Comarison of the Effectiveness of Citronella Oil Distillation with and without the Addition of a Burner: Literature Review

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ABSTRACT

Citronella essential oil is an important commodity in the agro-industrial sector, but the distillation process at the MSME level is still dominated by single-boiler technology with limited heat sources, resulting in low yields, long distillation times, and high energy consumption. Simple innovations such as the addition of a burner or a dual-burner system to the boiler have been identified as a technical solution to improve heat stability and vapor pressure. This article presents a literature review of three studies evaluating the application of an additional burner to the citronella oil distillation process and compares them with several conventional distillation studies without a burner for the same commodity. The results show that the dual-burner system provides consistent improvements in distillation performance parameters. The addition of a burner can accelerate the distillation process by 0.17% - 0.4% or an increase of 28-66%. These improvements are influenced by more stable heat distribution, higher vapor pressure, and accelerated vapor penetration into the material matrix. In contrast, the literature on burnerless distillation shows oil yields ranging from 0.60–0.75% with a distillation time of 280–320 minutes, while the dual burner system is able to achieve yields of 0.75–0.80% with a time of 250–270 minutes at similar capacities and distillation methods. This study confirms that the addition of a burner is a simple yet effective technical intervention in increasing the efficiency of citronella oil distillation at the MSME scale. These findings form the basis for the development of further experimental research on the HH2 (1 boiler 2 kettles) distillation model with an additional burner as the main variable for increasing production capacity and quality of essential oils.

Kata Kunci: burner, citronella oil, essential oil, yield

1. INTRODUCTION

1.1 Background

Citronella essential oil (Cymbopogon nardus) is one of Indonesia's strategic agro-industrial commodities due to its high economic value and stable market demand across various sectors, including the perfume, cosmetic, pharmaceutical, and household product industries(Amarullah et al., 2023). As one of the major producers of citronella raw materials, Indonesia has significant potential to increase value added through distillation processes As one of the major producers of citronella raw materials, Indonesia has significant potential to increase value added through distillation processes (Anwar et al., n.d.). However, in practice, distillation technologies employed by micro, small, and medium enterprises (MSMEs) are still predominantly based on conventional steam distillation systems utilizing a single boiler with

limited heat sources. These conditions result in prolonged distillation times, high energy consumption, and suboptimal oil yields (Samang & Aktawan, 2025).

Limited heat supply in single-boiler systems often leads to fluctuations in temperature and steam pressure during the distillation process, thereby preventing stable steam generation (Samang & Aktawan, 2025). In this context, the addition of burners or the implementation of dual-furnace systems has begun to be identified as a simple technical innovation with the potential to enhance distillation performance without requiring substantial modifications to the existing equipment design.

Nevertheless, the application of additional burner technology at the MSME level remains limited, and studies that systematically compare the performance of citronella oil distillation systems with and without additional burners are still relatively scarce. Therefore, a literature-based study is needed to synthesize findings from previous research in order to provide a more comprehensive understanding of the effectiveness of burner addition as a solution for improving the efficiency of citronella oil distillation that is practical and suitable for MSME conditions.

1.2 Problem Statement

1) How does the stability of temperature and steam pressure affect the efficiency of the citronella oil distillation process based on findings from previous studies?
2) To what extent does the addition of burners or the implementation of a dual-furnace system improve the performance of citronella oil distillation compared to a single-boiler system without heat source modification?
3) What are the differences in distillation time and essential oil yield between distillation systems with additional burners and conventional systems without burners for citronella?
4) Why does a single-boiler distillation system without additional burners produce wide variations in performance in terms of processing time and oil yield?
5) How relevant is the application of burner addition as a simple and applicable technological solution for improving the efficiency of citronella oil distillation at the MSME scale?

1.3 Research Question

Based on the identified research gap, the research questions addressed in this review are:

1) How does the addition of burners influence the performance of citronella oil distillation based on previous research findings?
2) What are the differences in distillation time, oil yield, and effective capacity between distillation systems with additional burners and conventional systems without burners?

1.4 Spesific Objective

This study aims to:

1) Examine the effect of burner addition on the efficiency of citronella oil distillation based on a literature review.
2) Compare the distillation performance of citronella oil between systems with additional burners and systems without burners using the same commodity.
3) Develop a conceptual basis for further experimental research on the HH2 distillation model (one boiler–two stills).

1.5 Author's Argument

The addition of burners represents a simple, economical, and applicable technical intervention that has a significant impact on improving the efficiency of citronella oil distillation.

Through enhanced heat stabilization and increased steam pressure, a dual-burner system is expected to overcome the limitations of conventional distillation technologies commonly used by MSMEs.

1.6 Spesific Focus of the Problem

This review specifically focuses on the analysis of citronella oil distillation performance using key indicators, namely distillation time, oil yield, and effective equipment capacity, in relation to the use of additional burners in steam distillation systems.

1.7 Scope and Limitation of the stufy (Scope and Limitation)

This study is limited to a literature review of research utilizing citronella (Cymbopogon nardus) as the raw material and steam distillation as the extraction method. The analysis does not include detailed chemical composition analysis of the essential oil nor an in-depth economic evaluation. Furthermore, this study does not conduct direct experimental testing; therefore, the findings are based on the synthesis of results from previous studies.

1.8 Novelty Plan

The novelty of this study lies in the development of a comparative literature-based analysis that specifically distinguishes the performance of citronella oil distillation systems with additional burners from those without burners. Moreover, this review positions the comparative findings as a foundational reference for designing further experimental research on the HH2 distillation model, which has received limited attention in previous studies.

2. LITERATURE REVIEW

Mapping Theory and Key Concepts

2.1 Citronella Essential Oil

Citronella essential oil (Cymbopogon nardus) is a volatile oil produced through steam distillation of the leaves and stems of the plant (Haris, Uzwatania, et al., 2024a; Nurhidayanti et al., 2023). The major components of citronella oil, such as citronellal, citronellol, and geraniol, are sensitive to variations in temperature and pressure during the distillation process (Phovisay et al., 2019). Therefore, maintaining stable thermal conditions during distillation is a critical factor in determining both the yield and quality of the resulting essential oil (Solekha et al., 2023).

2.2 Principles of Steam Distillation for Essential Oils

Steam distillation operates based on the principle that volatile compounds evaporate together with water vapor at temperatures lower than their normal boiling points (Akdağ & Öztürk, 2019). The effectiveness of this process is determined by the rate of steam generation, steam pressure, and heat distribution within the distillation system (Karo Karo et al., 2023). Single-boiler systems commonly used at the MSME scale often experience fluctuations in temperature and pressure, which adversely affect distillation duration and reduce oil extraction efficiency (Haris, Delfitriani, et al., 2024).

2.3 Burner Concept and Dual-Furnace Systems

Burners function as the primary heat source for generating steam in the boiler (Aquino et al., n.d.). The addition of burners or the implementation of dual-furnace systems aims to increase heat capacity, maintain stable temperature and steam pressure, and accelerate the oil

extraction process (Achmad et al., 2020). Theoretically, increased steam pressure enhances steam penetration into plant tissues, allowing essential oil compounds to be released more effectively from the plant matrix (Budaraga & Salihat, 2021).

2.4 Sintesis dan Perbandingan Penelitian Terdahulu

Several studies have investigated improvements in citronella oil distillation performance through modifications of heating systems. Achmad et al. (2020) reported that the use of a dual-furnace system reduced distillation time by 15.16% while simultaneously increasing oil yield and effective equipment capacity compared to a single-furnace system (Achmad et al., 2020). Other studies implementing additional burners fueled by alternative energy sources in citronella distillation processes have also reported improvements in heat stability and operational efficiency (Efendi et al., 2024).

In contrast, conventional distillation systems without additional burners generally report lower oil yields and longer processing times. Oil yield variations in single-boiler systems typically range from 0.60% to 0.75%, with distillation durations reaching 280–320 minutes (Kawulur et al., 2022), depending on feedstock capacity and operating conditions. This comparison indicates that the primary difference in distillation performance lies in the system's ability to maintain stable temperature and steam pressure throughout the process..

2.5 Penyajian Kerangka Teoretis

Based on the mapping of theories and findings from previous studies, the theoretical framework of this review positions burner addition as the independent variable influencing temperature and steam pressure stability within the distillation system. Thermal stability subsequently affects steam penetration rates, oil extraction kinetics, and the efficiency of oil–water separation. The ultimate impact is reflected in shorter distillation times, higher oil yields, and increased effective equipment capacity. This framework serves as a conceptual foundation for designing further experimental research on the HH2 distillation model, with burner addition as the primary variable..

3. METHODS

3.1 Type of Research and Study Design

This study employs a literature review design using a narrative comparative analysis approach. The review aims to compare findings from previous studies that examined the performance of citronella essential oil distillation systems with and without burner addition. This approach was selected to identify patterns of efficiency improvement in the distillation process as well as research gaps that may serve as a foundation for the development of further experimental studies.

3.2 Data Sources and Selection Criteria

1) Data Source

Research data were obtained from secondary sources in the form of scientific articles published in accredited national journals and reputable international journals. The literature was retrieved from scientific databases such as Google Scholar, ScienceDirect, IOP Publishing, as well as national journals focusing on agricultural technology and agro-industrial engineering.

2) Literature Selection Criteria

The inclusion criteria for this study were as follows:

a. Articles addressing the distillation of citronella essential oil (Cymbopogon nardus).
b. Studies employing steam distillation methods.
c. Articles that explicitly describe the heating system configuration, either with burner addition or without burners.
d. Articles presenting quantitative data related to distillation time, oil yield, or production capacity.

The exclusion criteria included articles that did not specify the heating system configuration, utilized commodities other than citronella, or failed to clearly report distillation performance parameters..

3.3 Data Collection Techniques

Data collection was conducted through a systematic literature search using keywords such as citronella oil, steam distillation, burner addition, and double furnace. The collected information included distillation equipment configuration, number and type of burners, feedstock capacity, distillation time, oil yield, and other relevant operational parameters. Data from each article were recorded and classified into two groups: systems with additional burners and systems without burners, to facilitate comparative analysis.

3.4 Data Analysis Techniques

Data analysis was carried out using a descriptive-comparative approach. Quantitative data from each study were compared to identify differences in distillation performance between systems with and without burner addition. The results were presented in the form of narrative synthesis and relative comparisons (percentage increases or decreases), without conducting inferential statistical analysis. This approach was adopted to emphasize trends in distillation efficiency improvement and to formulate technical implications relevant to the application of essential oil distillation technologies at the MSME scale.

4. FINDINGS

The literature review on citronella essential oil (Cymbopogon nardus) distillation reveals consistent performance differences between distillation systems with additional burners and conventional systems without burners. The synthesized data are organized based on distillation time, oil yield, and effective equipment capacity, which represent the primary indicators of distillation efficiency.

The synthesis of two studies that explicitly implemented additional burner systems demonstrates that increased heat supply through dual burners accelerates the distillation process and improves oil yield. Achmad et al. (2020) reported that the application of a dual-furnace system in citronella distillation reduced distillation time by 15.16% and increased oil yield by 5.44% compared to a single-furnace system. In addition, effective equipment capacity increased by 4.12% due to improved steam pressure stability. Similar findings were reported by Efendi et al. (2024), who showed that the use of an additional burner fueled by used oil in citronella distillation improved heat stability and MSME productivity.

In contrast, studies on conventional distillation systems without burner addition consistently reported performance limitations. Budaraga et al. (2020) observed that citronella oil yields in single-boiler systems ranged from 0.60% to 0.75%, with distillation times reaching 280–320 minutes. Kawulur (2022) further demonstrated that prolonged distillation times in systems without heat-source modification were not necessarily accompanied by increased oil yield, due to temperature and steam pressure fluctuations during the process

To clarify performance differences reported in the literature, a summary of comparative data is presented in Table 1.

Peneliti	Tahun	Heating system	Commodity	Distillation Time	Yield (%)	Key Findings
Achmad et al.	2020	1 vs 2 furnace (dual burner)	Citronella	257,33 minute	0,77%	Equioment effectiveness increased by 4,12%
Efendi et al.	2024	Additional Burner (oil)	Citronella	120 minute	1%	Improve thermal stability
Budaraga et al.	2020	Single boiler	Citronella	280–320 minute	0,60–0,75	No heat-source modification applied
Kawulur	2022	Single boiler	Citronella	>300 minute	0,70%	Long processing time tih fluctuating heat

Based on these findings, it can be concluded that burner addition exerts a positive effect on citronella oil distillation performance. Distillation systems equipped with additional burners consistently achieve shorter processing times and higher oil yields compared to systems without burners under the same commodity and distillation method. Accordingly, this literature review provides an initial response to the research problem, indicating that limited heat supply in single-boiler systems is a major constraint on distillation efficiency, and that burner addition constitutes an effective and applicable technical solution for improving citronella oil distillation performance at the MSME scale.

5. DISCUSSION

5.1 Burner Addition as a Key Factor in Distillation Performance Improvemen

The literature review indicates that the most fundamental difference between distillation systems with and without burners lies in their ability to maintain sufficient and continuous heat supply. In single-boiler systems, the generated heat is often inadequate to sustain stable steam pressure throughout the distillation process, resulting in a gradual decline in steam generation rates (Haris, Uzwatania, et al., 2024b). Burner addition addresses this limitation by increasing system heat capacity, enabling a more consistent distillation process. These findings suggest that the heat source is not merely a supporting component, but a critical determinant of citronella oil distillation performance.

5.2 Significance of Reduced Distillation Time from a Process Perspective

The reduction in distillation time observed in dual-burner systems reflects not only improved time efficiency, but also enhanced heat and mass transfer rates within the system. From a process standpoint, faster and greater steam generation promotes more intensive contact between water vapor and plant tissues (Adiandasari & Wusnah, 2021). This effect shortens the initial distillation phase, which often constitutes a bottleneck in single-boiler systems. Therefore, reduced distillation time in systems with additional burners should be interpreted as an indicator of overall thermal performance improvement rather than merely a reduction in operating duration.

5.3 Mechanisms Underlying Increased Essential Oil Yield

The increase in essential oil yield observed in systems with additional burners can be explained through the physical and chemical mechanisms of steam distillation. Higher and more stable steam pressure enhances steam penetration into the citronella plant matrix, facilitating more effective release of volatile compounds from plant cells (Samang & Aktawan, 2025). In systems without burners, temperature and pressure fluctuations hinder optimal oil release even when distillation time is extended. These findings confirm that oil yield is more strongly influenced by process condition quality than by distillation duration alone, in accordance with steam distillation theory for essential oils.

5.4 Effective Equipment Capacity and Its Implications for MSME Applications

The reported increase in effective equipment capacity in dual-burner systems has important implications for MSME-level technology adoption. Effective capacity reflects the ability of equipment to produce oil output per unit time; thus, improvements in this parameter signify increased productivity without enlarging equipment size or feedstock input. From the perspective of appropriate technology, burner addition represents a relatively simple and easily adoptable solution compared to complete replacement of the distillation system. Consequently, this review demonstrates that minor modifications to heating systems can yield substantial improvements in essential oil production efficiency.

5.5 Consistency of Findings Across Studies and Argument Validity

The consistency of performance improvements reported across multiple studies strengthens the validity of the argument that burner addition provides tangible benefits in citronella oil distillation. Despite variations in equipment design, fuel type, and production scale, the uniform direction of findings indicates that the positive effects of burners are systemic rather than context-specific. This reinforces the conclusion that the relationship between heat supply, steam pressure, and distillation efficiency constitutes a strong causal linkage within steam distillation systems for essential oils.

5.6 Theoretical Implications for Steam Distillation Studies

From a theoretical perspective, this review enriches the understanding of the role of thermal energy in steam distillation frameworks. Burner addition can be viewed as an intervening variable that strengthens the relationship between energy input and oil yield output. These findings shift the focus of distillation optimization from process duration alone toward the control of thermal conditions and steam pressure. Accordingly, this study contributes to the development of a more mechanism-based approach to essential oil distillation optimization.

5.7 Study Limitations and Implications for Future Research

Despite the clear trends identified, this study has limitations that must be acknowledged. The analysis is based on secondary data from a relatively limited number of studies; therefore,

generalization of the findings should be approached with caution. Variations in equipment configuration and operating conditions across studies may also influence the magnitude of reported performance improvements. Consequently, further experimental research with stricter variable control—particularly using the HH2 distillation model (one boiler–two stills)—is required to empirically validate and strengthen the conclusions of this review.

6. CONCLUSION

This literature review demonstrates that burner addition or the implementation of dual-furnace systems in steam distillation of citronella essential oil consistently improves performance compared to single-boiler systems without heat-source modification. Systems equipped with additional burners achieve distillation time reductions of approximately 15–20% and oil yield increases of 0.17–0.40%, corresponding to relative improvements of 28–66%. These improvements are closely associated with enhanced temperature and steam pressure stability, which enable more effective release of volatile compounds. The findings confirm that distillation efficiency is influenced not merely by process duration, but primarily by the quality of thermal conditions during distillation.

Although based on literature analysis, this study provides strong scientific justification that burner addition constitutes a simple, applicable, and relevant technical solution for improving citronella oil distillation efficiency at the MSME scale. Nevertheless, due to the limited number of studies and the absence of direct experimental validation, further research with tighter variable control—particularly using the HH2 distillation model (one boiler–two stills)—is necessary to confirm and optimize the implementation of additional burner systems..

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