Elsevier.
- 22) Hassan, H. M. A., Mohamed, M. A., Youssef, A. W., & Hassan, E. R. (2010). Effect of using organic acids to substitute antibiotic growth promoters on performance and intestinal microflora of broilers. *Asian- Australian Journal of Animal Sciences*, 23, 1348–1353.
 - 23) Khan, S. H., & Iqbal, J. (2016). Recent advances in the role of organic acids in poultry nutrition. *Journal of Applied Animal Research*, 44(1), 359–369.
 - 24) Kim, J. W., Kim, J. H., & Kil, D. Y. (2015). Dietary organic acids for broiler chickens: A review. *Revista Colombiana De Ciencias Pecuarias*, 28, 109–123.
 - 25) Getachew, T. (2016). A review on effects of probiotic supplementation in poultry performance and cholesterol levels of egg and meat. *Journal of World Poultry Research*, 6(1), 31–36.
 - 26) Yang, Y., Lee, K. Y., & Kim, I. H. (2019). Effects of dietary protected organic acids on growth performance, nutrient digestibility, fecal microflora, diarrhea score, and fecal gas emission in weanling pigs. *Canadian Journal of Animal Science*, 99(3), 514–520.
 - 27) Easter, R. A. (2018). "Nutritional and Physiological Aspects of Gastrointestinal Health in Monogastric Animals." In *Proceedings of the 2018 Nutrition Conference*.
 - 28) Gracia, V., Catala-Gregori, P., Hernandez, F., Megias, M. D., & Madrid, J. (2017). Effect of formic acid and plant extracts on growth, nutrient digestibility, intestine mucosa morphology, and meat yield of broilers. *Journal of Applied Poultry Research*, 16, 555–562.
 - 29) Suryanarayana, M. V. A. N., Ravi, A., & Suresh, J. (2010). Effect of dietary supplementation of Sodium formate on the performance and carcass characteristics of cross-bred pigs. *Indian Journal Animal Nutrition*, 27, 411–414.
 - 30) Scheppach, W. (1994). "Effects of short chain fatty acids on gut morphology and function." *Gut*, 35(1 Suppl), S35–S38.
 - 31) De Vadder, F., Kovatcheva-Datchary, P., Goncalves, D., Vinera, J., Zitoun, C., Duchamp, A., Bäckhed, F., & Mithieux, G. (2014). "Microbiota-generated metabolites promote metabolic benefits via gut-brain neural circuits." *Cell*, 156(1-2), 84-96.
 - 32) Liu, Y., Yang, X., Xin, H., Chen, S., Yang, C., Duan, Y., & Yang, X. (2017). Effects of a protected inclusion of organic acids and essential oils as antibiotic growth promoter alternative on growth performance, intestinal morphology and gut microflora in broilers. *Animal Science .Journal*, 88(9), 1414–1424.