Eastern Journal of Agricultural and Biological Sciences (EJABS)
ISSN: 2753-3247
Website: https://qabasjournals.com/index.php/ejabs

Physiological evaluation for the effect of cinnamon and turmeric dressing bandages on rheumatoid arthritis induced experimentally in rats

Najlaa O.H. Aljubury

Department of Physiology, Pharmacology and Biochemistry, College of Veterinary Medicine, University of Al-Qadisiyah, Al-Qadisiyah, Iraq

Corresponding Author: Najlaa O.H. Aljubury; E-mail: *najlaa.aljubury@qu.edu.iq*

ARTICLE INFO

Received: November 14, 2025
Accepted: December 28, 2025
Volume: *5*
Issue: 3

KEYWORDS

Cinnamomum zeylanicum, Complete Freund's adjuvant (CFA), Curcuma longa, Curcumin, Herbal remedies, Inflammatory cytokines, Traditional medicinal systems

ABSTRACT

Rheumatoid arthritis (RA) is a long-term ongoing condition where the immune system attacks the tissues lining a joint(s) of body especially in hands and feet which resulting in swelling, stiffness, as well as structural and functional alterations of affected joints and /or other organs or systems of the body. This study aims experimentally to evaluate the effects of cinnamon, turmeric, and both (cinnamon and turmeric) dressing bandages in amelioration the impact RA through measurement of some related serum markers. Thus, a total of 50 adult male rats were purchased, acclimated, and divided equally into five groups as following; PC (CFA-injected, not-treated), NC (neither-injected, nor-treated), CEG (CFA-injected, cinnamon-treated), TEG (CFA-injected, turmeric-treated), and CTEG (CFA-injected, cinnamon and turmeric-treated). Post 30 days, blood were samples directly from heart, and the obtained sera were tested using the quantitative ELISA to measurement the levels of amyloid A (AA), anti-cyclic citrullinated peptide antibody (Anti-CCP-Ab), cross linked C-telopeptide of type I collagen (CTX-I), interleukin-6 (IL-6), matrix metalloproteinase-1 (MMP-1), matrix metalloproteinase-10 (MMP-10), rheumatoid factor (RF), and tumor necrosis factor-alpha (TNF-α). GraphPad Prism Software was applied to indicate significant differences between the values of the five study groups at $p<0.05$. In comparison to values of PC, the findings of experimentally study groups (CEG, TEG, and CTEG) were revealed a significant reduction in values of all study markers (AA, Anti-CCP-Ab, CTX-I, IL-6, MMP-1, MMP-10, RF and TNF-α); however, the values of these markers were remained higher than detected in rats of NC group. Among the findings of experimentally study groups, the highest values of AA, Anti-CCP-Ab, CTX-I, IL-6, MMP-1, RF and TNF-α were detected in rats of CEG while the lowest were identified in CTEG when compared to values of TEG. Nonetheless, values of MMP-10 indicated no significant differences were found between the rats of experimentally groups. In conclusion, though dressing bandages containing turmeric are more activity than cinnamon, dressing bandages composed both cinnamon and turmeric were highly active in amelioration the negative impact of RA than those covered solely with cinnamon or turmeric. Additionally, the studied markers can be used definitively in diagnosing of RA and estimation the severity of infection especially at acute phase of disease. However, furthermore studies on dressing bandages of cinnamon and turmeric are greatly required due to the low number of available data and investigating their effects on other serum markers.

1. Introduction

RA is a chronic autoimmune disorder characterized by persistent inflammation that targets primarily the synovial joints leading to progressive joint destruction and systemic complications (Hasan et al., 2022; Jahid et al., 2023). Although, the etiology involves a complex interplay between genetic susceptibility and environmental triggers with specific antigens that identified as significant risk factors, the pathological progression involves synovial hyperplasia and the release of pro-inflammatory

cytokines that mediate the erosion of articular cartilage and bone (Panagopoulos and Lambrou, 2018; Arleevskaya et al., 2022). This aberrant immune response leads to infiltration of immune cells including CD4+ T-cells, macrophages and neutrophils into the synovial membrane where they sustain the inflammatory environment and contribute to formation of invasive tissue (pannus) which ultimately erodes cartilage and subchondral bone (Nevius et al., 2016; Alivernini et al., 2022). Subsequently, this extends beyond articular damage to include systemic symptoms such as morning stiffness, fever, fatigue, malaise, and weight loss as well as extra-articular features like rheumatoid nodules (Trivedi, 2024). Other complications may involve cardiovascular, pulmonary, and skeletal systems which contributing significantly in increasing the rates of morbidity and mortality (Figus et al., 2021).

In general, the classification of RA is traditionally subdivided based on the serological presence or absence of RF and Anti-CCP-Abs which correlate with distinct risk profiles (Olalekan, 2014). The seropositive RA demonstrates by presence of either RF or Anti-CCP-Abs which indicates strong linkage to MHC class II-dependent immunity, whereas seronegative disease exhibits a different pathogenetic pathway (Malmström et al., 2017; Al-Maola et al., 2025). Conversely, seronegative RA is characterized by the absence of these autoantibodies and constitutes approximately one-third of all cases, generally presenting with a less severe disease course compared to the seropositive subset (Perera et al., 2024; Lhotellerie et al., 2025). For this reason, accurate diagnosis relies on a combined approach integrating patient history, physical examination and imaging modalities remains needed serological testing for acute phase reactants and autoantibodies to differentiate between the seropositive and seronegative cases (Perera et al., 2024; Soyfoo and Sarrand, 2026).

Worldwide, despite marked advances in treatment, about 40% of patients with RA do not respond to individual pharmacological agents and up to 20% do not respond to any of the available medications (Babaahmadi et al., 2023; Brown et al., 2024). To address this large unmet need, various medicinal plants offer promising complementary, anti-inflammatory and antioxidant support for managing the disease symptoms. These natural remedies may share their effects throughout reducing the joint pain, stiffness, and inflammation by modulating immune responses and inhibiting inflammatory pathways (Kaur et al., 2024; Jepkorir, 2025; Verma et al., 2025). Cinnamon (*Cinnamomum zeylanicum*) and turmeric (*Curcuma longa*) are two traditional potent medicinal plants which driven respectively by compounds cinnamaldehyde and curcumin, and utilized together to aid in digestion, modulate the immune system, regulate blood sugar, and reduce cholesterol (Kulicka et al., 2024; El-Saadony et al., 2025). In Iraq, aqueous extract of cinnamon was given experimentally to estimate its effect on immune RF and IL-1β markers (Kshash and Hussain, 2022) as well as antioxidants (Youssef et al., 2023); whereas, alcoholic extract of curcumin was administered to relief paw thickness and supporting blood parameters (Al-Graiti and Abd AL-Latif, 2019) as well as modulating inflammatory markers (Rasool et al., 2025). Hence, this study aims experimentally to evaluate the effects of cinnamon, turmeric, and both (cinnamon and turmeric) bandages in amelioration the impact RA on some related serum markers.

2. Materials and methods

2.2.1. Ethical approval

This study was licensed by the Scientific Committee in the College of Veterinary Medicine (University of Al-Qadisiyah).

2.2.2. Preparation of study materials

For induction RA, 0.1ml of complete Freund's adjuvant [CFA (Cat.No.F5881; Sigma Aldrich, USA)] was injected in the right planter foot. Cinnamon and turmeric were purchased from the local markers and utilized to preparation of bandages as described by other researchers (Ahmed et al., 2019; Chuysinuan et al., 2023).

2.2.3. Experimental study

A total of 50 adult male rats of 90 days old and 227-249 grams weight were purchased from a private Animal House in Al-Diwaniyah city (Al-Qadisiyah province, Iraq), transported, and subjected to acclimation period for one week; during which, study rats were fed pellets, given RO water, and exposed to 12/12 of light/dark conditions. Then, the study rats were divided randomly and equally into five groups as following;

1. Positive control (PC): Rats of this group were injected 0.1ml of CFA at three times interval in the right planter foot and left without treatment throughout the study period (30 days).
2. Negative control (NC): Rats of this group neither subjected to CFA-injection, nor treated by cinnamon or turmeric. However. 01ml of distilled water was injected at three times interval in the right planter foot.
3. Cinnamon experimental group (CEG): Rats of this group were injected 0.1ml of CFA at three times interval in the right planter foot; and then, they received a daily dressing bandage of cinnamon throughout the study period (30 days).
4. Turmeric experimental group (TEG): Rats of this group were injected 0.1ml of CFA at three times interval in the right planter foot; and then, they received a daily dressing bandage of turmeric throughout the study period (30 days).

5. Cinnamon and turmeric experimental group (CTEG): Rats of this group were injected 0.1ml of CFA at three times interval in the right planter foot; and then, they received a daily dressing bandage of cinnamon + turmeric throughout the study period (30 days).

2.2.4. Samples

Post ending of the experiment, each study rat was euthanized by chloroform and subjected to direct draining of blood from heart using a free-anticoagulant glass vacutainer. Then, all samples of blood were centrifuged at 5000rpm for 5 minutes and the obtained sera were pipetted and transferred into labeled Eppendorf tubes that kept frozen until be tested serologically (Ajaj et al., 2021).

2.2.5. Serological testing

Following the manufacturer instructions (SunLong Biotech, China) of quantitative enzyme-linked immunosorbent assay (ELISA) kits, levels of AA, Anti-CCP-Ab, CTX-I, IL-6, MMP-1, MMP-10, RF, and TNF-α were measured in sera of study rats. Briefly, contents of each ELISA's kit in addition to sera were prepared at room temperature, processed, optical density was measured, and the obtained values were used to calculate the concentration of the marker in the serum samples throughout the Standard Curve.

2.2.6. Statistical analysis

One-way ANOVA in the GraphPad Prism Software was applied to indicate significant differences between the values of the five study groups at $p<0.0001$ and estimate the levels of confidence interval at 95% (95%CI), (Gharban et al., 2024).

3. Results

In comparison to PC and NC, the findings of experimentally study groups (CEG, TEG, and CTEG) were shown a significant variation in their values. For serum AA, the findings of CEG (7.941±0.48ng/ml), TEG (7.54±0.68ng/ml) and CTEG (3.315±0.26ng/ml) were significantly reduced ($p<0.0001$; 95%CI: 1.444 to 12.39) when compared to PC (13.44±0.36ng/ml) but it remains higher than the values of NC (2.356±0.13ng/ml). Subsequently, the findings of CTEG were significantly ($p<0.0004$) lower than those identified in CEG and TEG (Figure 1).

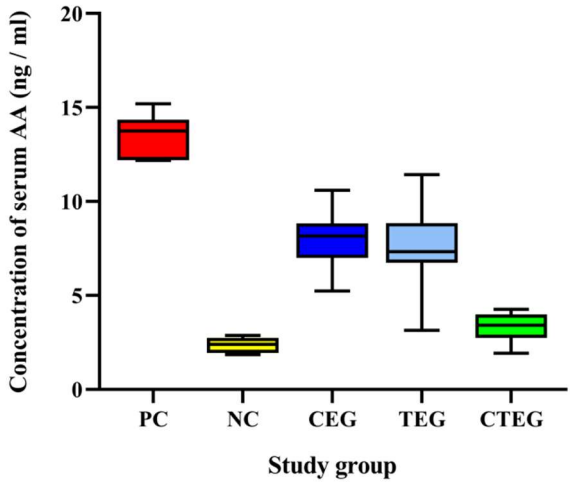

Figure 1. Levels of serum amyloid A (AA) among the rats of study groups; PC (CFA-injected, not-treated), NC (neither-injected, nor-treated), CEG (CFA-injected, cinnamon-treated), TEG (CFA-injected, turmeric-treated), and CTEG (CFA-injected, cinnamon and turmeric-treated).

In comparison to values of PC (24.01±1.4U/ml), the findings of Anti-CCP-Ab marker reduced significantly ($p<0.0001$; 95%CI: 4.752 to 23.77) among the study animals of CEG (17.51±1.31U/ml), TEG (16.44±1.07U/ml), and CTEG (8.8±0.86U/ml) but higher than the results of NC (4.544±0.3U/ml). However, values of CTEG were ameliorated markedly ($p<0.001$) when compared to those of CEG and TEG (Figure 2).

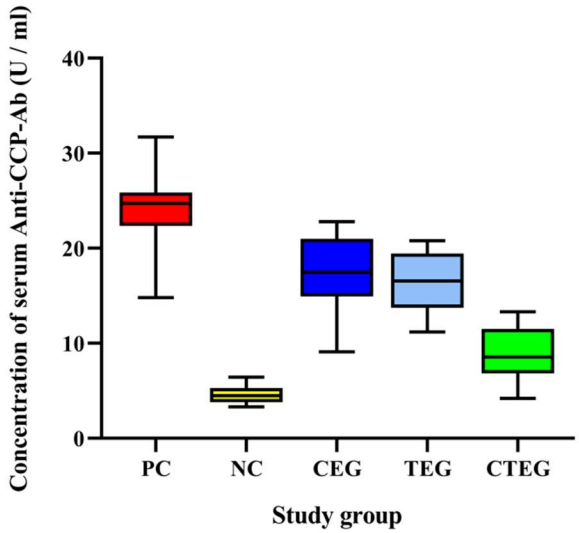

Figure 2. Levels of serum anti-cyclic citrullinated peptide antibody (Anti-CCP-Ab) among the rats of study groups; PC (CFA-injected, not-treated), NC (neither-injected, nor-treated), CEG (CFA-injected, cinnamon-treated), TEG (CFA-injected, turmeric-treated), and CTEG (CFA-injected, cinnamon and turmeric-treated).

Concerning CTX-I, there were significant decreases ($p<0.0001$; 95%CI: 30.23 to 363.2) in values of CEG (157.2±12.07pg/ml), TEG (129±11.85pg/ml) and CTEG (60.89±7.06pg/ml) when compared to values of PC (224±11.52pg/ml); however, the values of all three experimentally groups were higher than the values of NG (42.97±1.85pg/ml). Subsequently, the findings of CTEG were significantly ($p<0.0037$) lowered than recorded in rats of CEG and TEG (Figure 3).

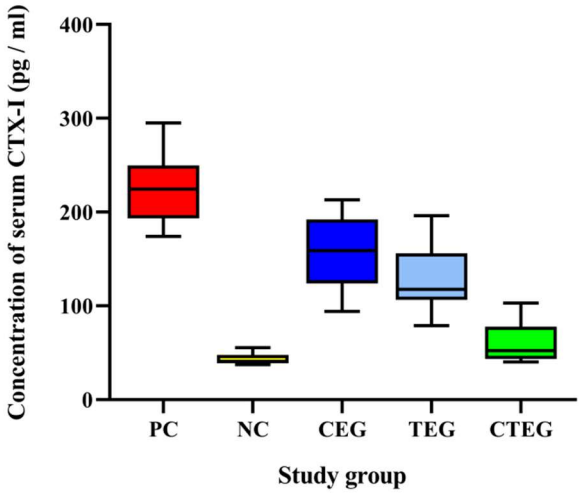

Figure 3. Levels of serum cross linked C-telopeptide of type I collagen (CTX-I) among the rats of study groups; PC (CFA-injected, not-treated), NC (neither-injected, nor-treated), CEG (CFA-injected, cinnamon-treated), TEG (CFA-injected, turmeric-treated), and CTEG (CFA-injected, cinnamon and turmeric-treated).

Regarding the findings of IL-6, significant decreasing ($p<0.0001$; 95%CI: 11.90 to 83.95) was observed in values of CEG (62.62±3.9ng/L), TEG (56.69±4.13ng/L), and CTEG (23.58±3.01ng/L) when compared to those of PC (83.6±4.16ng/L) but not to values of the NC (13.15±0.69ng/L). However, values of CTEG were significantly ($p<0.0127$) reduced more than the findings of CEG and TEG (Figure 4).

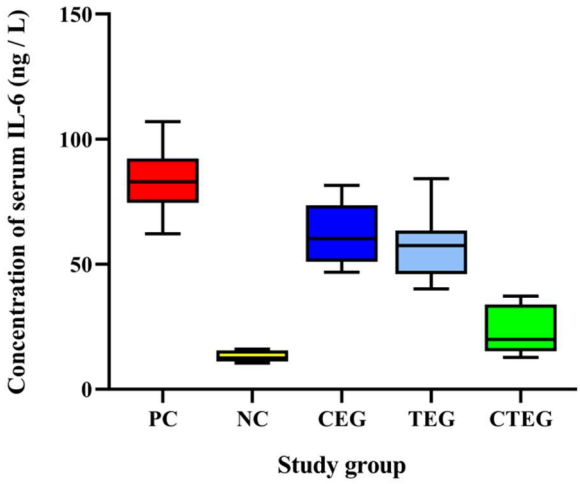

Figure 4. Levels of serum interleukin-6 (IL-6) among the rats of study groups; PC (CFA-injected, not-treated), NC (neither-injected, nor-treated), CEG (CFA-injected, cinnamon-treated), TEG (CFA-injected, turmeric-treated), and CTEG (CFA-injected, cinnamon and turmeric-treated).

Significantly ($p<0.0001$; 95%CI: 176.0 to 937.0), the findings of MMP-1 in CEG (638.9±64.02pg/ml), TEG (544.1±53.6pg/ml), and CTEG (422.4±69.88pg/ml) were lower than observed in PC (1006.1±34.57pg/ml) but higher than recorded in NG (171±7.02pg/ml). Among rats of experimentally groups, the findings of MMP-1 were significantly ($p<0.0284$) the highest in CET and lowest in CTEG when compared to TEG (Figure 5).

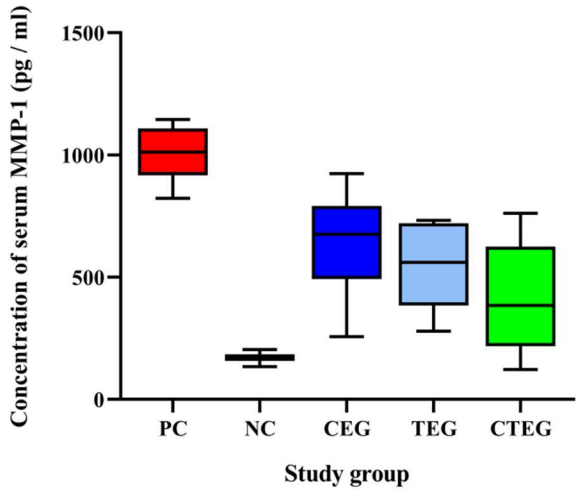

Figure 5. Levels of serum matrix metalloproteinase-1 (MMP-1) among the rats of study groups; PC (CFA-injected, not-treated), NC (neither-injected, nor-treated), CEG (CFA-injected, cinnamon-treated), TEG (CFA-injected, turmeric-treated), and CTEG (CFA-injected, cinnamon and turmeric-treated).

Relation to MMP-10, the findings of CEG (386.6±33.61pg/ml), TEG (371±10.56pg/ml), and CTEG (294.9±28.09pg/ml) were significantly ($p<0.0001$; 95%CI: 109.2 to 1234) lowered than recorded in PC (1523.4±44.13pg/ml) but higher than seen in rats of NC (235.2±17.81pg/ml). However, the findings of experimentally groups were shown insignificant differences ($p<0.0731$) between the values of CEG, TEG, and CTEG (Figure 6).

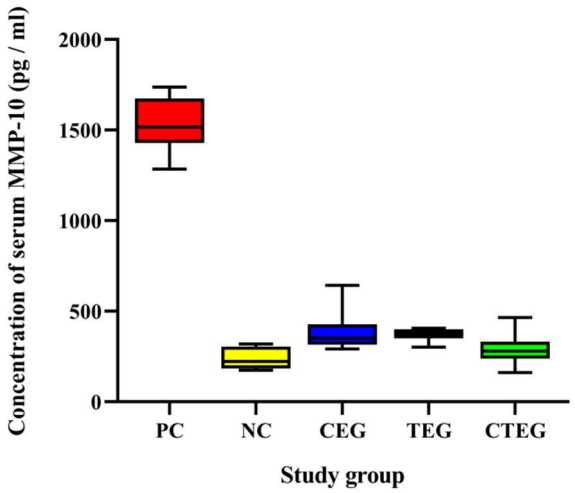

Figure 6. Levels of serum matrix metalloproteinase-10 (MMP-10) among the rats of study groups; PC (CFA-injected, not-treated), NC (neither-injected, nor-treated), CEG (CFA-injected, cinnamon-treated), TEG (CFA-injected, turmeric-treated), and CTEG (CFA-injected, cinnamon and turmeric-treated).

The findings of RF were reported a significant decrease ($p<0.0001$; 95%CI: 15.01 to 1106) in values of CEG (582.1±59.5pg/ml), TEG (414.2±57.3pg/ml) and CTEG (300±16.17pg/ml) when compared to those of PC (1304.1±28.14pg/ml) but not to values of NC (201.4±10.42pg/ml). Subsequently, the findings of experimentally groups were detected significantly ($p<0.00957$) the highest RF values in CET and the lowest in CTEG when compared to those of TEG (Figure 7).

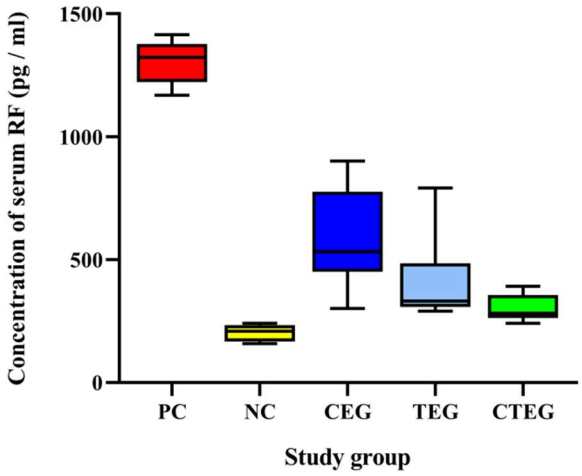

Figure 7. Levels of serum rheumatoid factor (RF) among the rats of study groups; PC (CFA-injected, not-treated), NC (neither-injected, nor-treated), CEG (CFA-injected, cinnamon-treated), TEG (CFA-injected, turmeric-treated), and CTEG (CFA-injected, cinnamon and turmeric-treated).

The findings of TNF-α in CEG (124.9±6.17ng/L), TEG (113.4±5.45ng/L), and CTEG (74.4±7.33ng/L) were reduced significantly ($p<0.0001$; 95%CI: 40.99 to 161.8) when compared to values of PC (160.5±7.16ng/L) but they high than detected in NC (33.9±2.2ng/L). Among the study rats of experimentally groups, values of TNF-α were markedly ($p<0.00248$) the highest in CEG and lowest in CTEG when compared to TEG (Figure 8).

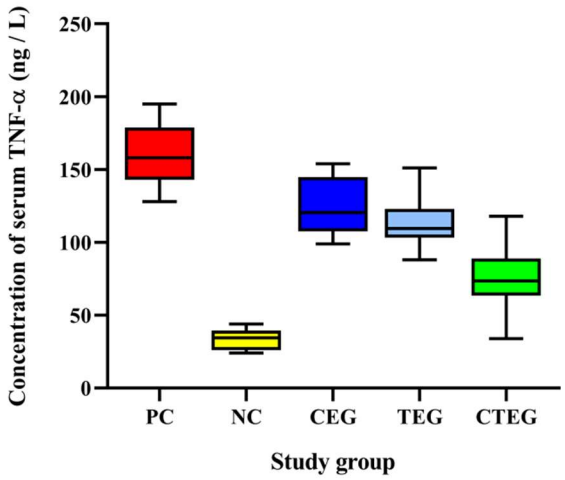

Figure 8. Levels of serum tumor necrosis factor-alpha (TNF-α) among the rats of study groups; PC (CFA-injected, not-treated), NC (neither-injected, nor-treated), CEG (CFA-injected, cinnamon-treated), TEG (CFA-injected, turmeric-treated), and CTEG (CFA-injected, cinnamon and turmeric-treated).

4. Discussion

The topical application of plant extracts through bandages represents an innovative therapeutic strategy that combines the anti-inflammatory properties of phytochemicals with the localized delivery advantages of wound dressing (Yang et al., 2025a). In this study, the findings of experimentally study groups (CEG, TEG, and CTEG) were revealed a significant reduction in values of all study markers (AA, Anti-CCP-Ab, CTX-I, IL-6, MMP-1, MMP-10, RF and TNF-α); however, the values of these markers were remained higher than detected in rats of NC group. Among the findings of experimentally study groups, the highest values of AA, Anti-CCP-Ab, CTX-I, IL-6, MMP-1, RF and TNF-α were detected in rats of CEG while the lowest were identified in CTEG when compared to values of TEG. Nonetheless, values of MMP-10 indicated no significant differences were found between the rats of experimentally groups. In a large proportion of patients, RA is associated with autoantibodies directed against posttranslational modified protiens and peptides including citrullinated, carbamylated, and acetylated targets as well as autoantibodies against the Fc portion of IgG (Burska et al., 2014; Trouw et al., 2017). These immunological markers particularly RF and anti-citrullinated protein antibodies, are now understood to play direct pathogenetic roles and may be present years before the clinical onset of symptoms (de Brito Rocha et al., 2019). Also, the presence of these autoantibodies defines a pre-RA stage that can be identified through the detection of familial or genetic risk factors, biomarker abnormalities, symptoms, and abnormal imaging findings prior to the development of clinical inflammatory arthritis apparent on physical examination (Rönnelid et al., 2021; Sahin et al., 2025). The pathological mechanisms driving transition involve a complex interplay between innate and adaptive immune systems, where fibroblast-like-synoviocytes interact with macrophages, monocytes, mast cells, and dendritic cells to sustain chronic synovitis (Salnikova et al., 2024). This inflammatory milieu is further perpetuated by the production of pro-inflammatory cytokines such as TNF-α and IL-6 which driven synovial hyperplasia and the subsequent destruction of cartilage and bone (Mateen et al., 2016; Shehu et al., 2020).

Worldwide, several studies have been investigated the potential therapeutic effects of cinnamon in RA due to anti-inflammatory and antioxidant properties that may help in modulating the immune response and reducing the joint inflammation (Makkar et al., 2021; Sharma et al., 2021; Kciuk et al., 2024; Li et al., 2024). Also, cinnamon exerts it effects by influencing multiple molecular targets including transcription factors and cytokines (Chen et al., 2022). Almulathanon and Sideek Tawffiq (2023) reported that the bioactive compounds existed in cinnamon have the ability to inhibit the nuclear factor-kappa B signaling pathway and downregulating the expression of pro-inflammatory mediators such as TNF-α and interleukins which are central to the pathogenesis of RA. Other studies demonstrated that cinnamon can attenuate the activation of osteoclasts and the subsequent bone and cartilage resorption that characterizes by disease progression (Babaahmadi et al., 2023). Moreover, cinnamaldehyde, bioactive substance found in cinnamon, has demonstrated the ability to block the phosphatidylinositol 3 kinas / protein kinase B signaling pathway, thereby inhibiting the metastasis and the proliferation of fibroblast-like synoviocytes,

which are the predominant cells involved in autoimmunity, cartilage damage, and inflammation within the synovial joint (Guo et al., 2024; Sankaranarayanan et al., 2024; Karimirad et al., 2025). Clinical evidences have been supported the mechanistic actions as cinnamon supplementation significantly reduces inflammatory biomarkers and improves clinical symptoms of inflammation in patient with RA (Shishehbor et al., 2018; Zhu et al., 2020; Clement, 2022).

On other hand, turmeric has been extensively studied for its therapeutic efficacy in RA through the modulation of multiple signal transduction pathways and nuclear transcription factors (Balendran et al., 2023). Curcumin, bioactive substance found prominently in turmeric, exerts its anti-inflammatory effects by downregulation the expression of pro-inflammatory cytokines such as TNF-α and IL-6, while simultaneously inhibiting the activation of JAK/STAT cascade critically involved in the transduction of signals from numerous cytokine receptors that drive the inflammatory destructive processes within the synovium (Ashrafizadeh et al., 2020; Srinivasan, 2022; Yang et al., 2025b). Additionally, curcumin has been shown to suppress the enzymatic activity of cyclooxygenase-2 and lipoxygenase, thereby reducing the synthesis of prostaglandins and leukotrienes that contribute to synovial inflammation and pain (Chin et al., 2016; Peng et al., 2021). *In vitro*, numerous studies have demonstrated that turmeric decreases the expression of IL-6 and blocking neutrophil recruitment through the inhibition of cellular signaling responsible for actin polymerization and the downregulation of adhesion molecules (Ghandadi and Sahebkar, 2017; Patel et al., 2020; Hussain et al., 2022). These anti-inflammatory mechanisms are further supported by evidence that curcumin ameliorates RA complications through modulating inflammatory and autoreactive responses in immune cells and synovial fibroblast cells via inhibiting the expression or function of pro-inflammatory mediators (Makuch et al., 2021; Pourhabibi-Zarandi et al., 2023).

5. Conclusion

Cinnamon and turmeric are two potent medicinal plants with a long history of use in traditional remedies due to their pharmacological properties. In the present study, though the dressing bandages containing turmeric are more activity than cinnamon, dressing bandages composed both cinnamon and turmeric were highly active in amelioration the negative impact of RA than those covered solely with cinnamon or turmeric. Additionally, the studied markers can be used definitively in diagnosing of RA and estimation the severity of infection especially at acute phase of disease. However, furthermore studies on dressing bandages of cinnamon and turmeric are greatly required due to the low number of available data and investigating their effects on other serum markers.

6. References

[1]. Ahmed, J., Altun, E., Aydogdu, M. O., Gunduz, O., Kerai, L., Ren, G., and Edirisinghe, M. (2019). Anti-fungal bandages containing cinnamon extract. *International Wound Journal*, *16*(3), 730-736.

[2]. Ajaj, E. A., Mohammad, H. A., and Gharban, H. A. (2021). First molecular confirmation of Coenurus cerebralis in sheep and goats with neurological behaviors in Iraq. *Veterinary World*, *14*(6), 1420.

[3]. Al-Graiti, K. H., and Abd AL-Latif, H. A. (2019). Comparative study to know therapeutic the effect of methotraxete dose and alcoholic extract of Curcuma longa on blood parameter and paw thickness in the white rats males that induced rheumatoid arthritis. *Biochemical and Cellular Archives*, *19*(2).

[4]. Alivernini, S., Firestein, G. S., and McInnes, I. B. (2022). The pathogenesis of rheumatoid arthritis. *Immunity*, *55*(12), 2255-2270.

[5]. Al-Maola, K. W., Younis, A. A., Al-Tae, F. M., and Al-Harbi, A. A. (2025). Correlation of Anti-MCV and Anti-CarP Antibodies with Other Clinical and Laboratory Parameters in Patients with Rheumatoid Arthritis. *Eastern Journal Of Medicine*, *30*(4), 653-662.

[6]. Almulathanon, A. A., and Sideek Tawffiq, Z. (2023). A promising role of cinnamon towards rheumatoid arthritis. *MMSL*, *92*(3), 226-234.

[7]. Arleevskaya, M., Takha, E., Petrov, S., Kazarian, G., Renaudineau, Y., Brooks, W., and Novikov, A. (2022). Interplay of environmental, individual and genetic factors in rheumatoid arthritis provocation. *International Journal of Molecular Sciences*, *23*(15), 8140.

[8]. Ashrafizadeh, M., Rafiei, H., Mohammadinejad, R., Afshar, E. G., Farkhondeh, T., and Samarghandian, S. (2020). Potential therapeutic effects of curcumin mediated by JAK/STAT signaling pathway: a review. *Phytotherapy Research*, *34*(8), 1745-1760.

[9]. Babaahmadi, M., Tayebi, B., Gholipour, N. M., Kamardi, M. T., Heidari, S., Baharvand, H., and Hassani, S. N. (2023). Rheumatoid arthritis: the old issue, the new therapeutic approach. *Stem cell research and therapy*, *14*(1), 268.

[10]. Balendran, T., Lim, K., Hamilton, J. A., and Achuthan, A. A. (2023). Targeting transcription factors for therapeutic benefit in rheumatoid arthritis. *Frontiers in Immunology*, *14*, 1196931.

[11]. Brown, P., Pratt, A. G., and Hyrich, K. L. (2024). Therapeutic advances in rheumatoid arthritis. *Bmj*, *384*.

[12]. Burska, A. N., Hunt, L., Boissinot, M., Strollo, R., Ryan, B. J., Vital, E., and Ponchel, F. (2014). Autoantibodies to posttranslational modifications in rheumatoid arthritis. *Mediators of inflammation*, *2014*(1), 492873.

[13]. Chen, P., Zhou, J., Ruan, A., Zeng, L., Liu, J., and Wang, Q. (2022). Cinnamic Aldehyde, the main monomer component of Cinnamon, exhibits anti-inflammatory property in OA synovial fibroblasts via TLR4/MyD88 pathway. *Journal of Cellular and Molecular Medicine*, *26*(3), 913-924.

[14]. Chin, K. Y. (2016). The spice for joint inflammation: anti-inflammatory role of curcumin in treating osteoarthritis. *Drug design, development and therapy*, 3029-3042.

[15]. Chuysinuan, P., Pengsuk, C., Lirdprapamongkol, K., Thanyacharoen, T., Techasakul, S., Svasti, J., and Nooeaid, P. (2023). Turmeric herb extract-incorporated biopolymer dressings with beneficial antibacterial, antioxidant and anti-inflammatory properties for wound healing. *Polymers*, *15*(5), 1090.

[16]. Clement, Y. (2022). Herbs and dietary supplements in rheumatoid arthritis: The clinical evidence. *West Ind J Immunol*. 1(2022), 15-25.

[17]. de Brito Rocha, S., Baldo, D. C., and Andrade, L. E. C. (2019). Clinical and pathophysiologic relevance of autoantibodies in rheumatoid arthritis. *Advances in Rheumatology*, *59*(1), 2.

[18]. El-Saadony, M. T., Saad, A. M., Mohammed, D. M., Alkafaas, S. S., Ghosh, S., Negm, S. H., and El-Tarabily, K. A. (2025). Curcumin, an active component of turmeric: biological activities, nutritional aspects, immunological, bioavailability, and human health benefits-a comprehensive review. *Frontiers in immunology*, *16*, 1603018.

[19]. Figus, F. A., Piga, M., Azzolin, I., McConnell, R., and Iagnocco, A. (2021). Rheumatoid arthritis: extra-articular manifestations and comorbidities. *Autoimmunity reviews*, *20*(4), 102776.

[20]. Ghandadi, M., and Sahebkar, A. (2017). Curcumin: An effective inhibitor of interleukin-6. *Current pharmaceutical design*, *23*(6), 921-931.

[21]. Gharban, H. A., Sray, A. H., and Essa, I. M. (2024). Serological prevalence of anti-Fasciola hepatica antibodies in sheep. *Egyptian Journal of Veterinary Sciences*, *55*(6), 1583-1590.

[22]. Guo, J., Yan, S., Jiang, X., Su, Z., Zhang, F., Xie, J., and Yao, C. (2024). Advances in pharmacological effects and mechanism of action of cinnamaldehyde. *Frontiers in pharmacology*, *15*, 1365949.

[23]. Hasan, A. A., Khudhur, H. R., and Hameed, A. K. (2022). Rheumatic autoimmune diseases (focus on RA): prevalence, types, causes and diagnosis. *Karbala Journal of Pharmaceutical Sciences*, *1*(20).

[24]. Hussain, Y., Abdullah, Khan, F., Alsharif, K. F., Alzahrani, K. J., Saso, L., and Khan, H. (2022). Regulatory effects of curcumin on platelets: an update and future directions. *Biomedicines*, *10*(12), 3180.

[25]. Jahid, M., Khan, K. U., and Ahmed, R. S. (2023). Overview of rheumatoid arthritis and scientific understanding of the disease. *Mediterranean journal of rheumatology*, *34*(3), 284-291.

[26]. Jepkorir, M. (2025). *In Vivo Anti-Inflammatory Activity, Safety and Effect on Gene Expression Profiles of Selected Medicinal Plants against Rheumatoid Arthritis in a Mouse Model* (Doctoral dissertation, COHES-JKUAT).

[27]. Karimirad, R., Inbaraj, B. S., and Chen, B. H. (2025). Recent Advances on the Analysis and Biological Functions of Cinnamaldehyde and Its Derivatives. *Antioxidants*, *14*(7), 765.

[28]. Kaur, C., Mishra, Y., Kumar, R., Singh, G., Singh, S., Mishra, V., and Tambuwala, M. M. (2024). Pathophysiology, diagnosis, and herbal medicine-based therapeutic implication of rheumatoid arthritis: an overview. *Inflammopharmacology*, *32*(3), 1705-1720.

[29]. Kciuk, M., Garg, A., Rohilla, M., Chaudhary, R., Dhankhar, S., Dhiman, S., and Kontek, R. (2024). Therapeutic potential of plant-Derived compounds and plant extracts in rheumatoid Arthritis—Comprehensive review. *Antioxidants*, *13*(7), 775.

[30]. Kshash, I. M., and Hussain, K. A. M. (2022). Preparation of A Green Nanocomposite From Cinnamomum Zeylanicum and Its Effect on Some Immunological Parameters in Rats with Rheumatoid Arthritis. *International Journal of Health Sciences*, (III), 6153-6168.

[31]. Kulicka, J., Bychowski, M., Kwaśna, J., Załęska, A., Kaźmierczyk, I., Lenart, K., and Bednarek, S. (2024). Unlocking the Power of Cinnamon: A Detailed Review of Cinnamon Therapeutic Effects in Chronic Disease Management. *Quality in Sport*, *28*, 56834-56834.

[32]. Lhotellerie, F., Ben Ismail, A. E., Sarrand, J., and Soyfoo, M. (2025). Seronegative Rheumatoid Arthritis: A Distinct Immunopathological Entity with Erosive Potential. *Medical Sciences*, *14*(1), 14.

[33]. Li, J., Cao, J., Chen, Q., Liu, D., and Li, R. (2024). Investigating the therapeutic potential of sinomenine in rheumatoid arthritis: anti-inflammatory, antioxidant, and immunomodulatory mechanisms. *Naunyn-Schmiedeberg's Archives of Pharmacology*, *397*(6), 3945-3958.

[34]. Makkar, R., Behl, T., Kumar, A., Nijhawan, P., and Arora, S. (2021). Emerging therapeutic effects of herbal plants in rheumatoid arthritis. *Endocrine, Metabolic and Immune Disorders-Drug Targets (Formerly Current Drug Targets-Immune, Endocrine and Metabolic Disorders)*, *21*(4), 617-625.

[35]. Makuch, S., Więcek, K., and Woźniak, M. (2021). The immunomodulatory and anti-inflammatory effect of curcumin on immune cell populations, cytokines, and in vivo models of rheumatoid arthritis. *Pharmaceuticals*, *14*(4), 309.

[36]. Malmström, V., Catrina, A. I., and Klareskog, L. (2017). The immunopathogenesis of seropositive rheumatoid arthritis: from triggering to targeting. *Nature Reviews Immunology*, *17*(1), 60-75.

[37]. Mateen, S., Zafar, A., Moin, S., Khan, A. Q., and Zubair, S. (2016). Understanding the role of cytokines in the pathogenesis of rheumatoid arthritis. *Clinica chimica acta*, *455*, 161-171.

[38]. Nevius, E., Gomes, A. C., and Pereira, J. P. (2016). Inflammatory cell migration in rheumatoid arthritis: a comprehensive review. *Clinical reviews in allergy and immunology*, *51*(1), 59-78.

[39]. Olalekan, S. A. (2014). *Mechanism of B Cell Suppression of Regulatory T cells in Proteoglycan-Induced Arthritis*. PhD Dissertation, Rush University, USA. .

[40]. Panagopoulos, P. K., and Lambrou, G. I. (2018). Bone erosions in rheumatoid arthritis: recent developments in pathogenesis and therapeutic implications. *Journal of musculoskeletal and neuronal interactions*, *18*(3), 304.

[41]. Patel, S. S., Acharya, A., Ray, R. S., Agrawal, R., Raghuwanshi, R., and Jain, P. (2020). Cellular and molecular mechanisms of curcumin in prevention and treatment of disease. *Critical reviews in food science and nutrition*, *60*(6), 887-939.

[42]. Peng, Y., Ao, M., Dong, B., Jiang, Y., Yu, L., Chen, Z., and Xu, R. (2021). Anti-inflammatory effects of curcumin in the inflammatory diseases: status, limitations and countermeasures. *Drug design, development and therapy*, 4503-4525.

[43]. Perera, J., Delrosso, C. A., Nerviani, A., and Pitzalis, C. (2024). Clinical phenotypes, serological biomarkers, and synovial features defining seropositive and seronegative rheumatoid arthritis: a literature review. *Cells*, *13*(9), 743.

[44]. Pourhabibi-Zarandi, F., Shojaei-Zarghani, S., and Rafraf, M. (2021). Curcumin and rheumatoid arthritis: A systematic review of literature. *International Journal of Clinical Practice*, *75*(10), e14280.

[45]. Rasool, D. F., Fatah, H. R., and Zangana, E. K. M. (2025). Anti-inflammatory and immunomodulatory effect of purslane and turmeric in rheumatoid arthritis rat models. *Cellular and Molecular Biology*, *71*(8), 22-29.

[46]. Rönnelid, J., Turesson, C., and Kastbom, A. (2021). Autoantibodies in rheumatoid arthritis–laboratory and clinical perspectives. *Frontiers in immunology*, *12*, 685312.

[47]. Sahin, D., Di Matteo, A., and Emery, P. (2025). Biomarkers in the diagnosis, prognosis and management of rheumatoid arthritis: A comprehensive review. *Annals of Clinical Biochemistry*, *62*(1), 3-21.

[48]. Salnikova, D. I., Nikiforov, N. G., Postnov, A. Y., and Orekhov, A. N. (2024). Target role of monocytes as key cells of innate immunity in rheumatoid arthritis. *Diseases*, *12*(5), 81.

[49]. Sankaranarayanan, J., Lee, S. C., Kim, H. K., Kang, J. Y., Kuppa, S. S., and Seon, J. K. (2024). Cinnamaldehyde-Mediated Suppression of MMP-13, COX-2, and IL-6 Through MAPK and NF-κB Signaling Inhibition in Chondrocytes and Synoviocytes Under Inflammatory Conditions. *International Journal of Molecular Sciences*, *25*(23), 12914.

[50]. Sharma, D., Chaubey, P., and Suvarna, V. (2021). Role of natural products in alleviation of rheumatoid arthritis—A review. *Journal of food biochemistry*, *45*(4), e13673.

[51]. Shehu, S., Kurya, A. U., Aliyu, U., and Sharma, D. C. (2020). Role of inflammatory cytokines in the pathogenesis of rheumatoid arthritis and novel therapeutic targets. *Asian J Immunol*, *3*, 37-46.

[52]. Shishehbor, F., Rezaeyan Safar, M., Rajaei, E., and Haghighizadeh, M. H. (2018). Cinnamon consumption improves clinical symptoms and inflammatory markers in women with rheumatoid arthritis. *Journal of the American College of Nutrition*, *37*(8), 685-690.

[53]. Soyfoo, M., and Sarrand, J. (2026). Biomarkers in Rheumatoid Arthritis: From Traditional Serology to Precision Medicine Integration. *Diagnostics*, *16*(2), 330.

[54]. Srinivasan, K. (2022). Anti-inflammatory influences of culinary spices and their bioactives. *Food Reviews International*, *38*(sup1), 1-17.

[55]. Trivedi, J. (2024). Clinical Presentation and Diagnosis of Rheumatoid Arthritis. *Ann Clin Med Case Rep*, *13*(18), 1-7.

[56]. Trouw, L. A., Rispens, T., and Toes, R. E. (2017). Beyond citrullination: other post-translational protein modifications in rheumatoid arthritis. *Nature Reviews Rheumatology*, *13*(6), 331-339.

[57]. Verma, S., Panchpuri, M., Dwibedi, V., Rath, S. K., and Devi, A. (2025). Exploring herbal synergies in the management of rheumatoid arthritis: a multifaceted approach to inflammation and joint health. *Inflammopharmacology*, *33*(11), 6457-6484.

[58]. Yang, B., Xu, J., Liu, S., Wu, C., Li, Y., Lv, M., and Wang, G. (2025a). Applications of bioactive herbal extracts in dressing materials for skin wound repair: Ingredients, mechanisms and innovations. *Interdisciplinary Medicine*, e20240117.

[59]. Yang, Y. Z., Li, J. D., Zhang, J. G., Zhang, K., Zhang, A. R., Li, P. P., and Guo, H. Z. (2025b). Mechanism of action and new developments in the study of curcumin in the treatment of osteoarthritis: a narrative review. *Inflammopharmacology*, 1-12.

[60]. Youssef, M. A., Hamza, N. M., and Hussain, K. A. M. (2023). The effect of aqueous extract of Cinnamonum zeylanicum on some biochemical parameters in male white rats in which rheumatoid arthritis is induced. In *AIP Conference Proceedings*. AIP Publishing LLC, 2414(1), 020031.

[61]. Zhu, C., Yan, H., Zheng, Y., Santos, H. O., Macit, M. S., and Zhao, K. (2020). Impact of cinnamon supplementation on cardiometabolic biomarkers of inflammation and oxidative stress: a systematic review and meta-analysis of randomized controlled trials. *Complementary therapies in medicine*, *53*, 102517.