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Original Research Article

Investigation of the effects of alcoholic frankincense extract on oxidative stress and inflammatory parameters in C57BL/6 mice with induced autoimmune encephalomyelitis

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Abstract

Objective: Multiple sclerosis (MS) is a chronic autoimmune disease characterized by neuroinflammation and demyelination. Frankincense, a natural oleo-gum-resin obtained from the genus Boswellia (family Burseraceae), possesses anti-inflammatory and immunomodulatory properties. This study aimed to evaluate the therapeutic effects of alcoholic frankincense extract in an experimental model of MS.

Materials and Methods: Female C57BL/6 mice were randomly assigned to three groups (n = 5). Experimental autoimmune encephalomyelitis (EAE) was induced by subcutaneous immunization with $MOG_{35–55}$/CFA and intraperitoneal injection of pertussis toxin. Mice were treated orally with alcoholic frankincense extract (200 mg/kg) for 33 days. Serum levels of IL-17A, IL-23, transforming growth factor-β (TGF-β), and total antioxidant capacity (TAC) were measured, and brain tissues were examined histopathologically.

Results: EAE induction caused significant weight loss, severe clinical symptoms, increased IL-17A and IL-23 levels, reduced TGF-β and TAC, and marked neuroinflammation with myelin damage. Frankincense treatment significantly improved clinical scores and body weight, decreased pro-inflammatory cytokines, enhanced antioxidant capacity, and attenuated inflammatory infiltration and myelin degradation in brain tissue.

Conclusion: Alcoholic frankincense extract ameliorated EAE-associated inflammation and oxidative stress and exerted a protective effect on myelin integrity, suggesting its potential as a complementary therapeutic approach for MS. Further studies are warranted to confirm its clinical applicability.

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Introduction

Multiple sclerosis (MS) is an autoimmune, inflammatory, and demyelinating disease of the central nervous system (CNS), which typically begins in early adulthood and leads to progressive neurological symptoms such as muscle weakness, sensory disturbances, visual impairments, and balance disorders (Yamasaki 2025). It is one of the most common causes of non-traumatic neurological disability in young adults and imposes a considerable socio-economic burden, particularly in industrialized societies (Pierret et al. 2025). In the pathophysiology of MS, the breakdown of immune tolerance toward myelin antigens leads to the migration of autoreactive lymphocytes—especially $CD4^+$ T cells of the Th1 and Th17 subsets—into the CNS. This process is accompanied by the production of pro-inflammatory cytokines (such as Interleukin—17 (IL-17), Interferon-gamma (IFN-γ), and Tumor Necrosis Factor-alpha (TNF-α)), activation of microglia, increased permeability of the blood-brain barrier, and ultimately, axonal and myelin damage (Lorenzut et al. 2025; Zéphir 2018).

Current treatments, including interferons, glatiramer acetate, and immune-modulating drugs such as fingolimod and natalizumab, are somewhat effective in reducing disease severity (Weber et al. 2012). However, these therapies are often associated with significant side effects, highlighting the need for safer and more effective therapeutic approaches (Mirabella et al. 2022). In this regard, attention has increasingly turned to natural compounds with immunomodulatory properties. One such compound is frankincense resin, derived from the *Boswellia serrata* tree, which has long been recognized in traditional medicine for its anti-inflammatory and healing properties (Hamidpour et al. 2015; Khalifa et al. 2023).

Studies have shown that the bioactive compounds found in frankincense — particularly boswellic acids— possess anti-inflammatory, antioxidant, and immune-regulatory properties (Ammon 2016; Anthoni et al. 2006). These compounds inhibit inflammatory pathways such as NF-κB, reduce the activity of the enzyme 5-lipoxygenase (5-LOX), and suppress the production of pro-inflammatory cytokines like IL-1β, IL-6, and TNF-α (Ammon 2006). Shadab et al. reported that boswellic acids can modulate T cell subsets by reducing Th1 and Th17 cells while increasing regulatory T cells (Tregs) and Th2 cells, thereby shifting the immune response toward a more anti-inflammatory profile (Shadab et al. 2024).

Given the importance of MS and the notable immunomodulatory and anti-inflammatory properties of frankincense and its active compounds, the present study was conducted to investigate the immunomodulatory effects of alcoholic frankincense extract in suppressing autoimmune inflammatory disease in C57BL/6 mice.

Materials and Methods

Extract preparation

The Frankincense resin was crushed into small pieces, and then, 250 g of the resin was dissolved in 500 ml of methanol for 72 hr using a shaker set. The solution was then centrifuged at 3,000 RPM for 10 min, after which, the surface solution was separated from the precipitate and passed through a Whatman paper filter. The obtained solvent was compacted and concentrated using a rotary device at 45°C, and then, using a pipette, 3 ml of the resultant fluid was put into the glass bottles. The bottles were placed in the freezer (-70°C) for 24 hr to be completely frozen and then, placed in the freeze drier (Zirbus, Germany) for 24 hr to produce a dry powder. In the end, the powder from the bottoms of the bottles was shaved and transferred to a 50-ml Falcon tube. The

prepared extract was stored at -18°C until running the experiments.

Induction of experimental autoimmune encephalomyelitis (EAE) in mice

EAE was induced in female C57BL/6 mice using Hooke Kit™ $MOG_{35–55}$/CFA Emulsion PTX (Cat. No. EK-2110), according to the manufacturer's instructions (Hooke Laboratories, USA) and previously described protocols (Miller and Karpus 2007). Briefly, the mice were injected subcutaneously (s.c) on day zero with an emulsion of MOG35-55/CFA over two flank areas (0.2 ml /mouse). Mice received two intraperitoneal (i.p) injections of pertussis toxin dissolved in Phosphate-Buffered Saline (PBS) (pH of 7.4) at 2 and 24-hr after immunization (80 ng for each mouse). Mice were monitored with clinical scores and weighed daily from post immunization for 33 days.

Experimental animals and EAE clinical scoring

In this experimental study, female C57BL/6 mice aged 11–12 weeks and weighing 20–25 g were randomly assigned to three groups (n = 5 per group). The first group served as the healthy control and received only PBS without EAE induction. The second group was designated as the EAE control and received PBS following disease induction, without any treatment. The third group received an oral dose of 200 mg/kg (Chevrier et al. 2005; Umar et al. 2014) body weight of alcoholic extract of frankincense daily for 33 consecutive days following EAE induction.

Clinical evaluation of EAE severity was performed according to a standardized scoring system as follows (Bittner et al. 2014; Miller and Karpus 2007): 0 = no clinical signs; 0.5 = partially limp tail; 1 = completely limp tail; 1.5 = limp tail with mild hind limb impairment; 2 = limp tail with moderate hind limb weakness; 2.5 = limp tail with dragging of hind limbs; 3 = complete hind limb paralysis; 3.5 = complete hind limb paralysis with forelimb weakness; 4 = hind limb paralysis with partial forelimb paralysis; 4.5 = severe paralysis with minimal movement; and 5 = moribund or death.

Mice were monitored daily for body weight and clinical symptoms throughout the experimental period.

Proliferation assay

Splenic mononuclear cells (SMCs) isolated from mouse spleens using a Ficoll gradient were used for this assay. Then, 200 microliters containing 2×10^5 cells were cultured in Roswell Park Memorial Institute 1640 (RPMI-1640) culture medium in the presence of Myelin Oligodendrocyte Glycoprotein $_{35–55}$ ($MOG_{35–55}$) peptide or Phytohemagglutinin (PHA) as a T-cell stimulant in 96-well plates and then incubated at 37°C for 48 hr. In the next step, 30 µl of 3-(4,5-Dimethylthiazol-2-yl)-2,5-Diphenyltetrazolium Bromide (MTT) solution with a concentration of 5 mg/ml was added to each well and incubated for 4 hr, followed by centrifugation at 1200 rpm for 10 min. Then, 100 µl of the supernatant was removed and 100 µl of Dimethyl Sulfoxide (DMSO) was added to each well, and the optical density (OD) of each well was measured using a Nanodrop spectrophotometer at 570 nm, with 630 nm as reference.

The MTT assay was employed to evaluate the proliferative capacity and metabolic activity of immune cells, which reflects their viability and response to antigenic stimulation.

ELISA assay

A total of 1000 µl of complete culture medium containing 1×10^6 splenic mononuclear cells was added into each well of 24-well plates and then, incubated at 37°C for 48 hr in the presence of $MOG_{35–55}$ peptide or PHA antigen. The plates were then centrifuged at 1200 rpm for 10 min, and the supernatants were collected. The levels of inflammatory cytokines (TGF-β, IL-17A, and IL-23) secreted by the isolated splenic cells were measured using the

ELISA method. The cytokines were measured using EASTBIOPHARM enzyme-linked immunosorbent assay (ELISA) kits (EASTBIOPHARM Co., Hangzhou, China) according to the manufacturer's instructions, with readings performed at 450 nm (Kim et al. 2012; Tian et al. 2018).

FRAP test

Serum total antioxidant capacity (TAC) was measured using the Ferric Reducing Antioxidant Power (FRAP) method. In this method, the reduction of iron ferric ions (Fe^{3+}) to ferrous iron (Fe^{2+}) in the Fe^{3+}-TPTZ complex caused by available reducing agents in biological samples forms a blue-colored complex, with an increased absorbance, which is measured using a spectrophotometer at 593 nm against distilled water (Mohammadi et al. 2022). For this study, the Total Antioxidant Capacity Assay Kit-TAC kit of Navand Salamat Company was used according to the manufacturer's instructions.

Histological assessment

On day 33 post-immunization, the animals were sacrificed, and their brains were excised and placed in 10% formalin. In the pathology laboratory, the samples were treated with a tissue processor 48 hr after fixation in a formalin solution. After processing, paraffin blocks were prepared, and using a microtome, slides were produced with a thickness of 5 micrometers. On each slide, three sections of 5 μm were stained with Hematoxylin-Eosin (H&E) and Luxol fast blue (LFB) staining. The sections were examined by a pathologist, using light microscopy with a magnification of 40x.

Statistical analyses

All statistical analyses were performed using SPSS software (version 16; IBM Corp., Armonk, NY, USA). Data are presented as mean ± standard deviation (SD). Differences among experimental groups were assessed using one-way analysis of variance (ANOVA), followed by Tukey's post hoc test for multiple comparisons. A p-value of less than 0.05 was considered statistically significant.

Results

Body weight changes and clinical scores

The changes in body weight and clinical scores of the experimental groups are illustrated in Figures 1 and 2. As shown in Figure 1, the body weight of animals in the control group remained stable throughout the study period. In contrast, the EAE group exhibited a significant reduction in body weight starting around day 11 post-immunization, which continued progressively until the end of the study. From day 25 onward, the reduction in body weight was statistically significant compared to the control group ($p<0.05$). In the treatment group, although an initial decrease in body weight similar to the EAE group was observed, the decline was less severe, and from approximately day 24, the body weight of treated animals was significantly higher than that of the EAE group ($p<0.05$).

Regarding clinical scores (Figure 2), animals in the control group showed no signs of EAE throughout the study (score = 0). In the EAE group, clinical signs began to appear around days 10–11 post-immunization, rapidly worsening and reaching peak severity (clinical score of approximately 2.5–3) on days 13–14. Following this peak, clinical scores remained consistently high in this group. In the treatment group, although the onset and peak of clinical signs were similar to those of the EAE group, from around days 19–20 onward, the severity of clinical symptoms gradually and significantly declined. This reduction continued clearly until the end of the study, and by the final days, the clinical scores of the treated group were markedly lower than those of the EAE group ($p<0.05$).

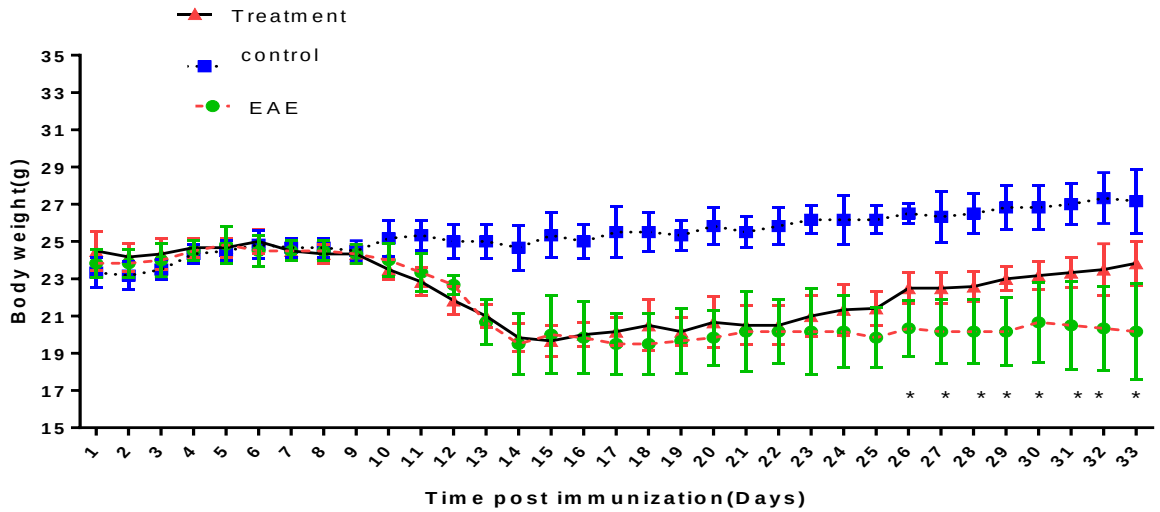

Figure 1. Body weight changes in control, experimental autoimmune encephalomyelitis (EAE), and treatment mice. Data are expressed as mean ± SD. *p<0.05.

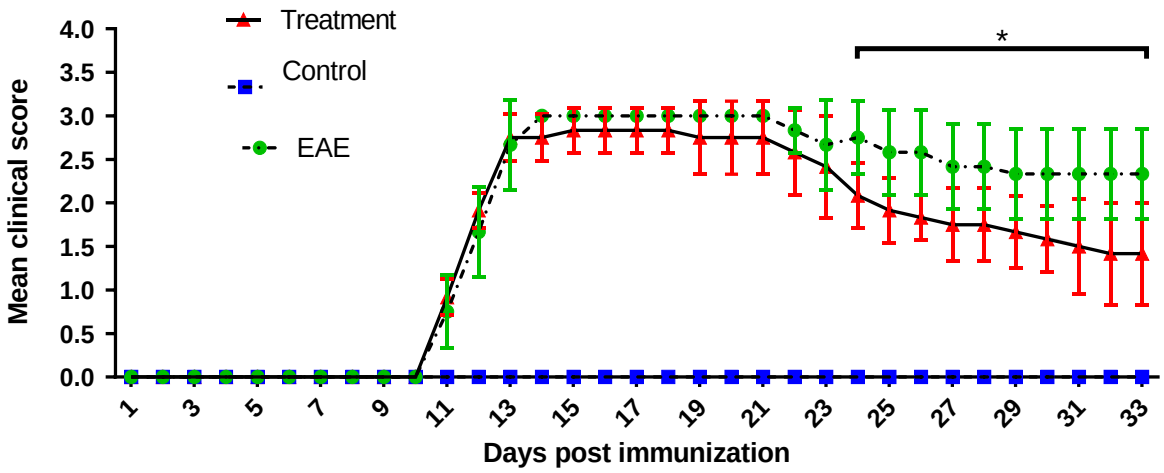

Figure 2. Mean clinical score in control, experimental autoimmune encephalomyelitis (EAE), and treatment mice. Data are expressed as mean ± SD. *p<0.05.

Changes in serum levels of inflammatory cytokines

The results related to the levels of key cytokines produced by splenic cells of mice in the different experimental groups, are presented in Table 1. In the EAE group, the mean level of IL-17A showed a significant increase of approximately 43.88% compared to the control group (p = 0.000). Treatment with alcoholic Frankincense extract led to a significant reduction of about 25.18% in IL-17A levels in the treatment group compared to the EAE group (p = 0.002). It is noteworthy that the IL-17A level in the treatment group remained only about 7.65% higher than that of the control group, which was not statistically significant.

The IL-23 level in the EAE group showed a significant increase of approximately 57.15% compared to the control group (p = 0.0000). In the treatment group, IL-23 levels were significantly reduced by about 20.54% compared to the EAE group (p = 0.011). However, IL-23 levels in the treatment group remained approximately 24.87% higher than those in the control group, which was not statistically significant.

Regarding TGF-β, the EAE group exhibited a significant decrease of about 13.05% in the mean level compared to the

control group (p = 0.029). In the treatment group, TGF-β levels showed only a slight increase of approximately 2.58% compared to the EAE group, which was not statistically significant. This increase was insufficient to compensate for the initial disease-related reduction, and the TGF-β level remained about 10.80% lower than that of the control group.

Changes in serum total antioxidant capacity (TAC)

The serum levels of TAC in the studied groups are presented in Table 2. In the control group, the mean TAC level was 1.94 ± 0.20. In contrast, in the EAE group, the mean TAC level decreased to 1.27 ± 0.29. This reduction, approximately 34.54% compared to the control group, was statistically significant (p= 0.02). However, in the group treated with Frankincense extract, the mean TAC level increased to 2.06 ± 0.56. This increase was substantial and statistically significant compared to the EAE group (p=0.007), reflecting an approximate 62.20% enhancement in antioxidant capacity. Moreover, the TAC level in the treatment group not only returned to the level observed in the control group but also slightly exceeded it, with an approximate increase of 6.19% compared to the control. However, this difference was not statistically significant (p = 0.85).

Changes in cell proliferation

The results of cell proliferation, assessed by the stimulation index (SI), are presented in Table 3. In the EAE group, the SI increased significantly, showing an approximately 33.90% rise compared to the control group (p=0.002). In the group treated with Frankincense extract, the mean SI was 1.50 ± 0.20. Although this represented a reduction of approximately 5.06% compared to the EAE group, the difference was not statistically significant (p = 0.656). However, when comparing the treatment group with the control group, the SI remained significantly elevated in the treatment group (p=0.011), with an approximate 27.12% increase relative to the control.

Table 1. Levels of cytokine IL-23, IL-17A and TGF-β produced by mouse splenic cells in three groups of control, experimental autoimmune encephalomyelitis (EAE), and treatment mice.

		Control	EAE	Treatment	p-value Control Vs EAE	p-value Treatment Vs EAE	p-value Treatment Vs Control
IL-17A	Mean	244.3	351.5	263	0.000	0.002	0.67
	SD	21.06	16.67	59.79			
IL-23	Mean	86.73	136.3	108.3	0.0000	0.011	0.052
	SD	13.67	15.44	14.40			
TGF-β	Mean	935	813	834	0.029	0.87	0.073
	SD	47	76	89			

Table 2. Comparison of mean serum total antioxidant capacity in control, experimental autoimmune encephalomyelitis (EAE), and treatment mice.

		Control	EAE	Treatment	p-value Control Vs EAE	p-value Treatment Vs EAE	p-value Treatment Vs Control
Total antioxidant capacity (TAC)	Mean	1.94	1.27	2.06	0.02	0.007	0.85
	SD	0.20	0.29	0.56			

Table 3. Comparison of the splenic lymphocyte proliferation stimulation index (S.I.) among control, experimental autoimmune encephalomyelitis (EAE), and treated mice.

		Control	EAE	Treatment	p-value Control Vs EAE	p-value Treatment Vs EAE	p-value Treatment Vs Control
Stimulation Index (SI)	Mean	1.18	1.58	1.50	0.002	0.656	0.011
	SD	0.13	0.14	0.20			

Histopathology of brain tissue

To assess myelin degradation in the brains of mice, Luxol Fast Blue (LFB) staining was performed, and to compare the degree of cellular infiltration among the three experimental groups, hematoxylin and eosin (H&E) staining was used (Figures 3 and 4). Histopathological analysis revealed that the brain tissue in the control group maintained a normal structure; myelin appeared dense and intact (Figure 3, Control), and no signs of inflammation or perivascular cellular infiltration were observed (Figure 4, Control).

In contrast, EAE-induced mice exhibited extensive myelin degradation, characterized by a marked reduction in myelin staining intensity (paler, less dense areas) compared to the control group (Figure 3, EAE). Furthermore, in the EAE group, there was severe infiltration of inflammatory cells, manifested as perivascular cuffing and widespread cellular aggregates within the brain parenchyma, indicative of a pronounced and acute inflammatory response (Figure 4, EAE).

In the treatment group, although full restoration of myelin integrity was not achieved, there was a noticeable reduction in myelin loss and partial recovery of myelin structure compared to the EAE group (Figure 3, Treatment). Additionally, the intensity of inflammatory cell infiltration in the brains of treated mice was markedly reduced, and perivascular inflammatory foci were smaller and less dense than those observed in the EAE group, suggesting a modulatory effect of the treatment on the neuroinflammatory response (Figure 4, Treatment).

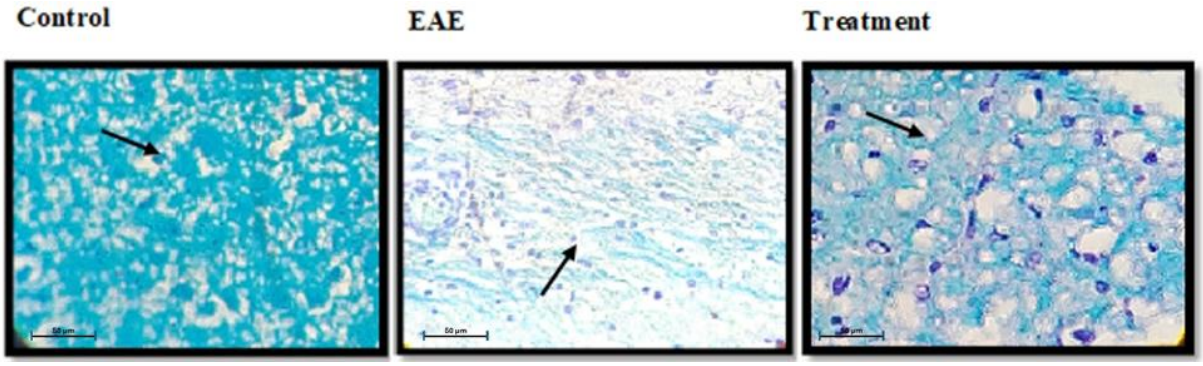

Figure 3. Comparison of myelin degradation in the brains of control, experimental autoimmune encephalomyelitis (EAE), and treatment mice. Black arrows indicate degree of demyelination. 400X

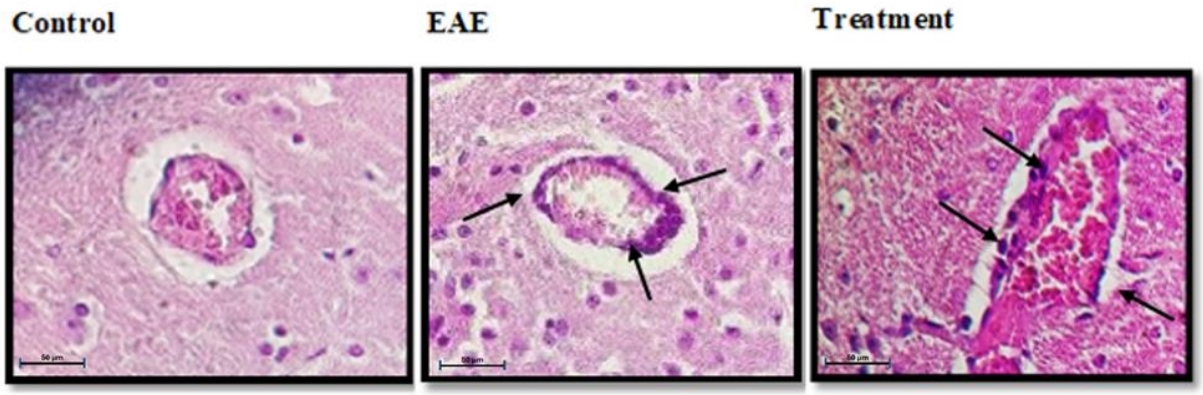

Figure 4. Comparison of cell infiltration rate in the brain section in three groups of control, experimental autoimmune encephalomyelitis (EAE), and treatment. 400X

Discussion

The results of the present study demonstrated that *B. serrata* (frankincense) extract significantly reduced the severity of EAE symptoms in the animal model. These effects included a significant decrease in clinical symptoms, improved body weight, reduced levels of pro-inflammatory cytokines such as IL-17A and IL-23, enhanced serum total antioxidant capacity (TAC), and reduced cellular infiltration and myelin degradation in brain tissue. These findings are consistent with previous studies on the anti-inflammatory and immunomodulatory effects of frankincense and its active compounds, especially boswellic acids (Aldahlawi et al. 2020; Ammon 2006).

Body weight loss in the EAE group began around day 11 post-immunization and was accompanied by a progressive worsening of clinical signs, indicating successful disease induction in this model. Treatment with alcoholic frankincense extract helped preserve body weight and reduce clinical severity from day 19–20, which is in line with earlier studies showing the neuroprotective effects of frankincense (Abdel-Tawab et al. 2011). This improvement is likely attributed to reduced neuroinflammation and preservation of myelin integrity.

Changes in inflammatory cytokines were among the most significant findings of this study. A 43.88% increase in IL-17A in the EAE group compared to controls highlights the crucial role of this cytokine in the pathogenesis of multiple sclerosis. IL-17A, primarily produced by Th17 cells, facilitates the infiltration of inflammatory cells across the blood-brain barrier (BBB) and contributes to myelin destruction (Huppert et al. 2010; Kebir et al. 2007). A 25.18% reduction in IL-17A levels following treatment with frankincense suggests the plant role in regulating Th17-mediated immune responses. Stürner et al. have also reported significant reductions in IL-17A-producing CD8+ T cells after treatment with standardized frankincense extracts (Stürner et al. 2018).

The 57.15% increase in IL-23 levels in the EAE group and its 20.54% reduction following treatment underscore the critical role of the IL-23/IL-17 axis in the disease pathogenesis. IL-23, mainly produced by macrophages and dendritic cells, plays a key role in the differentiation and activation of Th17 cells (Cua et al. 2003; Langrish et al. 2005). The current study demonstrated that alcoholic frankincense extract can inhibit this pathway, thereby reducing Th17-related immune responses. This effect is likely mediated through active compounds such as boswellic acids, which have been shown to inhibit Th17 differentiation and function via direct suppression of the RORγt and STAT3 pathways (Stürner et al. 2014). These compounds also suppress NF-κB activity, thereby reducing the production of other pro-inflammatory cytokines such as TNF-α and IL-6, which are implicated in MS pathogenesis (Doğan et al. 2025).

A 13.05% reduction in TGF-β levels in the EAE group and the absence of a significant rebound after treatment reflect the complex role of this cytokine in multiple sclerosis. TGF-β plays a dual role in this disease: on one hand, it acts as an anti-inflammatory cytokine, while on the other, it promotes the differentiation of Th17 cells (Mangan et al. 2006; Sotiropoulos and Chitnis 2020). The observed decrease in acute phases of the disease likely reflects disruption of normal regulatory mechanisms.

Another key finding of the study was the improvement in TAC levels in the frankincense-treated group. Oxidative stress plays a central role in myelin damage and neuronal injury in CNS autoimmune diseases (Wójcik et al. 2021). TAC levels were significantly reduced in EAE mice, suggesting elevated oxidative stress. The observed improvement in TAC levels indicates a potential role for alcoholic frankincense extract in activating the Nrf2 pathway (Atieh 2023). The Nrf2/ARE

signaling pathway, through upregulation of antioxidant enzymes such as superoxide dismutas (SOD), glutathione peroxidase (GPx), and heme oxygenase-1(HO-1), protects neural tissue against oxidative damage (Loboda et al. 2016). Although oxidative stress was not directly measured in brain tissue, the significant improvement in systemic TAC levels and reduction of histopathological damage suggest a possible attenuation of oxidative injury within the CNS. Previous studies have shown that acetyl-11-keto-β-boswellic acid (AKBA), a major bioactive component of frankincense, exerts potent antioxidant and neuroprotective effects in brain tissue by activating the Nrf2 pathway and reducing reactive oxygen species (ROS)-mediated injury (Assaran et al. 2024; Atieh 2023). Therefore, the present findings are in line with these reports and imply that the improvements observed may, at least in part, result from reduced oxidative stress in the CNS.

Analysis of the SI revealed a slight reduction in SI following treatment with frankincense, although this decrease was not statistically significant. This finding suggests that frankincense acts more as an immunomodulator rather than an immunosuppressant, which is a therapeutic advantage in autoimmune diseases where strong immunosuppression may increase the risk of infections (Almeida-da-Silva et al. 2022; Mikhaeil et al. 2003).

Histopathological results also supported the clinical and molecular findings. Significant reductions in demyelination and inflammatory cell infiltration in the treatment group confirmed the protective and anti-inflammatory effects of frankincense extract. These histological improvements directly result from observed molecular mechanisms, including reduced pro-inflammatory cytokines (IL-17A and IL-23) and enhanced TAC. Reduced inflammation leads to decreased damage to myelin and neurons, thereby improving clinical symptoms (Alizadeh et al. 2015). Although complete remyelination was not observed, partial myelin repair and reduced inflammatory cell infiltration highlight the therapeutic potential of frankincense in slowing disease progression and mitigating neuronal damage. These findings are consistent with other EAE studies using alternative therapeutic agents and point to shared molecular mechanisms in modulating inflammation and preserving myelin (Kopper and Gensel 2018; Shadab et al. 2024).

One of the major strengths of this study was the use of the standardized EAE animal model to simulate the pathophysiology of MS, which provided a highly controlled and reliable setting for evaluating the effects of frankincense extract. The application of diverse parameters—including clinical, immunological, antioxidant, and histopathological indices—enabled a multidimensional assessment of treatment response, thereby enhancing the validity and interpretability of the findings.

Despite these valuable outcomes, the current study also had several important limitations. First, only one dose of alcoholic frankincense extract was examined, and dose–response relationships were not evaluated. Second, although the study investigated some immune mechanisms, it did not include comprehensive molecular analyses—such as the expression of regulatory genes (e.g., *RORγt, STAT3, or NF-κB*) or the assessment of antioxidant pathways like Nrf2/ARE—that could have provided deeper mechanistic insights. Third, oxidative stress markers were not directly measured in brain tissue, which limits the ability to confirm tissue-level antioxidant effects. Fourth, the study also did not identify or quantify the specific bioactive compounds within the frankincense extract, which limits understanding of which constituents may be responsible for the observed effects. Finally, the investigation was confined to the acute phase of the disease and did not assess long-term or chronic outcomes.

Therefore, future studies are warranted to include larger sample sizes, multiple dosages, detailed molecular analyses, direct measurement of oxidative stress markers in CNS tissue, and longitudinal evaluations to deepen our understanding of the mechanisms underlying frankincense effects and to pave the way for potential clinical applications.

Overall, the findings of this study suggest that alcoholic frankincense extract may help mitigate the progression of inflammatory diseases such as MS through modulation of immune responses, reduction of inflammation, inhibition of oxidative stress, and protection of myelin structure. However, further large-scale clinical studies are necessary to determine the optimal dosage, long-term safety, and clinical efficacy of this extract.

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Conflicts of interest

The authors have no conflicts of interest to declare.

Ethical Considerations

This study has been ethically approved by the Research Ethics Committee of Birjand University of Medical Sciences (IR.BUMS.REC.1395.289).

Code of Ethics

IR.BUMS.REC.1395.289

Data Availability

The present study data are available from the corresponding author upon reasonable request.

Declaration of Interest Statement

No potential conflict of interest was reported by the author(s).

Authors' Contributions

Abdolghader Tane: Conceptualization, methodology, investigation, data curation, writing – original draft preparation.
Yaser Mohammadi: Methodology, formal analysis, validation, writing – original draft preparation.
Mohsen Naseri: Methodology, resources, animal model development, investigation, data curation.
Gholamreza Anani Sarab: Conceptualization, project administration, funding acquisition, supervision, validation, writing – review & editing, final approval of the manuscript.
Hamidreza Safari: Investigation, laboratory analysis, data curation, visualization.
Niloofar Honari: Investigation, assistance in animal handling and sample collection.
All authors have read and approved the final version of the manuscript.

Abbreviations

MS: Multiple sclerosis. CNS: Central nervous system. 5-LOX: 5-lipoxygenase. Tregs: T cells. EAE: Experimental Autoimmune Encephalomyelitis. s.c: Subcutaneously. PBS: Phosphate-buffered saline. ROS: Reactive Oxygen Specie. FRAP: Ferric Reducing Antioxidant Power. Fe3+: Ferric ions. Fe2+: Ferrous iron. H&E: Hematoxylin-Eosin. LFB: Luxol fast blue. SD: Standard deviation. AKBA: Acetyl-11-keto-β-boswellic acid

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