Trends in Animal and Poultry Sciences
https://journals.pagepal.org/index.php/TAPS
ISSN (E), 3007-293X; (P), 3007-2921
https://doi.org/10.54219/taps.02.01.2024.91



Evaluating the effects of Vitamin C, Betaine, Vinegar, and Sodium Bicarbonate on growth performance, digestibility, immune response, and hematological parameters in Broilers

Muhammad Asad[1]*, Muhammad Usman-Ul-Hassan[1], Junaid Ali Khan[1], Atif Rehman[1], Asif Raza[1], Gul Naz[2]

[1]*Department of Poultry Sciences, Muhammad Nawaz Shareef University of Agriculture, Multan, Pakistan.
[2]Institute of Molecular Biology and Biotechnology, University of Lahore, Pakistan

Article Info

Keywords:

Heat stress, Vitamin C, Betaine, Vinegar, Sodium bicarbonate, Growth performance, Digestibility

Date:

Received: 15 January 2023
Accepted: 10 April 2024
Published: 15 June 2024

Copyright: © 2024 by the authors. This article is distributed under the Creative Commons Attribution (CC BY) license, allowing for open access and sharing under specified terms and conditions. (https://creativecommons.org/licenses/by/4.0/).

Abstract

Heat stress significantly impacts the poultry industry, especially during the summer season, leading to reduced growth performance, feed intake, immunity, digestibility, and hematological disturbances in broiler chickens. This study aimed to evaluate the effects of Vitamin C, betaine, vinegar, and sodium bicarbonate supplementation on the growth performance, digestibility, immunity, and hematology of broilers under heat stress conditions. A total of 200 broiler chickens were divided into five groups (A-E), with Group A serving as a control group under ideal environmental conditions. The remaining groups (B-E) were subjected to heat stress at 37.5°C and supplemented with Vitamin C (250 mg/kg), betaine (2 g/kg), vinegar (10 ml/kg), and sodium bicarbonate (250 mg/kg), respectively. The study spanned 42 days, covering three stages: starter, grower, and finisher phases. Data on feed intake, weight gain, feed conversion ratio (FCR), hematological parameters, and immunity were collected and analyzed using ANOVA. Results indicated that Vitamin C supplementation significantly improved growth performance, feed intake, and FCR, making it the most effective treatment under heat stress. Betaine also showed favorable results but ranked second to Vitamin C. Vinegar and sodium bicarbonate negatively affected feed intake and FCR, though they improved hematological parameters. These findings suggest that Vitamin C is the best anti-stressor for broilers under heat stress, while betaine can also be used. However, vinegar and sodium bicarbonate should be avoided in such conditions due to their adverse effects on growth performance.

Introduction

Meat production, particularly in the poultry sector, has experienced significant growth over the past several decades (Mottet and Tempio, 2017). Pakistan's poultry industry plays a crucial role in addressing the gap between meat supply and demand, providing an affordable source of animal protein. As the availability of red meat continues to decline, poultry meat remains the most cost-effective source of protein for the general population, helping to stabilize animal protein prices. However, despite these efforts, protein consumption in Pakistan remains below the recommended levels. As demand for meat is expected to rise over time, the poultry sector must improve production efficiency and reduce costs, primarily through enhanced feed efficiency. Ensuring a consistent supply of chicken meat and eggs is a key objective for poultry industries globally. To meet this demand, the poultry industry has intensified its focus on high-quality broiler production (Gallus gallus domesticus) by adopting advanced farming

*asaddasti786@gmail.com

practices, integrating modern technologies, and developing precise diet formulations (Brugaletta et al., 2022).

One of the major challenges in poultry farming is heat stress, which occurs when the ambient temperature exceeds the birds' ability to dissipate heat. When temperatures rise beyond the thermoneutral zone, chickens reduce their feed intake and growth as a natural response to combat heat stress (Renaudeau et al., 2012). The global poultry industry has experienced a two fold increase in meat production over the past two decades, reaching 126 million tons by 2020. Poultry now accounts for approximately 37% of global meat production, up from 29% at the beginning of the century (Mottet and Tempio, 2017). As the world's population is projected to grow from 7.8 billion to 9.9 billion by 2050, the demand for poultry products will continue to rise, making it critical to address the challenges posed by heat stress (Kaneda et al., 2020).

Heat stress not only affects feed intake and growth but also impairs nutrient digestion. The activity of digestive enzymes, which are essential for nutrient absorption, is significantly reduced at higher temperatures (Hai et al., 2000, Al-Zghoul et al., 2019). In extreme cases, when birds are unable to dissipate heat effectively, multiple organ dysfunctions can occur, leading to severe physiological disturbances and even mortality (Shakeri et al., 2020).

Several studies have explored the effects of amino acid (AA) supplementation in heat-stressed broilers. When comparing diets with varying levels of AAs, no statistically significant difference was observed between birds on 100% AA diets and those on diets with higher AA levels, suggesting that additional AAs may exceed the birds' actual nutritional requirements. Notably, broilers subjected to cyclic heat stress performed better on diets with lower crude protein content but higher concentrations of methionine, lysine, and threonine compared to those on regular crude protein diets. Furthermore, improvements in intestinal health, indicated by the increased expression of tight junction proteins, were observed in heat-stressed birds (Xu et al., 2014).

Materials and Methods

The study was conducted at the poultry farm of Muhammad Nawaz Sharif University of Agriculture, Multan, Pakistan, using 200 Cobb-500 broiler chicks from a commercial hatchery. Before the chicks arrived, the poultry house and equipment were thoroughly cleaned and sanitized using a 5% formalin solution, with additional fumigation using potassium permanganate and formalin potassium permanganate (KMNO4) and formalin in a 1:2 ratio (17.5 grams of KMNO4 to 35 ml of formalin). An "all-in/all-out" system was applied to maintain hygiene.

Pre-brooding preparations ensured optimal conditions, including brooding temperature, relative humidity, and bedding material. Upon arrival, chicks were assessed for quality based on clean eyes, healed navels, and proper physical appearance. A sample of 50 chicks was weighed to assess average weight and uniformity. Fresh drinking water and feed were provided immediately, and baby feeders were used during the first three days. Crop fill was checked 24 hours post-placement, with 80% achieving proper crop fill. Brooding temperature started at 95°F and decreased by 5°F daily until it reached 75°F. All chicks received the same diet during the first week.

Experimental Design

After the first week, the chicks were divided into five groups: A, B, C, D, and E, each containing 40 chicks. Each group was further subdivided into four replicates (A1-A4, B1-B4, C1-C4, D1-D4, and E1-E4), with 10 birds per replicate to facilitate water treatment and feed management.

The 42-day trial was split into three phases: the starter phase (days 1–12), the grower phase (days 13–25), and the finisher phase (days 26–42). Diets for the starter phase consisted of 23% crude protein (CP) and 2850 Kcal/kg energy, followed by 20.84% CP and 3000 Kcal/kg energy in the grower phase, and 20% CP and 3100 Kcal/kg energy during the finisher phase. Birds were vaccinated per the recommended schedule, including vaccinations against Newcastle disease (ND), avian influenza (H9), infectious bursal disease (IBD), and infectious bronchitis (IBV).

Grouping and Treatment Administration

This experimental design describes a study to evaluate the impact of heat stress and dietary supplements on certain physiological and biological parameters in birds. Here's a brief interpretation of the experimental groups. Group A served as the control group, kept under ideal environmental conditions with no heat stress or supplements. The other four groups (B, C, D, and E) were subjected to heat stress, with the temperature set at 37.5°C ± 1°C. Dietary supplementation was administered as given in Table 1.

Table 1. The dietary supplements in different groups

Group	Dietary Supplement	Supplement Dose
A	No	
B	Vitamin C	250 mg/kg
C	Betaine	2 g/kg
D	Betaine	10 ml/kg
E	Sodium Bicarbonate	250 mg/kg

After the trial, three birds from each group were randomly selected to analyze growth performance, digestibility, immunity, and hematology.

Results

Feed Conversion Ratio (FCR)

The feed conversion ratio (FCR) was significantly affected by the different dietary treatments under heat stress (Fig.1).

© PagePal. All rights Reserved

The control group, which did not receive any supplementation, exhibited the highest FCR (2.03), indicating lower feed efficiency. In contrast, all supplemented groups showed a marked improvement in feed efficiency, with the most pronounced reductions in FCR observed in the groups receiving sodium bicarbonate (1.50), vinegar (1.53), and Vitamin C (1.57). The group receiving betaine supplementation showed an intermediate improvement with an FCR of 1.71. These findings suggest that the use of supplements, particularly sodium bicarbonate and vinegar, effectively improves feed efficiency under heat stress conditions.

Metabolizable Energy

The metabolizable energy (ME) values varied significantly among the treatment groups, indicating the influence of dietary supplementation on energy utilization during heat stress (Fig.2). The control group exhibited an ME value of 4.0 kcal/kg, which was matched by the sodium bicarbonate group at 4.33 kcal/kg, suggesting that sodium bicarbonate helps maintain high energy utilization. In contrast, birds supplemented with Vitamin C had the lowest ME (2.67 kcal/kg), followed by betaine (3.33 kcal/kg) and vinegar (3.67 kcal/kg). This indicates that while Vitamin C may provide benefits in other physiological areas, its impact on energy metabolism under heat stress is less pronounced compared to the other supplements tested.

Hematological Parameters

Hematological analysis revealed significant differences in hemoglobin levels between the control and treatment groups (Fig.3). Birds supplemented with betaine exhibited the highest hemoglobin concentrations (20.66 g/100ml), suggesting improved oxygen-carrying capacity and potential resilience against heat stress. Similarly, groups receiving vinegar (20.24 g/100ml) and sodium bicarbonate (19.71 g/100ml) demonstrated elevated hemoglobin levels compared to the control group (19.61 g/100ml). Interestingly, the group receiving Vitamin C supplementation had the lowest hemoglobin concentration (18.64 g/100ml), which might indicate a lesser role for Vitamin C in enhancing red blood cell production under these conditions.

Immunity and Newcastle Disease Virus Titer

The immune response, as measured by antibody titers against Newcastle disease virus (NDV), demonstrated a clear enhancement in the groups receiving dietary supplements (Fig.4). Both the Vitamin C and betaine groups had the highest titers (8.33), indicating a robust immune response under heat stress. The vinegar group followed closely with a mean titer of 8.00, while sodium bicarbonate (7.33) also improved the immune response compared to the control group, which had the lowest titer (7.00). These results suggest that dietary supplements, especially Vitamin C and betaine, bolster immune function during heat stress, potentially offering improved protection against pathogens like NDV.

Discussion

Heat stress has long been a major challenge in poultry production, known to disrupt physiological and metabolic processes, leading to impaired performance and increased susceptibility to diseases. This investigation demonstrates that dietary supplementation can mitigate the detrimental effects of heat stress, although with varying levels of efficacy depending on the supplement.

Vitamin C supplementation emerged as the most effective intervention, significantly improving growth performance, feed intake, and feed conversion ratio (FCR). This aligns with previous research highlighting Vitamin C's role as an antioxidant, which helps counteract oxidative stress induced by high temperatures. Studies by (Shakeri et al., 2020) and (Sahin et al., 2023) also demonstrated that Vitamin C reduces heat stress in broilers by enhancing antioxidant capacity, leading to better growth and immunity outcomes.

Betaine supplementation showed positive effects, albeit to a lesser extent than Vitamin C. Betaine is known for its osmo-regulatory properties, which help maintain cellular integrity under heat stress (Mushtaq and Pasha, 2013). In the current study, betaine improved both growth performance and hemoglobin levels, reflecting better water retention and cellular protection, which are essential during periods of heat stress. These findings corroborate those of (Uyanga et al., 2022), who also reported improved growth performance and heat tolerance in broilers supplemented with betaine.

Vinegar and sodium bicarbonate, while beneficial for some parameters, showed limited effects on growth performance and FCR. Although these supplements improved hematological parameters, their impact on feed intake was less favorable. Sodium bicarbonate, in particular, demonstrated high efficacy in enhancing metabolizable energy, as also reported by (Kang et al., 2024), who found that it improves energy utilization under heat stress by buffering blood pH and improving nutrient absorption. However, the lower growth performance observed in the vinegar group aligns with studies by (He et al., 2020), which suggest that vinegar may alter feed intake behavior, thereby affecting growth.

The immune response was also significantly enhanced by Vitamin C and betaine, as evidenced by higher antibody titers against Newcastle disease. This is consistent with findings from previous studies, such as those by (Srinontong

© PagePal. All rights Reserved

et al., 2024), which showed that Vitamin C boosts immune response under heat stress by reducing oxidative damage to immune cells. Similarly, betaine has been shown to enhance immune function by stabilizing cellular metabolism during stressful conditions (Li et al., 2024).

The hematological analysis revealed that betaine and vinegar were the most effective supplements for maintaining healthy hemoglobin levels. This suggests that these supplements enhance oxygen transport, which is crucial for sustaining energy production and overall physiological functions during heat stress. The role of betaine in improving hemoglobin levels has been supported by other studies, such as (De Baets et al., 2024), which demonstrated improved oxygen-carrying capacity in heat-stressed broilers supplemented with betaine.

Conclusion

This study demonstrates that dietary supplementation with Vitamin C and betaine significantly mitigates the adverse effects of heat stress in broilers, improving growth performance, feed efficiency, and immune response. While vinegar and sodium bicarbonate showed benefits in specific areas, particularly hematological parameters and energy metabolism, their overall impact on growth was less favorable. Therefore, Vitamin C and betaine emerge as the most effective interventions for enhancing broiler resilience under heat stress conditions. These findings support the use of targeted dietary strategies to improve poultry production efficiency in heat-stressed environments

Contributions

AR designed the study. MUH, GN, collected the samples; JAK and AR performed the lab experiments; MA analyzed the data and prepared the manuscript; GN revised the manuscript.

Source of funding

N/A

Conflict of interest

The authors declare no conflict of interest with anyone.

Ethical statement

All the procedures for animal handling and lab protocols were approved by the ethical committee, Department of Poultry Sciences, Faculty of Veterinary and Animal Science, Muhammad Nawaz Shareef University of Agriculture Multan, Pakistan

References

AL-ZGHOUL, M. B., SALEH, K. M. M. & JARADAT, Z. W. 2019. Expression of digestive enzyme and intestinal transporter genes during chronic heat stress in the thermally manipulated broiler chicken. *Poultry science,* 98**,** 4113-4122.

BRUGALETTA, G., TEYSSIER, J.-R., ROCHELL, S. J., DRIDI, S. & SIRRI, F. 2022. A review of heat stress in chickens. Part I: Insights into physiology and gut health. *Frontiers in physiology,* 13**,** 934381.

DE BAETS, R., BUYSE, K., ANTONISSEN, G. & DELEZIE, E. 2024. Betaine and feed restriction as potential mitigation strategies against heat stress in two strains of laying hens. *Poultry Science,* 103**,** 104104.

HAI, L., RONG, D. & ZHANG, Z. Y. 2000. The effect of thermal environment on the digestion of broilers. *Journal of Animal Physiology and Animal Nutrition,* 83**,** 57-64.

HE, S., YIN, Q., XIONG, Y., LI, J. & LIU, D. 2020. Characterization of heat stress affecting the growth performance, blood biochemical profile, and redox status in male and female broilers at market age. *Tropical Animal Health and Production,* 52**,** 3833-3841.

KANEDA, T., GREENBAUM, C. & KLINE, K. 2020. 2020 World Population Data Sheet. *Population Reference Bureau.[Online]. Available: https://bit. ly/3tJgT51*.

KANG, Z.-L., YAO, P.-L., ZHAO, S.-M., HOU, Q., XU, J.-G. & MA, H.-J. 2024. Effect of temperature and sodium bicarbonate combined on aggregation, rheology and conformation of low-salt chicken myofibrillar protein. *LWT,* 204**,** 116417.

LI, Y., YUAN, J., SUN, S., MA, F., XIONG, Y. & HE, S. 2024. Optimizing growth and antioxidant function in heat-stressed broilers with vitamin C and betaine supplementation. *International Journal of Biometeorology***,** 1-8.

MOTTET, A. & TEMPIO, G. 2017. Global poultry production: current state and future outlook and challenges. *World's poultry science journal,* 73**,** 245-256.

MUSHTAQ, M. & PASHA, T. 2013. Electrolytes, dietary electrolyte balance and salts in broilers: an updated review on acid-base balance, blood and carcass characteristics. *World's Poultry Science Journal,* 69**,** 833-852.

RENAUDEAU, D., COLLIN, A., YAHAV, S., DE BASILIO, V., GOURDINE, J.-L. & COLLIER, R. 2012. Adaptation to hot climate and strategies to

© PagePal. All rights Reserved

alleviate heat stress in livestock production. *Animal,* 6**,** 707-728.

SAHIN, K., SAHIN, E., DEEH, P. B., KAYRI, V., ORHAN, C. & SAHIN, N. 2023. Role of the antioxidant defence system and transcription factors in preventing heat stress in poultry: a dietary approach. *World's Poultry Science Journal,* 79**,** 651-687.

SHAKERI, M., OSKOUEIAN, E., LE, H. H. & SHAKERI, M. 2020. Strategies to combat heat stress in broiler chickens: Unveiling the roles of selenium, vitamin E and vitamin C. *Veterinary sciences,* 7**,** 71.

SRINONTONG, P., WANDEE, J. & AENGWANICH, W. 2024. The Effect of Vitamin C on Oxidative Stress, Nitric Oxide Formation and Viability of Broiler Finisher Blood Cells Subjected to High Ambient Temperature. *Indian Journal of Animal Research,* 58.

UYANGA, V. A., OKE, E. O., AMEVOR, F. K., ZHAO, J., WANG, X., JIAO, H., ONAGBESAN, O. M. & LIN, H. 2022. Functional roles of taurine, L-theanine, L-citrulline, and betaine during heat stress in poultry. *Journal of animal science and biotechnology,* 13**,** 23.

XU, D., LI, W., HUANG, Y., HE, J. & TIAN, Y. 2014. The effect of selenium and polysaccharide of Atractylodes macrocephala Koidz.(PAMK) on immune response in chicken spleen under heat stress. *Biological Trace Element Research,* 160**,** 232-237.

© PagePal. All rights Reserved

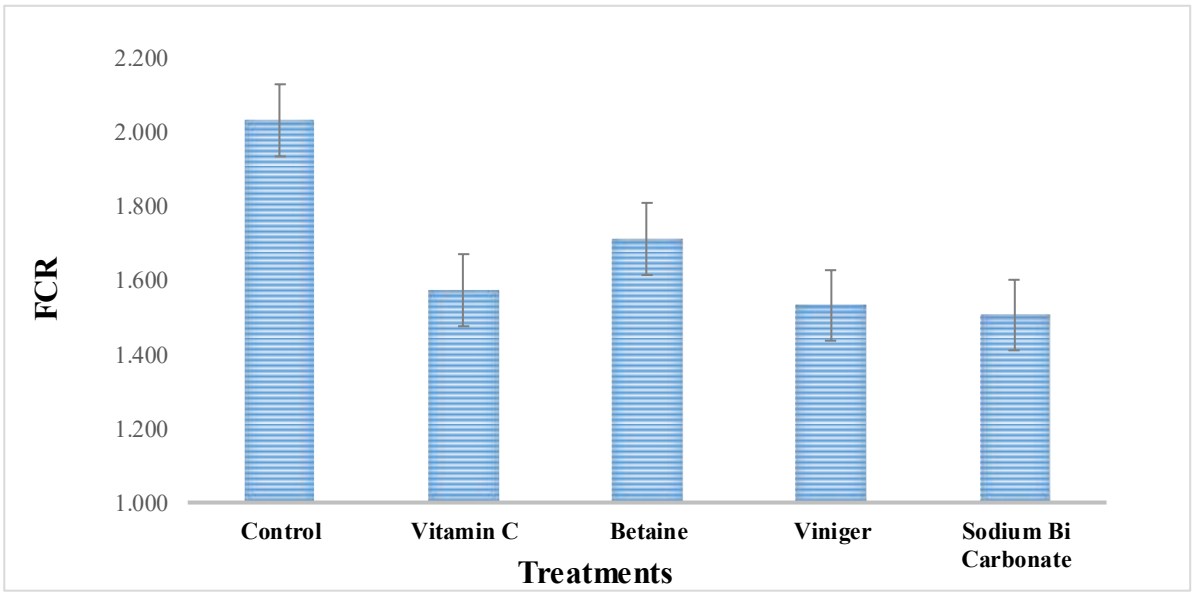

Fig 1: The feed conversion ratio (FCR) across the control and treatment groups.

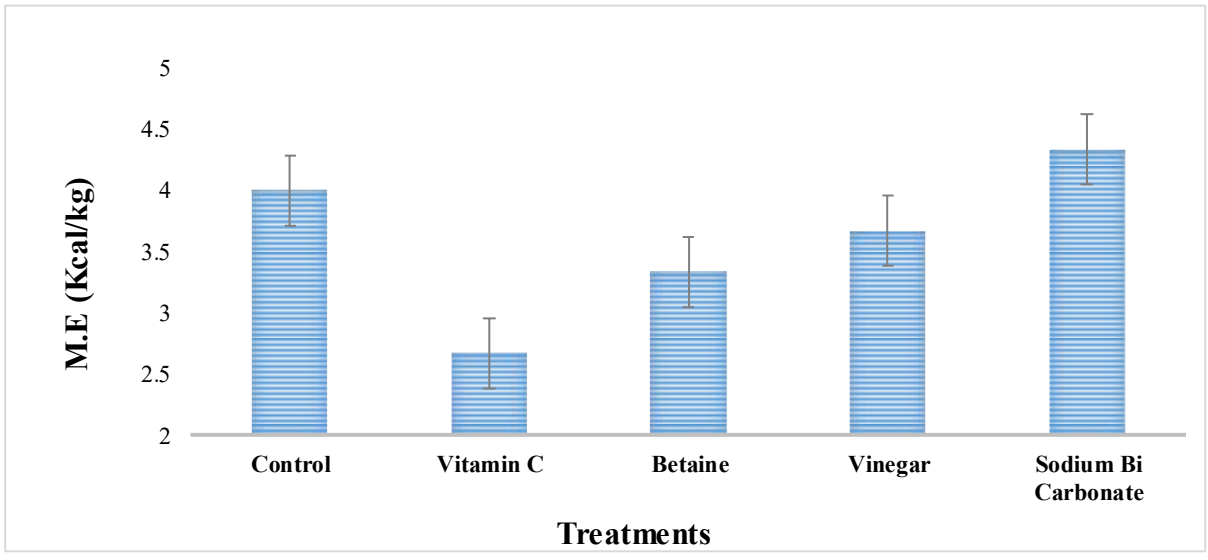

Fig 2: Metabolizable energy levels (kcal/kg) in different groups

*asaddasti786@gmail.com

©2024, PagePal Pvt. Ltd. (https://journals.pagepal.org/index.php/TAPS)

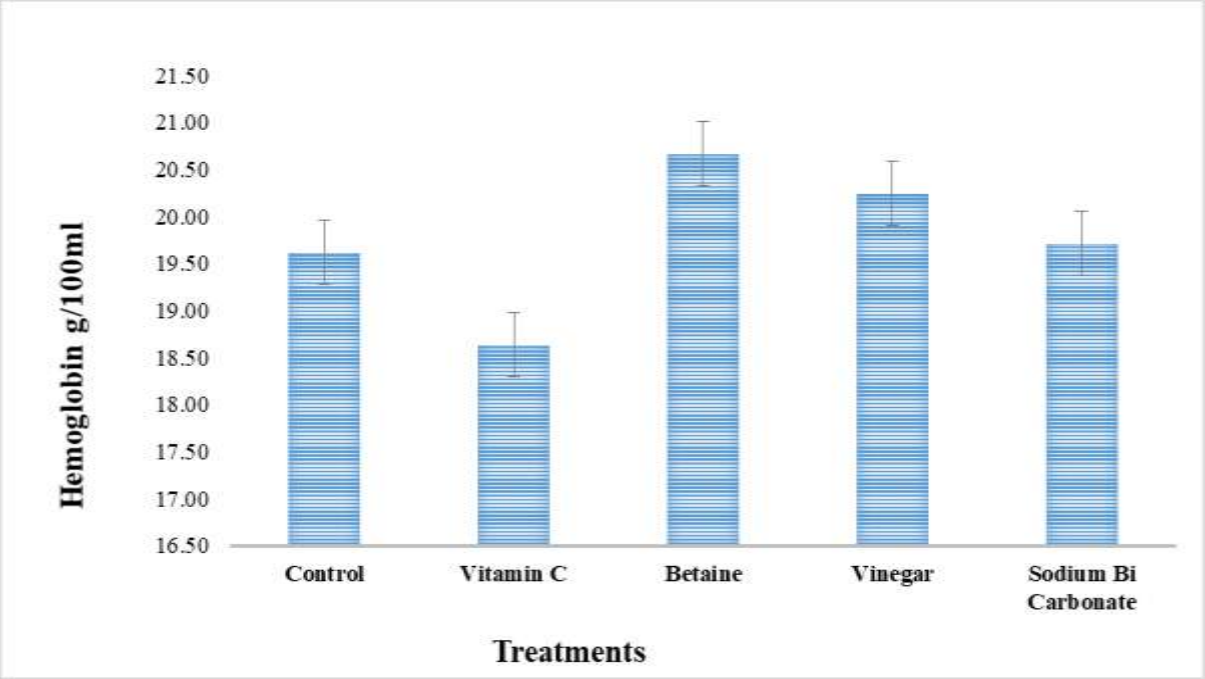

Fig 3: Hemoglobin g/100m concentration in control and treated groups

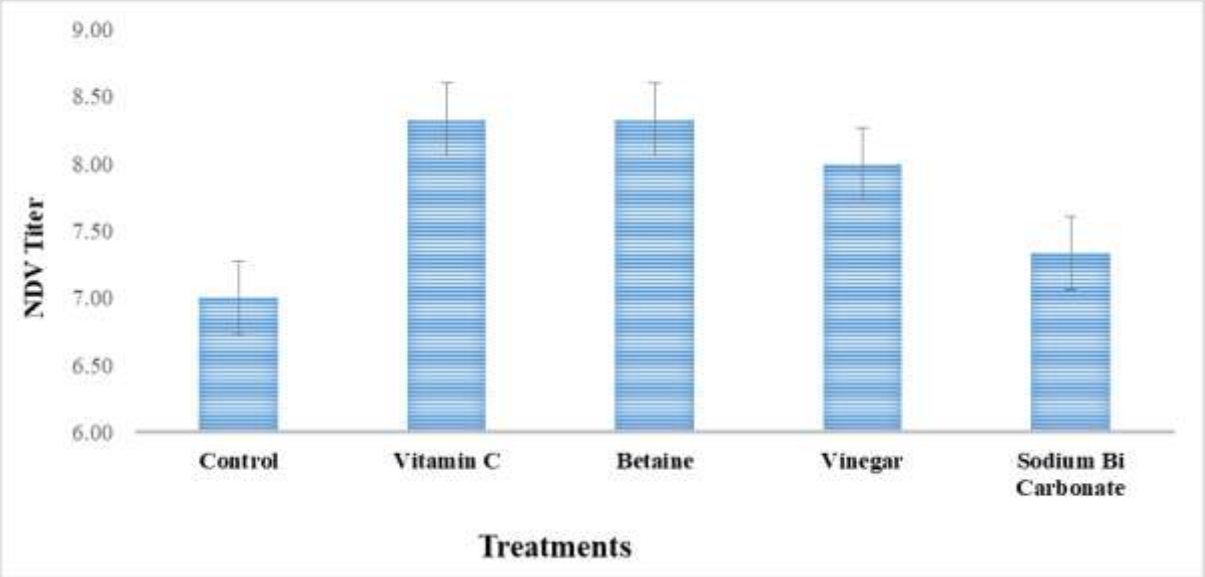

Fig 4: The immune response to the Newcastle disease virus in control and treated groups

© PagePal. All rights Reserved