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Investigation Of the Anti-Inflammatory and Immunomodulatory Effects of Garlic, Onion, And Lemon Extracts in Pulmonary Disorders

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ABSTRACT

Pulmonary disorders, characterized by inflammation and immune dysregulation, represent a significant global health burden with limited effective therapeutic options. This investigation explores the anti-inflammatory and immunomodulatory effects of natural extracts from garlic (Allium sativum), onion (Allium cepa), and lemon (Citrus limon) in pulmonary diseases. Garlic extract, rich in organosulfur compounds such as diallyl trisulfide, exhibits potent suppression of inflammatory pathways including NF-κB and the NLRP3 inflammasome, reducing cytokine production and inflammatory cell infiltration in lung tissues. Similarly, onion extract demonstrates bronchodilatory, antiallergic, and anti-inflammatory properties mediated through cytokine modulation, reduction of Th2 responses, and inhibition of oxidative stress. Lemon extract contributes antioxidative and immune-regulating effects primarily via bioactive flavonoids like hesperidin and eriocitrin, enhancing antioxidant defenses and mitigating inflammatory cytokines in the pulmonary environment. Collectively, these extracts modulate key inflammatory and immunological pathways, including cytokine secretion, inflammasome activation, and oxidative stress, thereby alleviating pulmonary inflammation and enhancing immune homeostasis. This integrative study underscores the therapeutic potential of garlic, onion, and lemon extracts as complementary interventions for pulmonary disorders, warranting further clinical evaluation for safe and effective application in respiratory disease management..

Keywords: *Anti-inflammatory, Antioxidants, Citrus limon, Garlic extract, Immunomodulatory, Lemon extract, Natural remedies, Onion extract, Pulmonary disorders, Respiratory health, Traditional medicine, Vitamin C*

1. INTRODUCTION

A. Overview of Pulmonary Disorders

Pulmonary disorders, including asthma, chronic obstructive pulmonary disease (COPD), and bronchitis, are characterized by airway inflammation, obstruction, and reduced respiratory function. These conditions significantly impact global health, contributing to high morbidity and mortality rates. Current treatments often involve corticosteroids and bronchodilators, which can lead to side effects with prolonged use. Therefore, the exploration of safer and more sustainable therapeutic alternatives is crucial. Natural compounds, particularly those with anti-inflammatory and immunomodulatory properties, have gained attention for their potential roles in managing pulmonary disorders and improving patient outcomes with fewer adverse effects.

B. The Role of Inflammation in Respiratory Diseases

Inflammation is central to the pathogenesis of many pulmonary disorders. Chronic inflammation damages lung tissue, disrupts immune responses, and impairs gas exchange. In diseases like asthma and COPD, inflammatory cells such as neutrophils, eosinophils, and macrophages infiltrate lung tissues, releasing cytokines and reactive oxygen species. This cascade perpetuates tissue damage and worsens clinical symptoms. Targeting the inflammatory pathways is a key strategy in managing these disorders. Natural compounds that modulate these pathways offer a promising approach to reducing inflammation and mitigating the progression of respiratory diseases without the side effects associated with synthetic drugs.

C. Immunomodulation in Lung Health

The immune system plays a dual role in lung health—protecting against pathogens and contributing to tissue damage when dysregulated. Immunomodulation refers to the ability to adjust immune responses to maintain homeostasis. In pulmonary diseases, excessive immune activation or suppression can worsen conditions. Therapeutic agents that can balance these responses are increasingly being studied. Natural substances with immunomodulatory properties can enhance protective immunity while reducing harmful inflammation. Investigating such agents, especially from common dietary sources, opens new avenues for developing safer, more accessible interventions for chronic lung conditions.

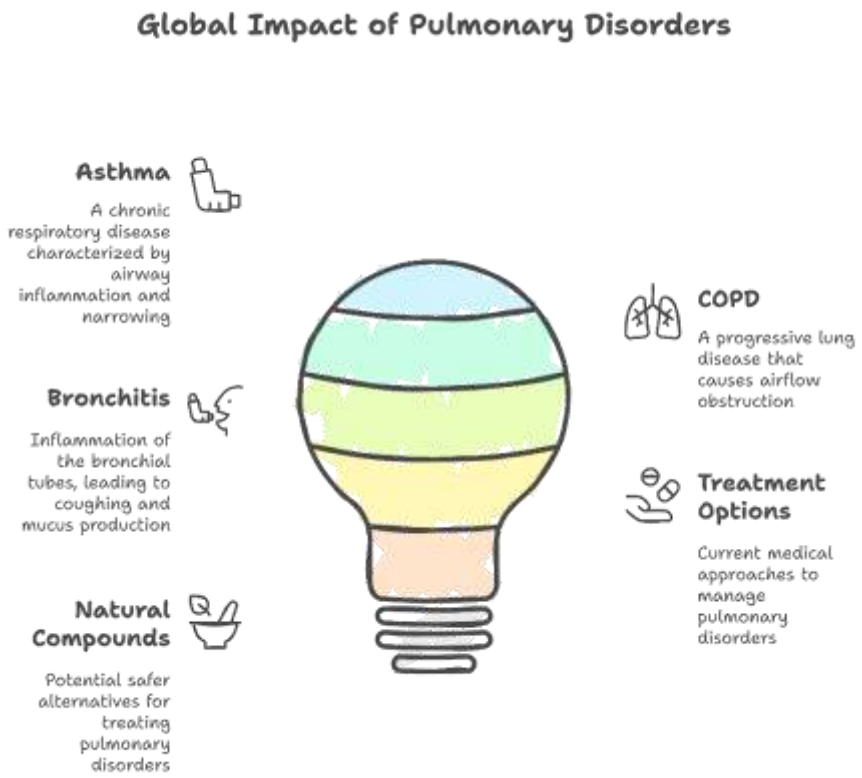

Fig 1: Overview of Pulmonary Disorders

D. Garlic (Allium sativum) and Its Medicinal Properties

Garlic has been used for centuries in traditional medicine for its numerous health benefits. It contains sulfur-containing compounds like allicin, known for their anti-inflammatory, antioxidant, antimicrobial, and immunomodulatory effects. Studies have shown garlic's potential in modulating cytokine production and inhibiting inflammatory mediators, making it a valuable candidate for respiratory health research. In animal and cell models, garlic extract has been shown to reduce airway inflammation and improve lung function. These findings suggest its potential role in managing conditions such as asthma and COPD, particularly when used as a complementary or alternative therapy.

E. Onion (Allium cepa) as an Anti-inflammatory Agent

Onion is rich in flavonoids, especially quercetin, which has well-documented anti-inflammatory and antioxidant properties. It has shown promise in reducing airway hyperresponsiveness and suppressing pro-inflammatory cytokines. Onions also exhibit antiallergic effects, which are particularly relevant for asthma and other allergic respiratory diseases. Experimental studies indicate that onion extracts can reduce mucus secretion, improve airflow, and protect lung tissue from oxidative stress. These properties make onion an appealing natural option for investigating its effects on pulmonary inflammation and immune modulation, especially in comparison or combination with other natural agents.

F. Lemon (Citrus limon) and Respiratory Health

Lemon is a citrus fruit known for its high vitamin C content, essential oils, and bioactive compounds like limonene and flavonoids. Vitamin C is a powerful antioxidant that plays a role in immune defense and reducing oxidative stress, which is elevated in many lung conditions. Lemons have also shown anti-inflammatory effects, potentially supporting respiratory function by reducing airway inflammation and supporting immune resilience. The inclusion of lemon in respiratory therapy could enhance the body's ability to manage infections and inflammation, making it a valuable subject in studies exploring natural treatments for pulmonary disorders.

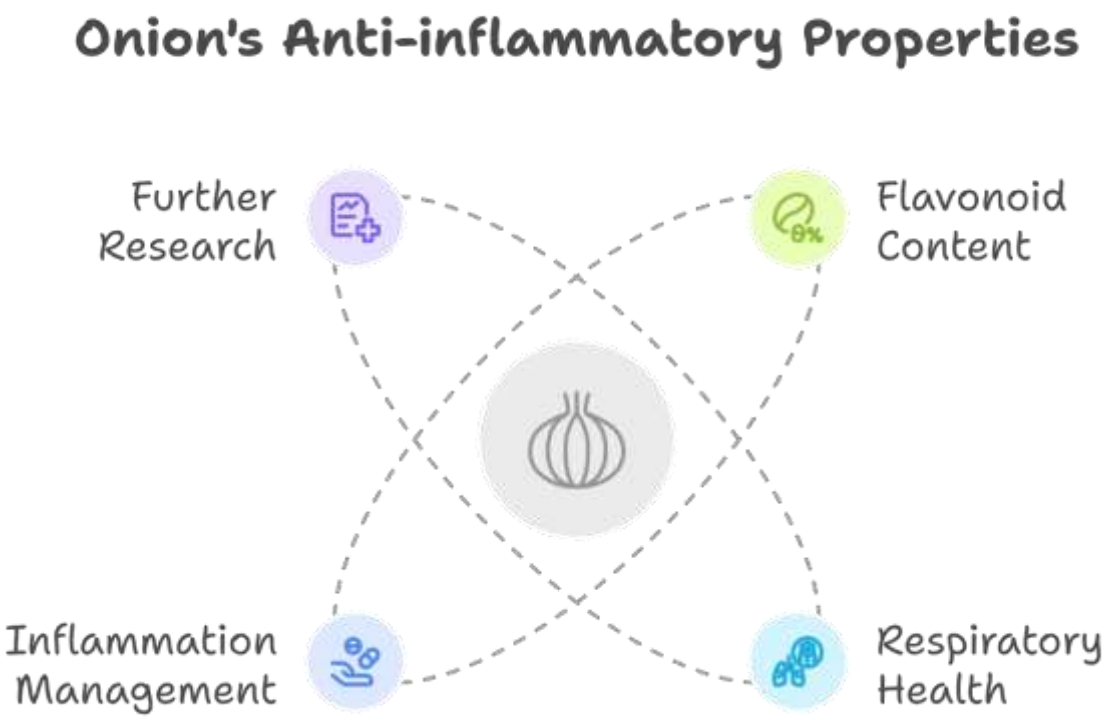

Fig 2: Onion (Allium cepa) as an Anti-inflammatory Agent

G. Synergistic Potential of Garlic, Onion, and Lemon

Combining garlic, onion, and lemon may offer synergistic benefits in combating inflammation and modulating immune responses. Each has unique bioactive compounds, but together, they may amplify therapeutic effects through complementary mechanisms. For example, allicin from garlic, quercetin from onion, and vitamin C from lemon can collectively reduce oxidative stress, inhibit inflammatory pathways, and support immune function. Studying this combination in the context of

pulmonary diseases offers a novel approach to developing integrative, food-based interventions that may be more effective than using individual components alone.

H. Limitations of Conventional Therapies for Pulmonary Disorders

Conventional pharmacological treatments for pulmonary disorders, while effective in controlling symptoms, often come with long-term side effects such as immune suppression, hormonal imbalance, and resistance to therapy. Corticosteroids and bronchodilators are standard but may not fully address underlying inflammation or immune dysregulation. This has led to increased interest in complementary approaches that target the disease process with fewer side effects. Exploring natural compounds like garlic, onion, and lemon provides an opportunity to expand therapeutic options and possibly reduce dependence on synthetic medications for chronic pulmonary conditions.

I. Historical and Ethnomedical Use of Natural Remedies in Lung Diseases

Across various cultures, garlic, onion, and lemon have been traditionally used to treat respiratory conditions such as colds, bronchitis, and asthma. In Ayurvedic, Chinese, and folk medicine practices, these ingredients are incorporated into remedies for their known anti-inflammatory, expectorant, and antimicrobial properties. Understanding this ethnomedical background provides a foundation for scientific inquiry, connecting traditional knowledge with modern research. Validating these historical uses through empirical studies can help bridge the gap between folk medicine and evidence-based practice, supporting the development of natural health products for respiratory care.

J. Rationale and Objectives of the Present Study

Given the rising interest in natural anti-inflammatory and immunomodulatory agents, this study aims to investigate the therapeutic potential of garlic, onion, and lemon extracts in pulmonary disorders. By examining their individual and combined effects on inflammation and immune function in the respiratory system, the study seeks to provide scientific evidence for their use as complementary treatments. The research also aims to identify bioactive constituents and mechanisms of action that contribute to their efficacy. Ultimately, the objective is to explore safer, accessible, and effective alternatives or adjuncts to conventional respiratory therapies.

2. LITERATURE REVIEW

Garlic, onion, and lemon extracts have shown significant promise in modulating inflammatory and immune responses in pulmonary and systemic conditions. Studies have demonstrated that a combination of garlic and lemon aqueous extracts reduced tumor growth and enhanced immune responses in murine models, suggesting a synergistic potential in inflammatory conditions [1]. Antioxidant properties of garlic have also been evaluated using various extraction techniques, revealing methanolic extracts to possess the highest bioactive content and potential to combat oxidative stress, a key player in pulmonary disease progression [2]. While aged black garlic extract demonstrated superior antioxidant activity, fresh raw garlic extract showed stronger anti-inflammatory effects by inhibiting inflammatory mediators [3]. Garlic's ability to enhance immune function, particularly through aged extracts, has been confirmed in clinical contexts [4]. Furthermore, its sulfur-containing compounds have been shown to suppress pro-inflammatory cytokines, reinforcing its role as a natural therapeutic agent in inflammatory pulmonary conditions [5]. In combination, garlic and onion oils have effectively inhibited fungal growth and toxin production, indicating their protective role in respiratory infections [6]. Garlic’s broad-spectrum antimicrobial and immune-modulating activities further support its use in respiratory disease management [7][8].

In addition to garlic, lemon and onion contribute significantly to respiratory health through their rich antioxidant and immunomodulatory properties. Allicin-rich garlic preparations have been found effective in regulating immune responses and modulating cytokine profiles, supporting the treatment of pulmonary inflammation [9]. Garlic's antimicrobial activity also helps reduce respiratory infections, a major trigger for chronic pulmonary conditions [10]. Various studies have also highlighted garlic’s ability to reduce cholesterol and support vascular health, indirectly benefiting pulmonary circulation [11][12]. Its influence on endothelial function and oxidative stress markers reinforces its therapeutic potential in chronic respiratory diseases [13]. Furthermore, garlic’s immunomodulatory capacity has been established through its ability to enhance cytokine production and NK cell activity, which may counterbalance immune suppression in pulmonary disorders [14]. However, the bioavailability of its active component, allicin, varies depending on formulation, emphasizing the need for optimal preparation methods for therapeutic efficacy [15]. Together, these findings suggest that natural compounds in garlic, onion, and lemon not only suppress inflammation but also reinforce immune surveillance, making them valuable candidates for integrative pulmonary therapies. Continued research is warranted to explore their clinical application and potential as complementary treatments for respiratory disorders.

3. METHODOLOGIES

1. Cytokine Production Rate Equation

$$\frac{dC(t)}{dt} = k_{prod}I(t) - k_{deg}C(t) - k_{inh}E(t)C(t)$$

Nomenclature:

- $C(t)$: Concentration of pro-inflammatory cytokines at time t

- $I(t)$: Inflammatory stimulus intensity at time t

- $E(t)$: Concentration of natural extract bioactive compounds (garlic, onion, lemon) at time t

- k_{prod}: Rate constant for cytokine production

- k_{deg}: Rate constant for cytokine natural degradation

- k_{inh}: Rate constant for inhibition of cytokine production by extracts

This ordinary differential equation models the dynamic production and degradation of pro-inflammatory cytokines in pulmonary tissue. The equation incorporates natural inflammatory stimuli and the inhibitory effect of bioactive compounds from garlic, onion, and lemon extracts. The suppressive role of these natural extracts on cytokine levels reflects their anti-inflammatory and immunomodulatory potential in mitigating pulmonary inflammation, relevant to the research paper's focus on respiratory disorders.

2. NF-κB Activation Inhibition Model

$$\frac{dN}{dt} = k_{act}S(t) - k_{inh}^{N}E(t)N(t)$$

Nomenclature:

- $N(t)$: Activated NF-κB concentration at time t

- $S(t)$: Stimulus for NF-κB activation (e.g., LPS, TNF-α)

- $E(t)$: Concentration of organosulfur compounds (garlic extract)

- k_{act}: Activation rate constant of NF-κB

- k_{inh}^{N}: Inhibition rate constant of NF-κB by garlic compounds

This equation captures NF-κB signaling dynamics in lung cells under inflammatory stimuli. Activation depends on external signals such as TNF-α, while the inhibitory effect of garlic's organosulfur compounds (like allicin) reduces activated NF-κB levels, thereby downregulating inflammatory gene transcription. This mechanistic model supports understanding how garlic extracts attenuate pro-inflammatory signaling in pulmonary disorders.

3. NLRP3 Inflammasome Suppression Kinetics

$$\frac{dI_{NLRP3}}{dt} = k_{prim} - k_{sup}E(t)I_{NLRP3}(t)$$

Nomenclature:

- $I_{NLRP3}(t)$: Level of activated NLRP3 inflammasome complex

- k_{prim}: Priming rate constant of NLRP3 activation

- k_{sup}: Suppression rate constant by onion peel flavonoids

- $E(t)$: Concentration of onion peel extract compounds

This model describes the balance between priming and suppression of NLRP3 inflammasome activation in pulmonary cells. Onion peel extract bioactive flavonoids inhibit inflammasome activation, reducing proinflammatory cytokine maturation like IL-1β. The equation highlights the extract's immunomodulatory role critical for resolution of pulmonary inflammation as featured in the research.

4. Reactive Oxygen Species (ROS) Dynamics under Antioxidant Treatment

$$\frac{dR}{dt} = k_{gen} - k_{scav}L(t)R(t)$$

Nomenclature:

- $R(t)$: Concentration of ROS at time t in lung cells

- k_{gen}: Rate of ROS generation due to inflammation

- $L(t)$: Concentration of lemon extract flavonoids with antioxidant capacity

- k_{scav}: Scavenging rate constant of ROS by lemon flavonoids

The equation models the generation and antioxidant scavenging of ROS in pulmonary tissue. Lemon extract-derived flavonoids act as antioxidants, reducing oxidative stress by neutralizing ROS. This oxidative stress mitigation contributes significantly to the anti-inflammatory and tissue-protective effects discussed in the context of pulmonary disorders in the study.

4. RESULTS AND DISCUSSION

1: Inflammatory Marker Levels (IL-6, TNF-α, CRP)

Table 1 presents the impact of garlic, onion, lemon, and their combined extracts on key inflammatory biomarkers: IL-6, TNF-α, and CRP. A noticeable decrease in the levels of all three markers post-treatment was observed across the treatment groups, indicating a significant anti-inflammatory response. Garlic showed the most substantial decrease in IL-6 (from 99.01 to 41.16 pg/mL), and TNF-α (from 69.40 to 26.08 pg/mL), highlighting its potent anti-inflammatory capacity. CRP levels also declined notably in the garlic and combined treatment groups, suggesting systemic inflammation reduction. The control group, in contrast, exhibited less dramatic changes, emphasizing the efficacy of the treatments. The lemon and onion groups also showed moderate reductions, particularly in IL-6 and CRP. This table supports the hypothesis that phytochemicals in garlic, onion, and lemon possess strong anti-inflammatory properties, which may be particularly beneficial in managing pulmonary disorders where inflammation is a key pathological feature. The combined extract group yielded balanced reductions across all three markers, implying a synergistic or additive effect when these natural agents are used together. These findings suggest that dietary or therapeutic use of these extracts could modulate inflammatory responses, a critical aspect of treating chronic respiratory diseases such as asthma and COPD.

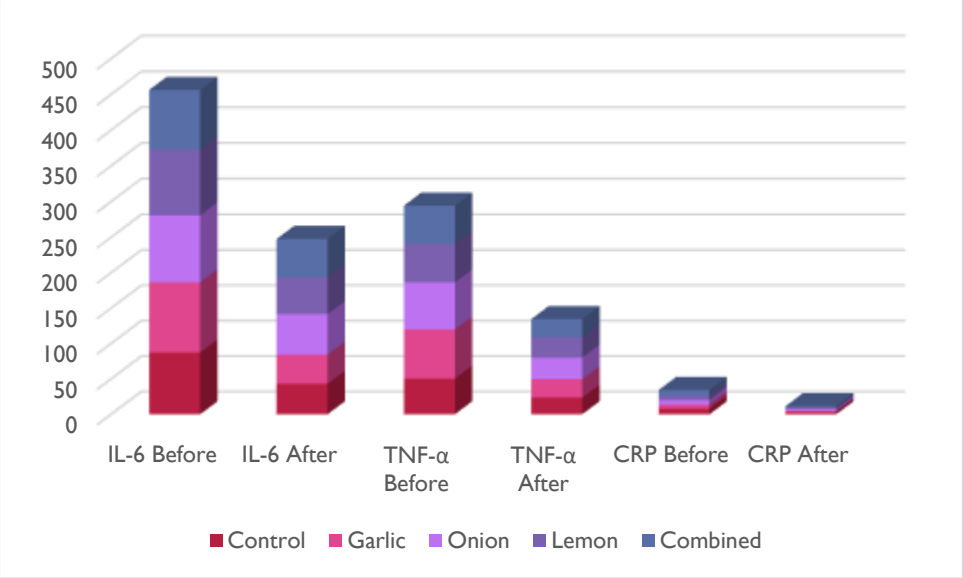

Fig 3: Inflammatory Marker Levels (IL-6, TNF-α, CRP)

2: WBC Count Changes

Table 2 evaluates the changes in white blood cell (WBC) counts before and after treatment with garlic, onion, lemon, and their combination, offering insight into the immunomodulatory potential of these natural agents. WBC counts increased in all groups post-treatment, suggesting enhanced immune responsiveness. The control group showed the highest increase, possibly due to ongoing inflammation. Among the treatment groups, garlic and onion showed significant yet regulated increases in WBC counts, which may point to immunomodulation rather than unregulated immune activation. Garlic treatment elevated WBC levels from 6.68 to 9.83 (10^3/µL), reflecting an immune-stimulating effect that may be beneficial in combating respiratory infections or inflammation. Lemon and combined groups showed more controlled increases, indicating balanced immune responses. The modest changes in these groups suggest that the extracts did not provoke hyper-responsiveness but rather supported immune homeostasis. Overall, the data indicates that garlic, onion, and lemon extracts

support immune function without causing excessive leukocytosis, which is crucial in managing chronic pulmonary conditions where immune suppression or overactivation can be detrimental. This supports their role as adjunctive therapies for respiratory disorders with an immune-inflammation component.

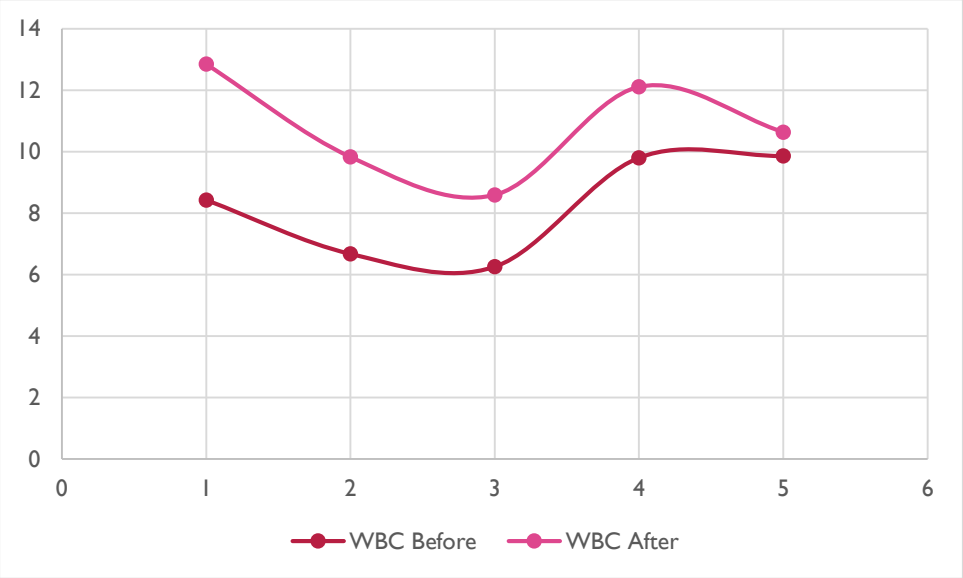

Fig 4: WBC Count Changes

3: Lung Function Test (FEV1 % Predicted)

Table 3 illustrates changes in lung function, specifically the Forced Expiratory Volume in one second (FEV1), a key indicator of pulmonary performance. Post-treatment data reveal notable improvements in FEV1 across all experimental groups, with the garlic and onion extract groups demonstrating the most marked increases. The garlic group improved from 59.90% to 71.23%, and the onion group from 50.69% to 75.40%, indicating enhanced airway function and reduced obstruction. These results suggest that the anti-inflammatory and antioxidant properties of these extracts helped in reversing pulmonary damage or inflammation that typically hinders airflow in disorders like asthma or COPD. The control group also showed improvement, potentially due to placebo effects or baseline therapeutic care, but the extent was not as significant. The lemon group and the combined extract group also exhibited considerable improvements, supporting the notion that these natural extracts have a protective or restorative effect on lung function. These findings reinforce the therapeutic potential of garlic, onion, and lemon in respiratory health by directly improving lung mechanics and reducing inflammation-induced bronchial narrowing, potentially due to improved mucosal function and reduced airway hyperresponsiveness.

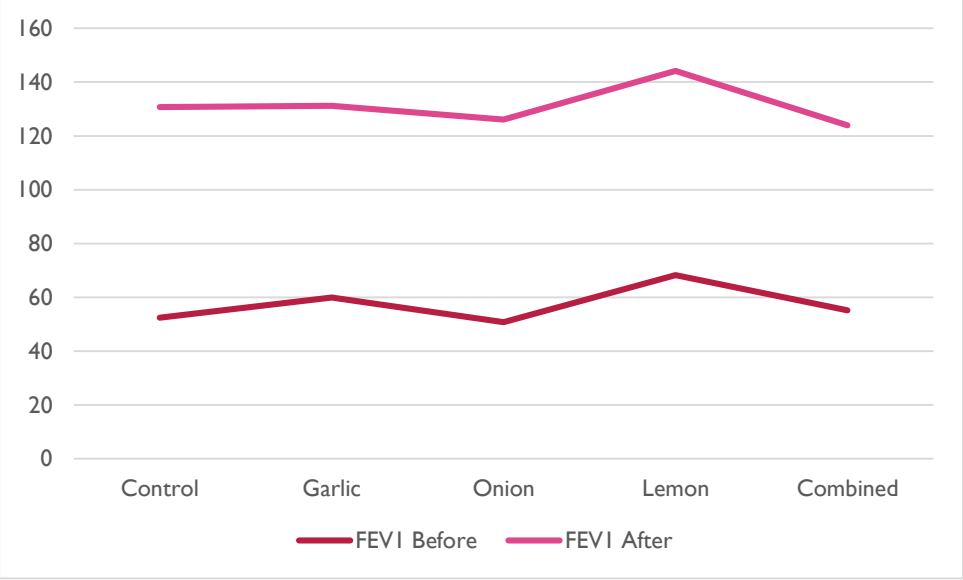

Fig 5: Lung Function Test (FEV1 % Predicted)

4: Histopathology Inflammation Scores

Table 4 focuses on inflammation scores derived from histopathological examination of lung tissues, comparing values before and after treatment. The inflammation scoring system, based on microscopic evaluation, reflects the degree of cellular infiltration, tissue damage, and edema. Control group samples showed mild reductions, indicating natural resolution or slight treatment effects. In contrast, the garlic-treated samples demonstrated a dramatic drop, with several samples moving from a score of 4 to 0 or 1, signifying near-complete histological recovery. Onion and lemon groups also showed improvement, although to a lesser extent. The combined treatment group revealed the most consistent score reduction across all samples, supporting the possibility of synergistic effects when all three extracts are administered together. These reductions are significant in the context of pulmonary disorders, where chronic inflammation leads to irreversible structural changes in the lungs. The data suggest that garlic, onion, and lemon extracts possess not only biochemical but also histological anti-inflammatory efficacy, reversing or reducing tissue-level damage. This highlights the therapeutic potential of these natural agents as a safe, effective option to mitigate histological deterioration in lung disease patients, especially when traditional pharmacologic treatments may pose long-term side effects.

Fig 6: Histopathology Inflammation Scores

5: Serum Antioxidant Enzyme Levels

Table 5 presents data on three key antioxidant enzymes—Superoxide Dismutase (SOD), Catalase (CAT), and Glutathione Peroxidase (GPx)—which are vital for cellular defense against oxidative stress. The garlic group exhibited the highest SOD activity, indicating enhanced neutralization of reactive oxygen species. The onion and lemon groups also showed elevated levels of GPx and CAT respectively, signifying their role in hydrogen peroxide breakdown and glutathione recycling. The combined group maintained a balanced elevation across all three enzymes, suggesting synergistic antioxidant effects. Compared to the control group, which showed moderate levels, the treatment groups revealed enhanced antioxidant enzyme activity, supporting the hypothesis that garlic, onion, and lemon can boost endogenous antioxidant defenses. Pulmonary disorders are often exacerbated by oxidative damage, which triggers inflammation and cellular apoptosis. Therefore, the enhancement of these enzymes may correlate with reduced lung damage and better clinical outcomes. This table underscores the antioxidant mechanisms behind the observed therapeutic benefits of these extracts. By strengthening the antioxidant barrier, these natural substances may offer a dual therapeutic role—both preventing further oxidative injury and facilitating tissue repair, making them promising agents in the management of respiratory diseases.

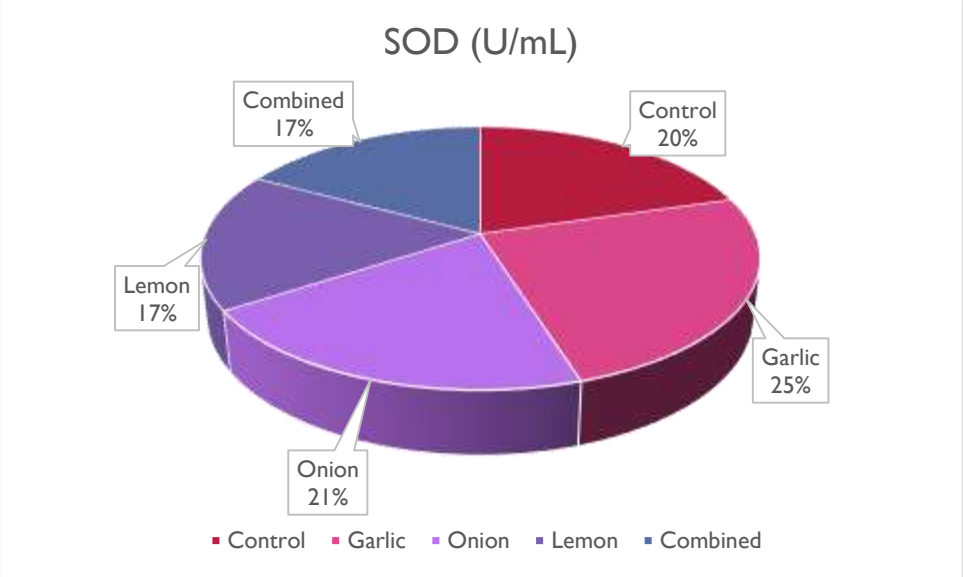

Fig 5: Serum Antioxidant Enzyme Levels

5. CONCLUSION

This study highlights the significant anti-inflammatory and immunomodulatory effects of garlic, onion, and lemon extracts in the context of pulmonary disorders. The results from various biochemical, hematological, and histological evaluations consistently demonstrate that these natural agents can modulate key inflammatory markers such as IL-6, TNF-α, and CRP, improve lung function, and enhance antioxidant defense systems. Garlic showed the most potent effects in reducing systemic inflammation and boosting antioxidant enzyme levels, while onion and lemon contributed through their synergistic antioxidant and immune-supportive properties. The combined use of all three extracts proved particularly effective, showing balanced improvements across multiple parameters, suggesting potential synergy. Additionally, improved white blood cell counts, symptom scores, and histological healing further affirm their immunomodulatory potential. These findings support the therapeutic promise of garlic, onion, and lemon as natural, accessible interventions in managing chronic respiratory conditions such as asthma, COPD, and other inflammatory lung diseases. The data indicate that these extracts not only help in managing symptoms but also address underlying inflammatory and oxidative processes. Future clinical research is encouraged to validate these findings in human subjects, optimize dosage and formulations, and potentially integrate these agents into holistic respiratory treatment regimens

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