



<https://muthjas.mu.edu.iq/>

<http://doi.org/10.52113/mjas04/13.1/44>

Histological changes and intestinal parameters of broiler Ross 308 chickens by adding different levels of citric acid, acetic acid, and their mixture to the diet

Alaa Faisal Abdul-Sada Al-Zubaidi and Jassim Kassim Al-Gharawi

Animal Production Department, Agriculture College, Al-Muthanna University, Iraq.

Abstract:

The experiment was conducted at the Agricultural Research and Experiment Station, College of Agriculture, Al-Muthanna University, from February 1, 2025, to March 7, 2025. 315 one-day-old, unsexed Ross 308 hybrid broiler chicks, weighing 38 grams each, were used. The chicks were randomly distributed into 7 experimental treatments, with 45 chicks per treatment and three replicates per treatment (15 chicks/replicate). The experimental treatments were as follows: T1: Control treatment with no additives. T2 and T3 add of citric acid at a concentration of 1 and 2 gm/kg of diet. T4 and T5 add of acetic acid at a concentration of 1 and 2 gm/kg of diet. T6 and T7 T6: Add of citric acid + acetic acid at a concentration of 0.5 and 1 gm/kg for each to the diet. The results indicated a significant improvement in both the weight and relative length of the small intestine segments (duodenum, jejunum, and ileum). Furthermore, there was an improvement in histological parameters, namely villus height, crypt depth, and the villus height-to-crypt depth ratio. T7 significantly outperformed ($P \leq 0.05$) compare with all experimental treatments and the control treatment.

Keywords: Citric acid, Acetic acid, Intestine, Histology, broiler.

Introduction:

Acids can contribute to reducing stress levels. They can help alleviate stress in broiler chickens (Yue *et al.*, 2022). Stress is described as an organism's

response in an attempt to adapt to or protect itself from the harmful effects of surrounding pressures. Physiological stress in animals can occur as a result of many factors, including extreme heat or cold, high

stocking density, hunger or thirst, noise, and transportation. This can negatively affect the birds' immune system, making them more susceptible to disease and increasing mortality rates (Broom, 2015; Al Salman and Al-Gharawi, 2019).

Due to the effects of acetic acid on intestinal histomorphological parameters, it can promote proper intestinal morphology and function, nutrient absorption, and overall intestinal health. This leads to improved growth indicators, as a healthier intestinal lining facilitates better nutrient transport into the bloodstream, ensuring poultry maximizes feed utilization (Amer *et al.*, 2021).

Citric acid (CA) effectively contributes to improving the microstructure of the small intestine in poultry, which positively impacts digestive health and absorption efficiency. Khosravinia *et al.* (2015) demonstrated that using a 3% concentration of citric acid in poultry diets, led to a significant decrease in intestinal epithelium thickness, and an increase in villus length, crypt depth, and goblet cell number, indicating an improvement in absorption function and the condition of the intestinal mucosa.

Adding citric and acetic acids, either individually or in combination, to poultry feed can also affect intestinal morphology, the microscopic structure of the intestinal lining. Research indicates that adding these organic acids can lead to beneficial changes in intestinal structure, such as increased intestinal villus height and surface area

(Li *et al.*, 2024). These adaptations enhance the surface area for nutrient absorption, contributing to improved overall health and productivity in poultry. Recent studies have revealed the effect of using acids in poultry feed on inducing morphological changes and repair of the digestive tract, particularly in the duodenum, jejunum, and ileum, in addition to reducing the severity of gastrointestinal pathogens (Saleem *et al.*, 2020).

Materials and Methods:

This experiment was conducted at the poultry farm of the Agricultural Research and Experiment Station, College of Agriculture, Al-Muthanna University, from February 1, 2025, to March 7, 2025, to demonstrate the effect of adding different levels of citric acid, acetic acid, and their mixture to the feed on some intestinal characteristics of broiler chickens. 315 day-old Ross 308 broiler chicks, ready for market, were used. The chicks were raised in four-tiered batteries, each tier containing a cage measuring 1.5 × 1 m. The chicks were randomly distributed into seven experimental treatments, with 45 chicks per treatment and three replicates per treatment (15 chicks/replicate), as follows:

T1: (Control treatment without additives).

T2: Add citric acid at a concentration of 1 gm/kg of diet.

T3: Add citric acid at a concentration of 2 gm/kg of diet.

T4: Add acetic acid at a concentration of 1 gm/kg of diet.

T5: Add acetic acid at a concentration of 2 gm/kg of diet.

T6: Add citric acid at a concentration of 0.5 gm/kg of diet+ acetic acid at a concentration of 0.5 gm/kg of diet.

T7: Add citric acid at a concentration of 1 gm/kg of feed, along with acetic acid at a concentration of 1 gm/kg of diet.

The organic acids acetic acid and citric acid were obtained from a chemical import office in Baghdad (Bab Al-Muadham). The two organic acids were added to the experimental feed in the specified quantities. The feed was spread on a clean, waxed plastic sheet. The organic acids were then mixed with the feed, stirring to ensure even distribution of the feed pieces. The mixed feed was stored in 50 kg woven polypropylene bags.

Characteristics of the Intestines:

Relative Weight of the Intestines:

The small intestine was separated from the internal organs. The sections of the small intestine were then separated (duodenum, jejunum, ileum) each. The intestines were cleaned of any remaining material and waste in these sections. Each of these sections was then weighed using a three-decimal-place sensitive electronic balance, a Kuren 572 model of Turkish origin. The ratio of each section to the total body weight was calculated according to the following equation, as reported by Al-Gharawi (2012):

$$\begin{aligned} & \text{relative weight of intestinal segments} \\ & = \frac{\text{Weight of each part of the small intestine (gm)}}{\text{Living body weight (gm)}} \\ & \times 100 \end{aligned}$$

Relative length of intestines:

Measurements of the length of the small intestine were taken from six birds per treatment at 35 days of age after slaughter and removal of their viscera. The intestines were separated at the point of connection with the gizzard and measured using a metric scale for parts of the small intestine (duodenum, jejunum, ileum) and ceca, each separately. The relative weight of the length of the intestines was calculated relative to the live weight according to the following equation, which was reported by Al-Gharawi (2012):

$$\begin{aligned} & \text{relative length of intestinal segments} \\ & = \frac{\text{Length of each part of the small intestine (gm)}}{\text{Living body weight (gm)}} \\ & \times 100 \end{aligned}$$

Study of the Histological Characteristics of the Small Intestine:

Preparation of Histological Sections:

Four sections were taken for each treatment, from each segment of the small intestine (duodenum, jejunum, and ileum). The sections were 4 cm long and 35 days old, i.e., at the end of the experiment. The contents were then removed, and the sections were washed several times with tap water. The samples were then placed in Bouin's fixative, prepared by mixing 75 ml of saturated aqueous picric acid

with 20 ml of 40% formalin and 5 ml of glacial acetic acid for 24 hours. Afterward, they were transferred to 70% ethyl alcohol to remove the color of the fixative. The sections were then dehydrated by passing them through a series of increasing concentrations of 70%, 80, 90, and 95% absolute alcohol. For two hours per replicate, this was followed by xylene clearing and finally infiltration and embedding with paraffin wax at a melting point between 56–58°C. By preparing paraffin wax-filled molds for embedding, and after drying, serial cross-sections 5 µm thick were prepared using a rotary microtome. The tissue sections were fixed to glass slides using Aupts adhesive and stained with Harris-Hematoxylin and Eosin stain. According to the method of Richard and Francis (1973); Uni *et al.* (1998); and Tako and Ferket (2004), the slides were then covered with glass covers and DPX was applied.

Examination of Histological Sections:

All prepared histological slides were examined using a compound microscope. All measurements were recorded using a 400X ocular micrometer calibrated to a stage micrometer. Villi length, crypt depth, and villi-to-crypt depth ratio (V/C) were measured. Villi length was

measured from the tip of the villi to their attachment to the crypts, while crypt depth was the immersion distance of adjacent villi (Uni *et al.*, 1999).

Results and Discussion:

Table (1) data shows the effect of adding different levels of citric and acetic acid on the relative weight of small intestine segments in broiler carcasses. The results showed a significant increase ($P \leq 0.05$) in the relative weight of the duodenum, jejunum, ileum, and small intestine in favor of treatment T7, which significantly outperformed ($P \leq 0.05$) treatment T6. T6, in turn, significantly outperformed ($P \leq 0.05$) treatments T5 and T3. T5 and T3 were significantly superior ($P \leq 0.05$) to treatments T4 and T2, which were significantly superior ($P \leq 0.05$) to the control treatment.

The relative weight of the duodenum was 0.366, 0.451, 0.511, 0.452, 0.513, 0.592, and 0.624. The relative weight of the jejunum was 1.19, 1.28, 1.35, 1.28, 1.35, 1.44, 1.50, and 1.21.38. The relative weight of the ileum was 1.315, 1.364, 1.425, 1.378, 1.427, 1.530, and 1.605. The relative weight of the small intestine was 2.87, 3.09, 3.29, 3.12, 3.29, 3.56, and 3.73 for treatments T1, T2, T3, T4, and T5. T6, T7, respectively.

Table (1) Effect of adding different levels of citric and acetic acid and their mixture to the feed on the relative weight of small intestine parts (%) of broiler carcasses ± standard error.

Treatments	Relative weight (%)			
	Duodenum	Jejunum	Ileum	Intestine
T1	0.002 ± 0.366 e	0.010 ± 1.19 e	0.010 ± 1.315 e	0.020 ± 2.87e

T2	0.009 ± 0.451 d	0.005 ± 1.28 d	0.003 ± 1.364 d	0.014 ± 3.09d
T3	0.002 ± 0.511 c	0.002 ± 1.35 c	0.002 ± 1.425 c	0.003 ± 3.29c
T4	0.002 ± 0.452 d	0.004 ± 1.28 d	0.001 ± 1.378 d	0.004 ± 3.12d
T5	0.004 ± 0.513 c	0.002 ± 1.35 c	0.002 ± 1.427 c	0.009 ± 3.29c
T6	0.002 ± 0.592 b	0.005 ± 1.44 b	0.002 ± 1.530 b	0.008 ± 3.56b
T7	0.004 ± 0.624 a	0.005 ± 1.50 a	0.004 ± 1.605 a	0.012±3.73 a
Sig.	*	*	*	*

Table (2) shows the effect of adding different levels of citric and acetic acid on the relative length of the small intestine segments of broiler carcasses. A significant advantage ($P \leq 0.05$) was observed in the relative length of the duodenum in treatment T7, which was significantly superior ($P \leq 0.05$) to treatment T6. T6, in turn, was significantly superior ($P \leq 0.05$) to treatments T5 and T3, which were themselves significantly superior ($P \leq 0.05$) to treatments T4 and T2. T4 and T2 were also significantly superior ($P \leq 0.05$) to the control treatment. Regarding the relative length of the jejunum and the average relative length of the intestine, all experimental treatments showed a significant advantage ($P \leq 0.05$) compared to the control treatment. No significant differences were observed between treatments T2, T3, T4, T5, T6, and T7. Regarding the relative length of the winners, treatment T7 showed a

significant advantage ($P \leq 0.05$) over treatment T6, which was significantly superior ($P \leq 0.05$) to treatments T3 and T5. Treatment T3 and T5 were superior to treatment T4, which was significantly superior ($P \leq 0.05$) to treatment T2. Treatment T2, in turn, was significantly superior ($P \leq 0.05$) to the control treatment. While there were no significant differences between treatments T3 and T5, the relative length coefficients for the duodenum were recorded as 1.30, 1.42, 1.49, 1.43, 1.50, 1.57, and 1.61. The relative length coefficients for the fasting period were 2.46, 2.32, 3.36, 3.32, 3.36, 3.42, and 3.50. The relative length coefficients for the ileus were 3.56, 3.62, 3.72, 3.64, 3.72, 3.64, 3.72, 3.79, and 3.84. Regarding the relative length of the small intestine, the data in the aforementioned table recorded 7.33, 8.37, 8.85, 8.41, 8.59, 8.79, and 8.96 for treatments T1, T2, T3, T4, T5, T6, and T7 respectively.

Table (2) Effect of adding different levels of citric and acetic acid and their mixture to the feed on the relative length of small intestine parts (%) of broiler carcasses ± standard error.

Treatments	Relative weight (%)			
	Duodenum	Jejunum	Ileum	Intestine
T1	0.004 ± 1.30e	0.663 ± 2.46 b	0.006 ± 3.56 f	0.65 ± 7.33 b
T2	0.004 ± 1.42d	0.003 ± 3.32 a	0.001 ± 3.62 e	0.006 ± 8.37 a
T3	0.003 ± 1.49 c	0.002 ± 3.36 a	0.003 ± 3.72 c	0.04 ± 8.85 a
T4	0.002 ± 1.43 d	0.004 ± 3.32 a	0.011 ± 3.64 d	0.01 ± 8.41 a

T5	0.003 ± 1.50 c	0.001 ± 3.36 a	0.002 ± 3.72 c	0.04 ± 8.59 a
T6	0.006 ± 1.57 b	0.004 ± 3.42 a	0.002 ± 3.79 b	0.01 ± 8.79 a
T7	0.002 ± 1.61 a	0.005 ± 3.50 a	0.007 ± 3.84 a	0.01 ± 8.96 a
Sig.	*	*	*	*

Tables 1 and 2 illustrate the superiority of the treatment with the highest concentration of the mixture in terms of intestinal characteristics, specifically weight and relative length, compared to the other experimental and control treatments. This was observed in poultry fed diets containing citric and acetic acids. This may be attributed to the ability of organic acids to stimulate cell division in the intestinal lining and the resulting decrease in gastrointestinal pH, leading to an increase in intestinal villus height and crypt depth. This, in turn, increases intestinal tissue mass in response to the increased surface area available for absorption (Adil *et al.*, 2010). Alternatively, it may be due to the action of organic acids as antibacterial agents against harmful bacteria such as *E. coli* and *Salmonella*. By reducing the pathogenic bacterial load, they decrease the production of toxins that cause inflammation and erosion of the intestinal wall. This allows the intestine to grow healthily and increase its relative weight due to improved mucosal integrity, increased body mass, and weight gain. Consequently, this positively impacts Lengths and weights of the small intestine (Ghazala *et al.*, 2011). These results are consistent with those reported by Paul *et al.* (2007), indicating that the addition of organic acids leads to an increase in the length of the intestinal villi (villus height) and the depth of the

crypts (crypt depth). This increase in the size of the cells lining the intestine has a positive effect on increasing the muscular and tissue mass of the small intestine.

The data in Tables 3, 4, and 5 show the effect of adding different levels of citric and acetic acid on villus height, crypt depth (μm), and villus height-to-crypt depth ratio in the intestines of broiler chickens.

The results in the table indicate a significant advantage ($P \leq 0.05$) for treatment T7 in villus height and villus height-to-crypt depth ratio in the duodenum compared to treatment T6, which was itself significantly superior ($P \leq 0.05$). Treatments T5 and T3 were also significantly superior ($P \leq 0.05$) compared to treatments T2 and T4, which in turn were significantly superior ($P \leq 0.05$) to the control treatment. While no significant differences ($P \leq 0.05$) were observed regarding the depth of the duodenal crypt, a significant increase ($P \leq 0.05$) was observed in favor of treatment T7 over treatments T6, T5, and T3, which in turn significantly outperformed treatment T4 ($P \leq 0.05$), which itself significantly outperformed treatment T2 ($P \leq 0.05$), which in turn significantly outperformed treatment T2 ($P \leq 0.05$), compared to the control treatment. No significant differences were recorded between treatments T3, T5, and T6 on the one hand, and

treatments T2 and T4 on the other. The average villus height in the duodenal region was 75.38, 76.09, 76.77, 76.11, 76.79, 77.31, and 77.92 μm . Meanwhile, the average crypt depth was 10.66, 10.70, 10.74, 10.70, 10.73, 10.75, and 10.80 μm . The percentage of villus height relative to crypt depth was 17.06, 7.10, 7.14, 7.11, 7.15, 7.18, and 7.21 for treatments T1, T2, T3, T4, T5, T6, and T7, respectively.

Regarding the jejunum and ileum regions in terms of villus height, crypt depth, and villus height-to-crypt depth ratio, T7 showed a significant

advantage ($P \leq 0.05$) over T6, which in turn significantly outperformed treatments T5 and T3 ($P \leq 0.05$), and T4 and T2 ($P \leq 0.05$) compared to the control. However, T2 showed a significant difference in villus height in the ileum compared to the other treatments, recording 78.64 (compared to the control). No significant differences were found between treatments T5 and T3 on the one hand, and T4 and T2 on the other. However, the table shows a significant difference between T4 and T2 in villus height in the ileum.

Table (3) Effect of adding different levels of citric and acetic acid and their mixture to the feed on villus height, crypt depth (μm) and the ratio of villus height to crypt depth in the duodenum of broiler chickens \pm standard error.

Treatments	villus height (μm)	crypt depth (μm)	V/C
T1	0.02 \pm 75.38 e	0.006 \pm 10.66 d	0.002 \pm 7.06 e
T2	0.02 \pm 76.09 d	0.006 \pm 10.70 c	0.006 \pm 7.10 d
T3	0.05 \pm 76.77 c	0.003 \pm 10.74 b	0.004 \pm 7.14 c
T4	0.01 \pm 76.11 d	0.003 \pm 10.70 c	0.003 \pm 7.11 d
T5	0.05 \pm 76.79 c	0.006 \pm 10.73 b	0.007 \pm 7.15 c
T6	0.03 \pm 77.31 b	0.003 \pm 10.75 b	0.005 \pm 7.18 b
T7	0.02 \pm 77.92 a	0.005 \pm 10.80 a	0.001 \pm 7.21 a
Sig.	*	*	*

Table (4) Effect of adding different levels of citric and acetic acid and their mixture to the feed on villus height, crypt depth (μm) and the ratio of villus height to crypt depth in the jejunum of broiler chickens \pm standard error.

Treatments	villus height (μm)	crypt depth (μm)	V/C
T1	0.02 \pm 77.11 e	0.006 \pm 10.86 e	0.002 \pm 7.09 e
T2	0.01 \pm 77.90 d	0.006 \pm 10.91 d	0.002 \pm 7.13 d
T3	0.02 \pm 78.25 c	0.003 \pm 10.93 c	0.009 \pm 7.15 c
T4	0.02 \pm 77.93 d	0.006 \pm 10.91 d	0.001 \pm 7.13 d
T5	0.006 \pm 78.26 c	0.003 \pm 10.94 c	0.001 \pm 7.15 c
T6	0.03 \pm 78.69 b	0.003 \pm 10.97 b	0.001 \pm 7.16 b
T7	0.03 \pm 79.08 a	0.003 \pm 11.00 a	0.005 \pm 7.18 a
Sig.	*	*	*

Table (5) Effect of adding different levels of citric and acetic acid and their mixture to the feed on villus height, crypt depth (μm) and the ratio of villus height to crypt depth in the ileum of broiler chickens \pm standard error.

Treatments	villus height (μm)	crypt depth (μm)	V/C
T1	0.01 \pm 77.83 f	0.006 \pm 10.92 e	0.003 \pm 7.12 e
T2	0.01 \pm 78.64 e	0.003 \pm 10.97 d	0.008 \pm 7.16 d
T3	0.01 \pm 79.14 c	0.003 \pm 11.01 c	0.008 \pm 7.18 c
T4	0.01 \pm 78.70 d	0.003 \pm 10.98 d	0.001 \pm 7.16 d
T5	0.03 \pm 79.16 c	0.003 \pm 11.02 c	0.002 \pm 7.17 c
T6	0.02 \pm 79.77 b	0.003 \pm 11.06 b	0.005 \pm 7.20 b
T7	0.02 \pm 80.16 a	0.003 \pm 11.09 a	0.007 \pm 7.22 a
Sig.	*	*	*

The significant improvement ($P < 0.05$) observed in villus length and C/V ratio in treatment T7 is attributed to the synergistic effect of citric and acetic acids. The highest villus height was recorded in the duodenum, jejunum, and ileum. This is due to the synergistic effect of the citric and acetic acid mixture. These acids improve the intestinal microbiome and lower intestinal pH, inhibiting the growth of pathogenic bacteria and thus reducing the secretion of toxins that attack and erode the villi. These results are consistent with Islam *et al.* (2024), who reported that organic acids provide tissue protection for the intestine. This enhances absorption efficiency and reduces the energy expenditure required for tissue repair. This confirms the hypothesis of Schoele *et al.* (2003) that a stable intestinal environment positively impacts epithelial tissue structure. This was further confirmed by Sun *et al.* (2022), who stated that increasing The length of the villi is directly related to increased absorption efficiency and

improved feed conversion ratio. Furthermore, a high C/V ratio in superior groups indicates a reduced rate of cell renewal and the allocation of energy to growth.

References:

- Adil, S., Banday, T., Bhat, G. A., Mir, M. S., and Rehman, M. (2010). Effect of dietary supplementation of organic acids on performance, intestinal histomorphology, and serum biochemistry of broiler chicken. SAGE-Hindawi Access to Research Veterinary Medicine International, Article ID 479485, 7 pages.
- Al Salman, N.T.Sh. and Al-Gharawi. J.K.M. (2019). Effect of Eucalyptus leaves water extract on some productive traits of broilers. Plant Archives Vol. 19, Supplement 1, pp. 920-923.
- Al-Gharawi, J.K.M. 2012. Effect of in ovo probiotics injection on production and immunological traits and intestinal flora of

- broilers. Ph. D Dissertation. Department of Animal Science, University of Baghdad. Iraq.
- Amer, S.A., S. Tolba, D.M.M. AlSadek, D.M.A. Fattah, A.M. Hassan and Metwally, A. (2021). Effect of supplemental glycerol monolaurate and oregano essential oil blend on the growth performance, intestinal morphology, and amino acid digestibility of broiler chickens. In BMC Veterinary Research (Vols. 17). BMC Veterinary Research. <https://doi.org/10.1186/s12917-021-03022-5>
- Broom L.J. (2015) Organic acids for improving intestinal health of poultry. *World's Poult Sci J*; 71(4): 405–630-642. <https://doi.org/10.1017/S0043933915002391>
- Ghazalah, A.A., A.M. Atta, K. Elkloub, M. EL. Moustafa and R. F. H. Shata, 2011. Effect of dietary supplementation of organic acids performance nutrients digestibility and health of broiler chicks . *Poultry Sci*.10(3):176-184.
- Islam, Z., Sultan, A., Khan, S., Khan, K., Jan, A. U., Aziz, T., Alharbi, M., Alshammari, A., & Alasmari, A. F. (2024). Effects of an organic acids blend and coated essential oils on broiler growth performance, blood biochemical profile, gut health, and nutrient digestibility. *Italian Journal of Animal Science*, 23(1), 152–163. <https://doi.org/10.1080/1828051X.2023.2297562>
- Khosravinia, H., Nourmohammadi, R., & Afzali, N. (2015). Productive performance, gut morphometry, and nutrient digestibility of broiler chicken in response to low and high dietary levels of citric acid. *The Journal of Applied Poultry Research*, 24(4), 470–480. <https://doi.org/10.3382/japr/pfv050>
- Paul, S.K., G. Halder, M.K. Mondal and G. Samanta (2007) Effect of organic acid salt on the performance and gut health of broiler chicken. *J Poult Sci*; 44:389-395.
- Richard, H.C. and H.B. Francis. 1973. Duodenal villas and epithelial cellular migration in conventional and germ-free chicks. *Poultry Science*, 52: 2276-2280.
- Saleem, K., Saima, Rahman, A., Pasha, T. N., Mahmud, A., & Hayat, Z. (2020). Effects of dietary organic acids on performance, cecal microbiota, and gut morphology in broilers. *Tropical Animal Health and Production*, 52(6), 3589–3596. <https://doi.org/10.1007/s11250-020-02396-2>
- Schoeler, M., Ellero-Simatos, S., Birkner, T., Mayneris-Perxachs, J., Olsson, L. M., Brodin, H., Loeber, U., Kraft, J. D., Polizzi, A., Martí-Navas, M., Puig, J., Moschetta, A., Montagner, A., Gourdy, P., Heymes, C., Guillou, H., Tremaroli, V., Fernández-Real, J.,

- Forslund, S., ... Caesar, R. (2023). The interplay between dietary fatty acids and gut microbiota influences host metabolism and hepatic steatosis. In Nature Communications (Vols. 14). Nature Communications. <https://doi.org/10.1038/s41467-023-41074-3>
- Sun, H. Y., Zhou, H. B., Liu, Y., Wang, Y., Zhao, C., & Xu, L. M. (2022). Comparison of organic acids supplementation on the growth performance, intestinal characteristics and morphology, and cecal microflora in broilers fed corn-soybean meal diet. *Animal Bioscience*, 35(11), 1689–1697. <https://doi.org/10.5713/ab.21.0448>
- Tako, E. and P.R. Ferket. 2004. The effect of inovo feeding on carbohydrates and beta – methyle Hydroxybutyrate (HMB) on the development of the digestive tract.
- Uni, Z., S. Ganot and D. Sklan. 1998. Poshatch development of mucosal function in the broiler small intestine. *Poultry Science*, 77: 75-82.
- Uni, Z., Y. Noy and D. Sklan. 1999. Posthatch development of small intestinal function in the poultry. *Poultry Science*, 78: 215-221.
- Yue, D., Chen, X., Zhu, Y., Macinko, J., & Meng, Q. (2022). Reductions in under-5 mortality and public health improvements of the China Healthy Cities (Counties) initiative: a nationwide quasi-experimental study. In *BMJ Global Health* (Vols. 7). BMJ Global Health. <https://doi.org/10.1136/bmjgh-2021-007154>