



Effect of Zingerone and/or Vitamin C on the Immune System of Albino Rats, Hematological, Biochemical, Gene Expression Biomarkers and Histological Study

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Abstract

THE immune system, a complex network of cells and chemicals, protects the body from foreign antigens. Zingerone offers significant benefits like antioxidant, anti-inflammatory, anticancer, and antimicrobial effects. Vitamin C, a potent antioxidant, shields crucial biomolecules like proteins, lipids, and nucleic acids against oxidative damage. Forty rats were classified into control, Zingerone, vitamin C and Zingerone + vitamin C treated groups. Hematological, biochemical, gene expression, histological and Immunohistochemical investigation were used in the evaluation of both substances on the immune system. Zingerone and Vitamin C have demonstrated potential synergistic effects on blood parameters and immune function. Their antioxidant action may enhance erythropoiesis and protect against oxidative stress, while their influence on leukocyte populations could improve immune defense and regulate inflammation as well as modulate cytokine levels and surge CD4 and CD8 positive T-lymphocytes. In conclusion These findings point to the complex interplay of dietary components in immune health and warrant further investigation for therapeutic potential.

Keywords: Zingerone, Vitamin C, Immunostimulant, Gene expression, Immunohistochemistry.

Introduction

The immune system, consisting of various cells, chemicals, and mechanisms, defends body organs against foreign antigens, including microbes, bacteria, fungi, parasites, viruses, cancer cells, and toxins. Beyond physical and chemical defenses, it comprises innate and adaptive immunity [1]. Innate immunity is divided into four types of defenses: anatomical (such as skin and mucous membranes), physiological (including temperature, low pH, and chemical mediators), endocytic, and phagocytic barriers. [2] Adaptive immunity, which relies on the innate immune system's initial actions, becomes vital when innate defenses fail to clear infectious agents. Its primary functions include recognizing specific antigens, distinguishing them from self-antigens, and

establishing pathogen-specific immune responses to eradicate particular pathogens [3].

Lately, the global community has been grappling with various health challenges, including resistance to antibiotics, antivirals, and anticancer drugs [4], side effects of commercial drugs, undeveloped drug delivery mechanism, metabolic disorder [4]. Researchers are exploring various strategies to address these health issues, with disease prevention being one of the key approaches. Enhancing the human immune system is considered a significant preventive measure to decrease the rising rates of diseases and mortality [5, 6].

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human immune system is considered a significant preventive measure to decrease the rising rates of diseases and mortality [7]. Ginger, scientifically known as *Zingiber officinale* Roscoe and belonging to the Zingiberaceae family, is native to South-East Asia and widely recognized globally for its therapeutic benefits, attributed to its diverse phytochemical composition. It is rich in minerals, vitamins, and enzymes such as zingibain, which is a proteolytic enzyme. With over 60 active ingredients, ginger's compounds are categorized into volatile and nonvolatile types. The volatile elements, primarily consisting of monoterpenoid and sesquiterpene hydrocarbons, give ginger its unique flavor and aroma. Meanwhile, the nonvolatile components include gingerols, shogaols, paradols, and zingerone. [8].

Zingerone constitutes approximately 9.25% of ginger's composition, belonging to the Methoxyphenol family and its associated derivatives [9]. Zingerone exhibits strong pharmacological properties such as antioxidant [10], anti-inflammatory [11], anticancer [12], and antimicrobial activities [13]. It uniquely scavenges reactive oxygen species (ROS), free radicals, peroxides, and other harmful oxidants [14]. Zingerone's antioxidant actions include inhibiting the xanthine oxidase enzyme, which plays a role in ROS production, reducing free radicals in radiolysed food, limiting lipid oxidation by curbing ferric ascorbate-induced lipid peroxidation in rat brains [14], and safeguarding in vitro DNA against ROS damage induced by stannous chloride [10]. It also mitigates oxidative stress in the intestinal smooth muscles, displaying an adaptogenic effect [15], and reduces mitochondrial damage, lipid peroxidation, and the expression of pro-apoptotic proteins like Bax, Apaf-1, and Caspases 3–9 [16]. Beyond its antioxidant capacity, Zingerone also offers hepatoprotection against Lipopolysaccharides-induced inflammation by suppressing pro-inflammatory cytokines such as TNF- α , TLR4, iNOS, interleukins (IL-1 β , IL-6, IL-33), and nuclear factor kappa B, highlighting its anti-inflammatory potential [17].

Vitamin C, essential yet not synthesized by animals due to a missing enzyme [18, 19], prevents scurvy, a lethal condition stemming from deficiency [20]. Its immune-modulating functions arise from its role as a potent antioxidant protecting vital biomolecules from oxidative harm [21], aiding in collagen stabilization through its role as a cofactor for lysyl and prolyl hydroxylases, and facilitating fatty acid transport into mitochondria for energy production as a cofactor for carnitine production hydroxylases [22].

This study aims to investigate the immunostimulant effects of Zingerone and/or Vitamin C by examining antioxidant mediators,

blood parameters, as well as histological and Immunohistochemical changes.

Material and Methods

Ethical Approval

The research was ethically sanctioned by the Faculty of Veterinary Medicine's ethics committee at Kafrelsheikh University, Egypt, resulting in the issuance of an ethical approval number, KFS-IACUC/189/2024

Chemicals

Zingerone and Vitamin C were obtained from Sigma-Aldrich in St. Louis, MO, USA. Each day, both substances were freshly prepared by dissolving in distilled water for oral delivery to rats. Superoxide testing kits were supplied by Bio diagnostic, located in Cairo, Egypt.

Animals grouping and Experimental design:

At the Department of Pharmacology, Faculty of Veterinary Medicine, Kafrelsheikh University, Egypt, forty healthy male Wistar rats with an average weight of 175 ± 2 gm were housed in well-ventilated plastic cages. They were given a two-week period to adjust without any treatment. Subsequently, they were divided into four groups of ten rats each. Group I received 1 mL of distilled water per rat per day orally for 4 weeks. Group II was administered Zingerone at a dose of 60 mg/kg/day orally for 4 weeks. Group III received Vitamin C at a dosage of 500 mg/kg/day orally for 4 weeks. Group IV was treated with a combination of Zingerone (60 mg/kg/day) and Vitamin C (500 mg/kg/day) orally for 4 weeks.

Sampling

Following the fourth week of study, isoflurane was used to put the rats unconscious and each rat's retro orbital plexus was used for collecting blood samples. The blood samples were then divided into aliquots, the first aliquote containing EDTA as anticoagulant (1mg/ml for haematological parameters. The second aliquot given time to coagulate before being centrifuged for five minutes. Clear sera that had been obtained were subjected to biochemical examination [10]. Rat thymus and spleen pieces were extracted, cleaned in cold saline, and either preserved at -80°C for molecular research or fixed in a 10% formalin solution for histological and immunohistochemical investigation [11].

Hematological and Biochemical biomarkers

whole blood is utilized to measure erythrocyte count, hemoglobin levels, and PCV%, as well as to establish the MCV, MCH, and MCHC. The TLC was conducted using an improved Neubauer hemocytometer along with leukocyte count diluting fluids. Blood films were prepared promptly

following the collection of the blood sample. Utilizing the manual method, two blood films were created for every blood sample. These films were then stained using Giemsa stain, and a differential leukocyte count was performed following [12]. Serum levels of TNF- α and IL-6 were determined using an enzyme-linked immunosorbent assay (ELISA) kit, commercially sourced from EIAAB Science in Wuhan, China.. All methods were carried out strictly in adherence to the guidelines provided by the manufacturer.

Real Time-PCR

Table (1) displays the primer sequence for the gene. The conversion of total RNA (1 μ g) to single-stranded complementary DNA (C-DNA) was achieved using QuantiTect Reverse Transcription Kit (Qiagen, USA) through a two-step RT-PCR process employing a random primer hexamer. The expression levels of CRF gene mRNAs were assessed by real-time PCR using Rotor-Gene Q (Qiagen, USA). C-DNA amplification was conducted using specific primers and Maxima SYBR Green/Fluorescein qPCR Master Mix. The $2^{-\Delta\Delta CT}$ method, as outlined by Livak and Schmittgen[26], was used to calculate the relative expression of the target gene.

Histopathological and immunohistochemical Examination

Samples of the thymus and spleen were immediately fixed for 24 hours following collection in a 10% formaldehyde solution. The typical paraffin embedding protocol was applied to the fixed samples, which includes dehydration in increasing ethanol concentrations, clearing in three distinct xylene solutions and transferred to melted paraffin solutions, and lastly embedding in paraffin wax at 60°C. The resulting paraffin blocks were sectioned into 4-5 μ m thick sections. These sections were stained with hematoxylin and eosin [26]. For immunohistochemical studies, Tissue sections were immersed in citrate buffer (10 mM citric acid, pH 6.0) for 16–18 hours at 60°C in order to reveal the antigen. Following this, they were incubated with 3% hydrogen peroxide for 10 minutes in order to inhibit endogenous peroxidase activity. Finally, they were blocked for one hour at room temperature using 1% sheep serum. The primary monoclonal antibodies CD4, CD8, at 1:50 dilution from DAKO Products were applied to the specimens and left instantly at 4°C. Horseradish peroxidase-labeled (HRP) 2nd antibodies (1:400 in 1% BSA) were employed for an hour at 37°C. Hematoxylin was used as a counterstain and 3,30-diaminobenzidine (DAB) as a chromogen [27].

Data Analysis

Data were gathered and analyzed using SPSS software (version 20), with one-way ANOVA and Duncan's multiple range tests applied to pinpoint

significant differences among the means. A p-value below 0.05 was deemed indicative of statistical significance.

Results

Hematological Findings

The Zingerone + Vitamin C group showed a slight improvement in RBC count, Hb concentration, and PCV compared to the control, suggesting a potential synergistic effect of Zingerone and Vitamin C on these hematological parameters. However, the Zingerone group had the highest increase in TLC, particularly in Neutrophils and Lymphocytes, indicating an immune response. Eosinophil counts were notably lower in the groups receiving Zingerone, with or without Vitamin C, compared to the control. Table 2

Serum immunoglobulin and cytokines

All groups (Control, Zingerone, Vitamin C, Zingerone + Vitamin C) show similar TNF- α concentrations, suggesting none of the treatments significantly altered TNF- α levels compared to the control. Zingerone extensively raised IL-6 levels linked to the control. Vitamin C treatment alone did not significantly alter IL-6 levels compared to the control. The combination of Zingerone and Vitamin C resulted in IL-6 levels that were higher than the control but lower than Zingerone alone, indicating a possible modulating effect of Vitamin C on the Zingerone-induced increase in IL-6. There appears to be no significant difference in IgM levels between any of the groups. All groups displayed similar IgG levels, with no significant changes observed across the treatments. The results suggest that Zingerone might have pro-inflammatory properties as evidenced by the increase in IL-6, an inflammatory cytokine. However, when Zingerone is combined with Vitamin C, the increase in IL-6 is less pronounced, implying a potential anti-inflammatory role for Vitamin C. The antibody levels (IgM and IgG) remained relatively unaffected by the treatments, indicating that these interventions might not significantly influence humoral immune responses

mRNA expression analysis

Zingerone treatment significantly decreased IL-4 expression compared to the control, while Vitamin C alone and the combination with Zingerone showed no significant change. Graph B - mRNA expression of IL-5. Both Zingerone and Vitamin C treatments significantly reduced IL-5 expression assessed to the control, with no noteworthy distinction between the two. The combination treatment also resulted in no significant change compared to each treatment alone. Zingerone treatment resulted in a significant reduction of IL-12 expression, similar to Vitamin C treatment. There was no substantial difference between the effects of Zingerone or Vit C alone and their combination.

Histopathological and immunohistochemical Examination

The histological findings of thymus of all groups show normal architecture of the organ which surrounded by connective tissue capsule continuous with thin septae that divide the thymic lobes partially into lobules. Each lobule consists of darkly stained cortex with high density of cells and lighter stained medulla of lymphocytes and reticular epithelial cells. Both the density of cells and thickness of cortex were significantly increased in Zingerone and Zingerone + vitamin C treated groups compare with the control and vitamin C groups (Fig. 3).

The splenic parenchyma of all groups revealed normal structure with presence of red pulp composed of venous sinuses, venules and splenic cords and white pulp rich in lymphocytes represented by peri-arterial lymph sheath (PALS) organized along the artery of the white pulp, lymphatic nodules. The density of cells and size of lymphatic nodules were markedly increased in Zingerone and Zingerone + vitamin C treated groups compare with the control and vitamin C groups (Fig. 4).

The Immunohistochemical findings of CD4 stained thymus and spleen sections revealed significant increase in CD4 positive T-cells in Zingerone and Zingerone + vitamin C treated groups compare with the control and vitamin C groups (Fig. 5 and 6). The same findings were obtained in the CD8 stained thymus and spleen sections (Fig. 7 and 8). As well as, it was shown the number of CD4 and CD8 positive cells/1000 cell in thymus and spleen were show in Fig.9.

Discussion

Zingerone and Vitamin C treatments, as well as their combination, subtly affect RBC counts and Hb levels, suggesting a synergistic influence on erythropoiesis potentially linked to their antioxidant capabilities, which are known to shield cells from oxidative damage [12]. These interventions also led to slight increases in erythrocyte size and hemoglobin content per cell, indicative of better iron utilization or erythropoietin activity, as proposed by [13]. Despite these variations, the stability of hemoglobin concentration relative to cell size was observed, suggesting balanced erythrocyte function. Notably, the treatments increased total leukocyte count, pointing to a potential enhancement of the body's immune defense, particularly through raised neutrophil levels, hinting at a response to infection or inflammation [14]. A significant decrease in eosinophils, especially with Zingerone, could reflect anti-allergic or anti-inflammatory actions, aligning with findings by [15]. Furthermore, an increase in lymphocytes with these treatments suggests an improvement in adaptive immunity, highlighting the beneficial role of such supplements in supporting immune function [16]

Zingerone and Vitamin C, both individually and in combination, may have beneficial effects on blood parameters related to erythropoiesis and immune function. These findings could be indicative of the antioxidant, anti-inflammatory, and immunomodulatory properties of these compounds. The changes observed in leukocyte counts, in particular, suggest an enhanced immune response, which might be beneficial in preventing or mitigating infections and inflammatory states. The data suggests that Zingerone may increase the inflammatory cytokine IL-6, an effect that appears to be moderated by Vitamin C, indicating its potential anti-inflammatory role [17]. No significant alterations were observed in TNF- α levels across treatments, which is consistent with research suggesting certain anti-inflammatory agents do not affect TNF- α without an inflammatory stimulus [18]. Additionally, the stable immunoglobulin levels (IgM and IgG) suggest that these treatments do not markedly influence humoral immunity, supporting findings that immunoglobulin levels are not significantly impacted by such substances in the absence of an immune challenge [19]. These results highlight the complexity of immune response modulation by dietary compounds and warrant further investigation into their potential clinical implications [20].

The observed decrease in IL-4 expression with Zingerone treatment suggests a potential immunomodulatory role for Zingerone, possibly influencing Th2-mediated immune responses which are typically associated with allergic inflammation [21]. The lack of significant change with Vitamin C and the combination treatment may indicate a ceiling effect of Zingerone's action or a complex interaction with Vitamin C that requires further exploration [22].

The significant downregulation of IL-5 by both Zingerone and Vitamin C suggests their role in mitigating eosinophilic responses, as IL-5 is critical for the growth and survival of eosinophils [23]. The absence of an additive effect in the combination treatment could again be due to the maximal effect being achieved by each agent independently or indicate a shared pathway of action [24].

For IL-12, the reduction with both treatments is noteworthy as IL-12 is involved in Th1 cell differentiation and is important for the immune response to intracellular pathogens [25]. The decrease in IL-12 expression could imply a shift away from Th1 responses, potentially reducing autoimmunity risk or excessive inflammation [26]. In conclusion, Zingerone and Vitamin C demonstrate potent immunomodulatory effects, particularly in downregulating cytokines associated with Th2 and Th1 immune responses.

Zingerone and Vitamin C, alone and in combination, may influence CD4 T-lymphocyte

populations in the thymus. Notably, the combination group (D) demonstrates a pronounced increase in CD4 T-lymphocytes, potentially indicating a synergistic effect that could enhance immune system function. Zingerone is known for its anti-inflammatory properties, which may account for its effects on immune cells [27]. Meanwhile, Vitamin C is well-documented for its role in supporting immune health, particularly in the proliferation of T-lymphocytes [17]. The results here could reflect the known effects of these compounds on the immune system, suggesting their combined use might optimize immune function. The increased CD4 T-lymphocyte expression in the spleen after Zingerone and Vitamin C treatments, particularly when combined, suggests a potential enhancement of adaptive immunity [17]. The data aligns with the understanding that Zingerone has immunomodulatory effects, while Vitamin C is crucial for lymphocyte function and proliferation [17]. The apparent synergy between Zingerone and Vitamin C could offer a promising avenue for strengthening immune responses, as supported by the observed increase in CD4 T-lymphocytes [28]. An increased expression of CD8 T-lymphocytes in the thymus after treatments with Zingerone and Vitamin C, singly and in combination, suggesting an enhancement of cytotoxic T-cell populations. Zingerone's role in immune modulation (Sharma & Gupta, 2019) and Vitamin C's importance in T-cell function [17] may underpin this effect. The synergy observed with combined treatments indicates a potential for augmented immune responses [28]. The spleen photomicrographs display variable CD8 T-lymphocyte expression across different treatments. Treatments both show increased CD8 expression, suggesting they may bolster cytotoxic T-cell populations, crucial for immune defense mechanisms. Notably, the Zingerone and Vitamin C combination (D) exhibits the most substantial increase in CD8 cells, hinting at a potential synergistic effect on adaptive immunity, perhaps due

to enhanced cell-mediated responses against pathogens or tumor cells [17, 28]

Conclusions

The Zingerone and Vitamin C have demonstrated potential synergistic effects on blood parameters and immune function. Their antioxidant action may enhance erythropoiesis and protect against oxidative stress, while their influence on leukocyte populations could improve immune defense and regulate inflammation. Treatments with these compounds modulate cytokine levels, suggesting an immunomodulatory role that might balance Th1 and Th2 responses. Additionally, they seem to promote an increase in both CD4 and CD8 T-lymphocyte populations, which are key to adaptive immunity. These findings point to the complex interplay of dietary components in immune health and warrant further investigation for therapeutic potential.

Conflict of interest statement: The authors have disclosed that they do not hold any conflicts of interest related to the publication of this article.

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Ethical Approval

The research was ethically sanctioned by the Faculty of Veterinary Medicine's ethics committee at Kafrelsheikh University, Egypt, resulting in the issuance of an ethical approval number, KFS-IACUC/189/2024

Author's contribution

M.M.E., A.A. designed the study plan, F.F., M.S., drafted the manuscript, S.H.B., A.H. helped in conducting the research work, conducting data analysis, and assisted in the writing of the manuscript, M.M.E., A.A. provided technical help in writing the manuscript, writing—review and editing. All authors have read and agreed to the published version of the manuscript.

TABLE 1. Primer sequences for gene under study

			bp	Accession number
Interleukin 5	F	GAAGAGAGGCGGAAGACCAG	83	AJ011299
	R	ACTTCATTGCCCACTCTGT		
Interleukin 4	F	TGTACCGGAACGGTATCCA	103	X16058
	R	ACATCTCGGTGCATGGAGTC		
Interleukin 12 R beta 1	F	AGATGCCCAGGGACAGAGAT	149	NM_001170604
	R	GGGACAGTCCTCTCTAGCCA		
GAPDH	F	CTCTCTGCTCCTCCCTGTTC	105	NM_017008.4
	R	TACGGCCAAATCCGTTTACA		

TABLE 2. The effect of Zingerone and Vitamin C on the hematological parameters

Group	RBC $10^6/\mu$ L	Hb g/dl	PCV %	MCV fl	MCH pg	MCHC %	TLC $10^3/\mu$ L	Netro. $10^3/\mu$ L	Lymph. $10^3/\mu$ L	Eosino. $10^3/\mu$ L	Mono. $10^3/\mu$ L
Control	5.71	17.1	51.3	89.8	29.9	33.3	14.42 ^b	1.54	12.25	0.26	0.33
Zingerone	5.56	16.8	50.04	90	30.2	33.6	16.45 ^a	2.16	14.21	0.05	0.26
Vit C	5.88	17.63	52.92	90	31.6	33.3	15.22 ^b	1.68	12.45	0.03	0.34
Zingerone +Vit C	5.91	17.73	53.19	90	30	33.3	16.21 ^a	2.10	12.23	0.02	0.29
Pooled SEM	0.59	0.44	1.2	3.7	1.2	1.01	1.2	0.1	0.56	0.001	0.01

Data expressed as Mean± SEM. Different subscript letters in the same column significantly difference $p < 0.05$

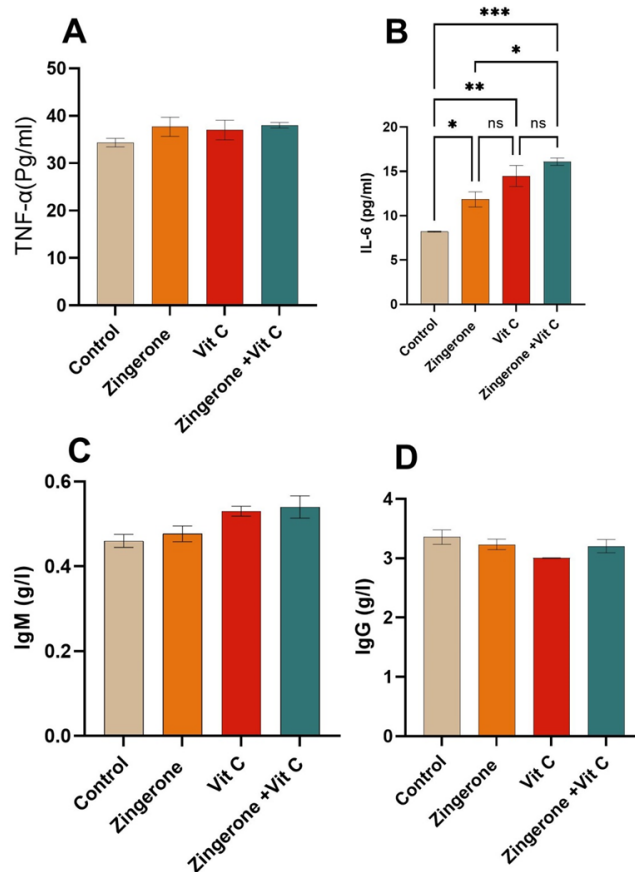


Fig. 1. Impact of Zingerone and Vitamin C on the A.TNF- α , B. IL-6, C. IgM, D.IgG. Data showed as Mean± SEM. * $p < 0.05$, ** $p < 0.01$,

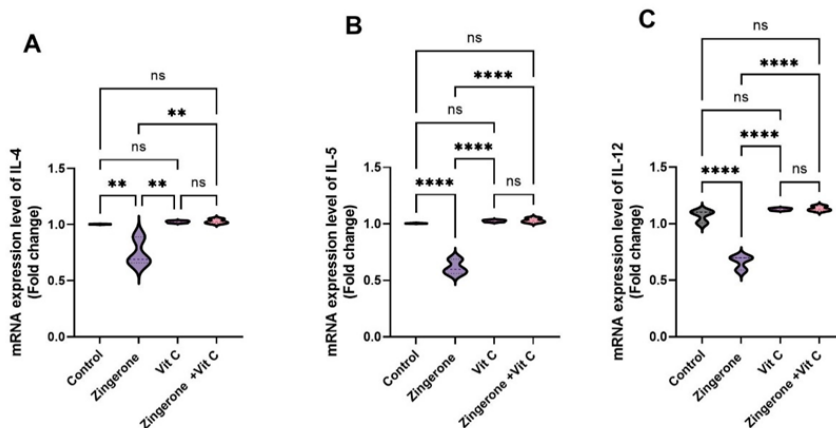


Fig. 2. The impact of Zingerone and Vitamin C on the mRNA expression of A. IL-4, B. IL-5, and C. IL-12 was assessed. Results are presented as Mean ± SEM. Statistical significance was indicated by ** (p < 0.01), *** (p < 0.001), and **** (p < 0.0001).

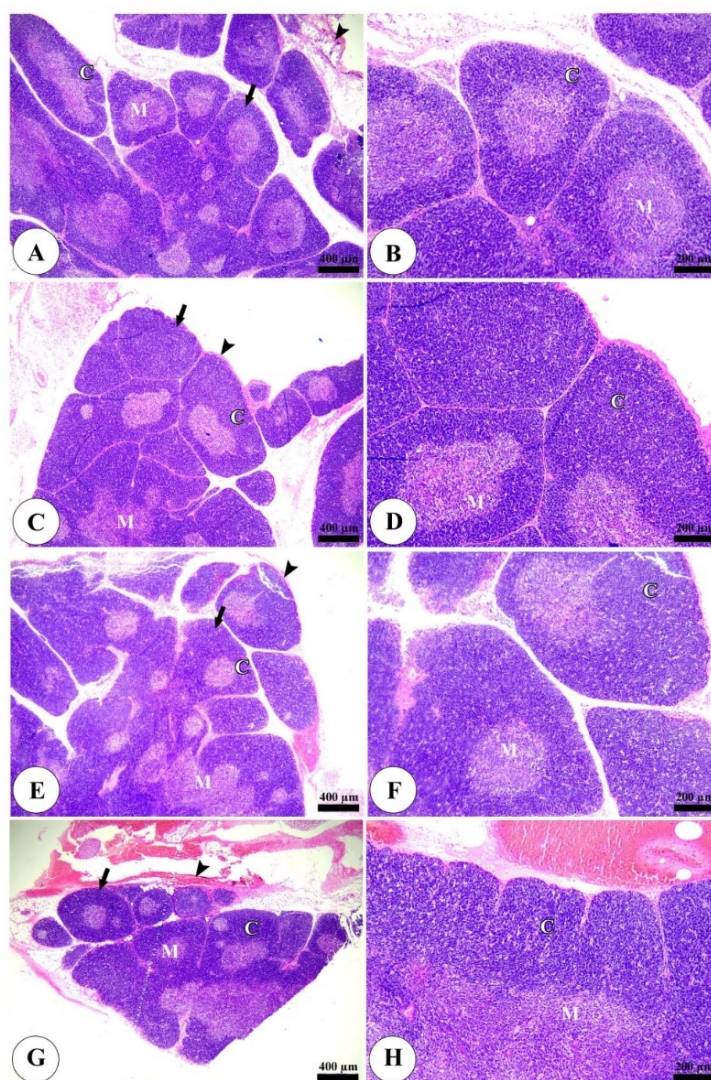


Fig. 3. Histomicrograph of thymus of control (A&B), Zingerone (C&D), vitamin C (E&F) and Zingerone + vitamin C (G&H) treated groups show connective tissue capsule (arrow heads), thymic lobules (arrows), cortex (C) and medulla (M). H&E stain.

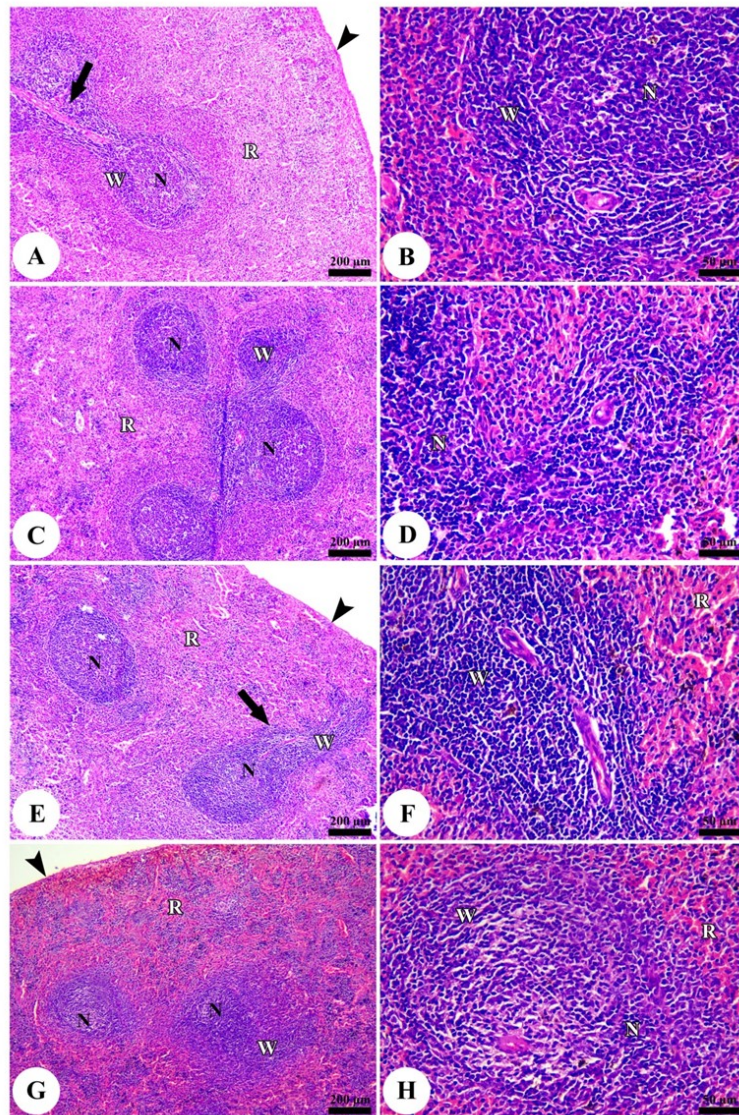


Fig. 4. Histomicrograph of spleen of control (A&B), Zingerone (C&D), vitamin C (E&F) and Zingerone + vitamin C (G+H) treated groups show connective tissue capsule (arrow heads), peri-arterial lymph sheath (PALS, arrows), red pulp (R), white pulp (W) and lymphatic nodules (N). H&E stain

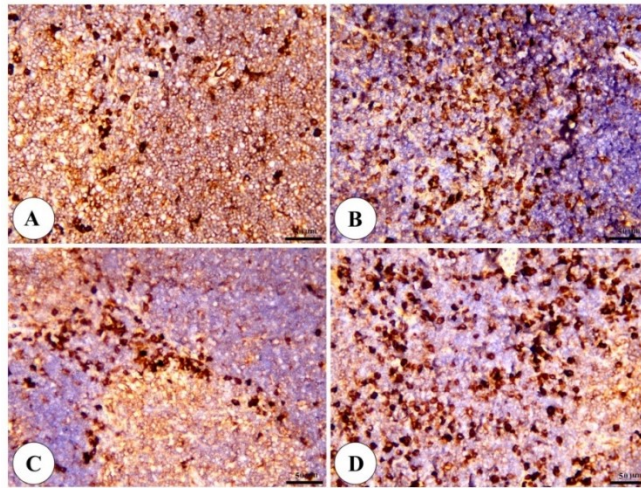


Fig. 5. Photomicrograph of thymus of control (A), Zingerone (B), vitamin C (C) and Zingerone + vitamin C (D) treated groups showing positive expression of CD4 T-lymphocytes (brown coloured cells). CD4 IHC, Bar= 50 µm.

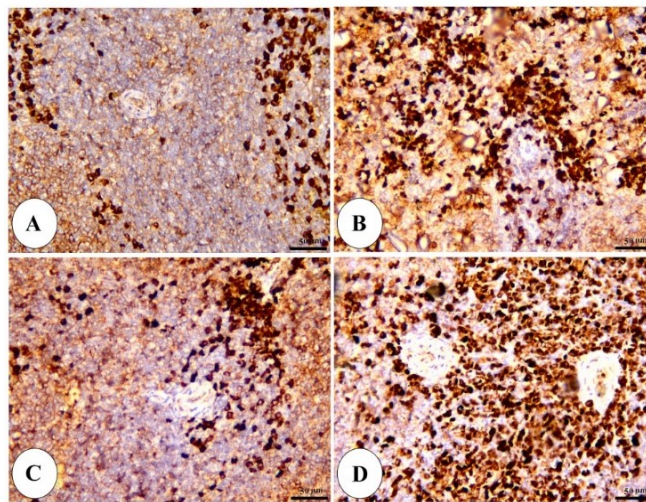


Fig. 6. Photomicrograph of spleen of control (A), Zingerone (B), vitamin C (C) and Zingerone + vitamin C (D) treated groups showing positive expression of CD4 T-

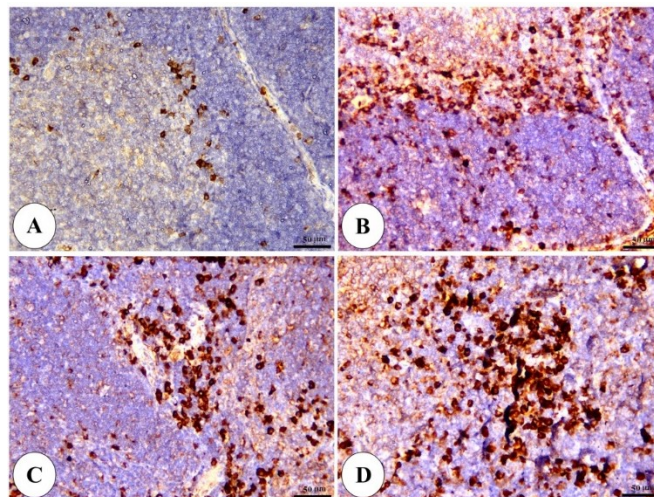


Fig. 7. Photomicrograph of thymus of control (A), Zingerone (B), vitamin C (C) and Zingerone + vitamin C (D) treated groups showing positive expression of CD8 T-lymphocytes (brown coloured cells). CD8 IHC, Bar= 50 µm.

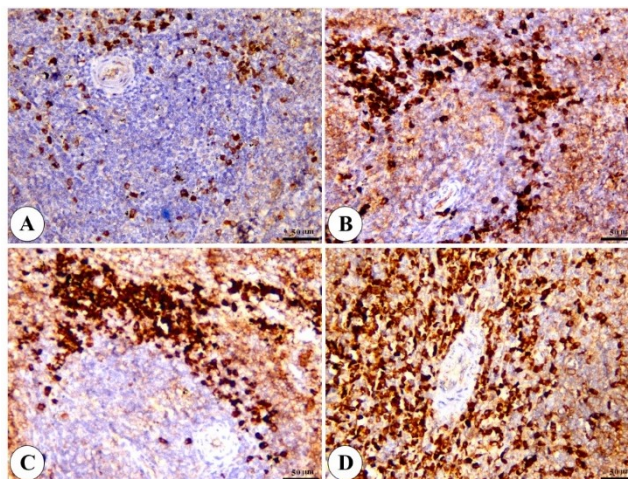


Fig. 8. Photomicrograph of spleen of control (A), Zingerone (B), vitamin C (C) and Zingerone + vitamin C (D) treated groups showing positive expression of CD8 T-lymphocytes (brown-coloured cells). CD8 IHC, Bar= 50 µm.

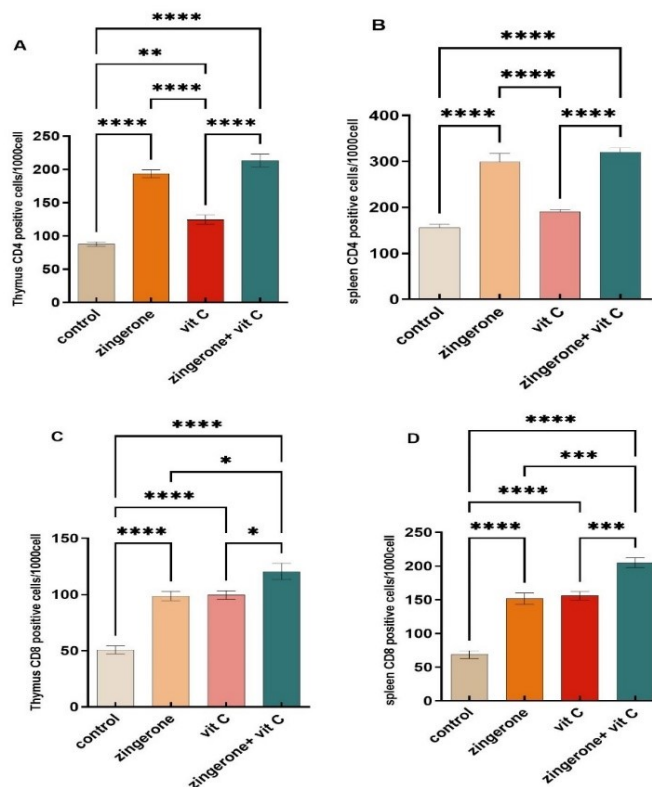


Fig. 9. % expression of the Thymus and spleen CD4,CD8

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تأثير الزنجبيل و/أو فيتامين ج على الجهاز المناعي للجرذان البيضاء؛ دراسة المؤشرات الهيماتولوجية، البيوكيميائية، التعبير الجيني والنسجية

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الجهاز المناعي، شبكة معقدة من الخلايا والمواد الكيميائية، يحمي الجسم من المستضدات الغريبة. يقدم الزنجبيل فوائد مهمة مثل تأثيرات مضادة للأكسدة، مضادة للالتهاب، مضادة للسرطان، ومضادة للميكروبات. فيتامين ج، مضاد قوي للأكسدة، يحمي الجزيئات الحيوية الهامة مثل البروتينات، الدهون، والأحماض النووية من التلف الأوكسدي. تم تصنيف أربعين جرذاً إلى مجموعات: السيطرة، الزنجبيل، فيتامين ج، ومجموعة معالجة بالزنجبيل وفيتامين ج. استخدمت التحقيقات الهيماتولوجية، البيوكيميائية، تعبير الجيني، النسجية والمناعية النسيجية في تقييم تأثير كلا المادتين على الجهاز المناعي. أظهر الزنجبيل وفيتامين ج تأثيرات تآزرية محتملة على المعايير الدموية ووظيفة المناعة. قد تعزز فعاليتها المضادة للأكسدة عملية إنتاج الكريات الحمر وتحمي من الإجهاد التأكسدي، بينما قد يحسن تأثيرهما على تعدادات الكريات البيض تحصين الدفاع المناعي وينظم الالتهاب وكذلك يعدل مستويات السيتوكينات ويزيد من خلايا تي اللمفاوية الإيجابية لـ CD4 و CD8 في الختام، تشير هذه النتائج إلى التفاعل المعقد بين المكونات الغذائية في صحة المناعة وتستدعي مزيداً من التحقيق لإمكاناتها العلاجية.

الكلمات المفتاحية: الزنجبيل، فيتامين ج، منشط المناعة، تعبير الجينات، المناعة النسيجية.