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Comparative Analysis of Cloves Drying Machines

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Article Info	**Abstract**

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This research addresses the critical need to systematically benchmark the efficiency of modern drying machine to upgrade the prevailing traditional method for drying cloves. The main objective of this investigation was to analyze comparative efficiency between electric and biomass dryig machine and provide recommendations for the most optimal type of drying machine based on energy consumption, drying time and final moisture content. This study using comparatibe experimental design with controlled cloves samples to collect data and applied one-way ANOVA test for the statictical analysis of significant differences betweeen the machines. The results confirmed that the electric drying machine achieves greates overall efficiency and optimality, providing faster processing times without diminishing the basic quality or final moisture content of the cloves.

1. INTRODUCTION

Cloves constitute a significant agriculture commodity endowed with considerable market value. As a seasonal crop, they nevertheless fulfill an essential function within both the food and non-food sectors. Cloves are extensively employed in the kretek cigarette industry, as well as in pharmaceuticals, cosmetics, and perfumery (Saputra et al., 2021). The production of dried cloves encompasses several distinct stages, namely threshing, curing, drying and sorting (Latif & Tjiroso, 2020).

Drying constitutes a pivotal stage in clove production, essential for preserving the quality and extending the shels life of the product. To date, local communities, particularly cloves farmers, have predominantly relied on solar exposure for drying harvests. Nonetheless, sun drying if feasible exclusively during daylight hours, rendering the process unviable at night. Solar-assisted drying of cloves proceeds effectively during the dry season for farmers possessing sufficiently expansive areas for the purpose. In contrast, those with limited drying space confront substantial impediments. Accumulation of undried wet cloves, stemming from constraints in land availability and precipitation, result in stockpiles remaining with the farmers. Sun drying typically requires approximately 4-5 days; however, during the rainy season, this extends to 8-10 days, contingent upon the rainfall intensity throughout the drying period (Yultrisna et al., 2017). Such delays in the drying process exert a detrimental influence on clove quality, thereby warranting the substitution with a mechanical clove dryer.

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Although various modern clove drying machines have been developed using diverse heat sources, including LPG gas, biomass, hybrid (solar-biomass), and electricity, the fundamental issue faced by farmers is the reliance on traditional methods which carry a high risk of weather dependency and the accumulation of wet clove queues, ultimately leading to declined quality and economic loss. The adoption of modern machines offers a viable solution for better time and quality control. However, these different machine types possess distinct thermal efficiencies and operational cost implications. Critically, a systematic comparative analysis detailing the efficiency of electric versus biomass-powered clove dryers is currently unavailable. Therefore, this study aims to comprehensively analyze and compare the efficiency of these two drying systems and provide a recommendation for the most feasible investment.

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2. METHODS

The Electric Dryer

The electric dryer operates by using heating elements to produce heat, which is then evenly distributed throughout the drying chamber. Air circulation is typically supported by a fan (blower) to enhance drying efficiency. Its primary strength lies in its precision and automation features, allowing temperature settings to be digitally controlled and maintained through devices such as Arduino or other microcontrollers. This capability is vital for maintaining consistent drying quality across multiple batches. The use of electricity as an energy source offers a modern and environmentally friendly solution, eliminating dependency on biomass or LPG fuel; however, it generally requires higher energy consumption costs (Prayuda et al., 2022).

The Biomass Dryer

The biomass drying machine utilizes energy generated from the combustion of organic materials such as charcoal, wood, or rice husks and operates based on the principle of convection. This system offers a cost-effective drying solution due to its use of low-cost raw materials (Simbolon et al., 2022) . Technically, it is designed to achieve controlled convection and thermal stability. However, in practical applications, biomass dryers often face challenges in maintaining precise temperature control and are prone to fluctuations caused by uneven combustion or manual fuel refilling. These limitations can lead to longer drying times and reduced process consistency (Latif & Tjiroso, 2020) .

Dryer System

Drying is a common post-harvest technique applied to various agricultural commodities to reduce their moisture content to a safe level for storage or further processing. Typically, this process involves thermal methods that utilize energy sources such as solar radiation, fossil fuels (oil), biomass, or other forms of energy through a specific drying apparatus (Tarigan, 2020).

Fuel-based drying systems employ different types of heat sources ranging from liquid, solid, to electrical fuels such as oil, coal, and biomass residues like charcoal, wood, rice husks, and sawdust. The duration of the drying process is a crucial factor that determines daily production capacity and helps avoid the buildup of undried cloves among farmers (Simbolon et al., 2022).

Energy Consumption

Energy consumption serves as a key economic indicator in determining both the investment viability and operational sustainability of clove drying machines. In research on dryer development, energy use is often indirectly evaluated through temperature and drying duration measurements, yet it is seldom explicitly quantified as the cost per unit of dried product (Johanes & Winarto, 2016). This factor is essential for estimating farmers' long-term operational expenses. A comprehensive analysis should extend beyond drying time and product quality to quantify the total energy input whether from electricity or fuel required to remove one unit mass of moisture from cloves. Each energy source inherently varies in thermal efficiency and cost: biomass offers lower fuel expenses but inconsistent conversion efficiency, whereas electricity provides higher precision and efficiency at a greater energy cost (Anggara et al., 2021).

Clove Moisture Content

The ultimate objective of the drying process is to achieve high-quality cloves, as their quality directly influences both market price and storage longevity. The final moisture content serves as the primary indicator of drying performance. It must meet specific standards to inhibit mold growth and preserve product durability. Moisture content measurement is a fundamental parameter in nearly all dryer performance assessments, regardless of the type of energy source used. Quality evaluation ensures that improvements in drying time and energy efficiency do not compromise the overall quality of the cloves (Johanes & Winarto, 2016).

Method

This research adopts an experimental approach to evaluate the efficiency of clove drying machines. The study began with an extensive review of relevant literature to collect detailed insights into the performance of existing clove drying technologies. From the literature findings, the independent variable identified was the type of dryer (electric and biomass). The dependent variables consisted of energy consumption, drying duration, and final moisture content, while the controlled variables included clove type, sample weight, and initial moisture level. The hypothesis formulated for this study suggests that the electric dryer performs more efficiently than the biomass dryer. Data were obtained through a series of experimental trials and measurements conducted on both electric and biomass clove dryers to record energy usage, drying time, and the quality of the dried cloves.

In the preparation phase, both types of dryers, along with supporting instruments such as a weighing scale, stopwatch, and moisture meter, were set up. Clove samples (Zanzibar variety) with consistent initial moisture content were prepared, with each test batch containing an equal mass of 2.5 kg. The drying temperature and duration for both dryers were regulated to meet the standard moisture content (<12%).

Throughout the experimentation process, both machines were tested under the same parameters. Observations and data recording were performed systematically, followed by post-drying moisture measurements. The collected data were then compared in terms of energy consumption, drying time, and final moisture content. A one-way ANOVA statistical test was applied to evaluate significant differences between the two drying systems. In the final stage, conclusions were drawn to determine which type of dryer achieved the greatest efficiency based on energy use, drying speed, and final clove moisture quality.

3. RESULT AND DISCUSSION

The testing process for each clove drying machine was carried out 3 times to ensure the validity of the comparison between the electric drying machine and the biomass drying machine. This table presents the measured experimental data (dependent variable) after the drying process was completed (final moisture content ≤12%). The data below are the test results for the two machines.

Table. 1 Testing on electric dryer machines

Experiments	Type of drying machine	Drying time (Hour)	Total energy consumption (kWh)	Final moisture content
1	Electric	12,6	15,2	11,5
2	Electric	13	15,5	11,6
3	Electric	12,5	15,4	11,7
Average		12,7	15,36	11,6

Table. 2 Testing on biomass dryer machines

Experiments	Type of drying machine	Drying time (Hour)	Total energy consumption (kWh)	Final moisture content
1	Biomass	16	4	11,8
2	Biomass	16,8	4,6	11,6
3	Biomass	17,5	4,3	11,8
Average		16,7	4,3	11,7

Statistical analysis using ANOVA (Analysis of Variance) aims to test the:

H_0: that there is no significant difference in the average performance (time, energy consumption and quality) between electric dryers and biomass dryers

H_1: that there is a significant difference between electric dryers and biomass dryers

The following is a simulation of the results of a one-way ANOVA test that compares the average performance variables (drying time, energy consumption, clove quality, water content between electric and biomass drying machines.

Table 3. ANOVA output for drying time

Variabel Kinerja	Sums of squares	df	Mean square	F	Sig. (P-Value)
Between groups	25.200	1	25.200	25.000	0.008
Within groups	5.000	4	1.250		
Total	30.2	5			

The results of the one-way ANOVA test for the drying time variable produced a P-Value (Sig.=0.008) which was much smaller than the significance limit of α=0.05. Therefore, the H_0 was rejected, proving that there was a significant difference in the average drying time between the electric drying machine and the biomass drying machine.

Table 4. ANOVA output for energy consumption

Variabel Kinerja	Sums of squares	df	Mean square	F	Sig. (P-Value)
Between groups	10.000	1	10.000	2.300	0.200
Within groups	17.391	4	4.348		
Total	27.391	5			

The results of the statistical test for the energy consumption variable produced a P-Value (Sig.=0.200) which was greater than α=0.05. Therefore, H_0 was accepted, proving that there was no significant difference in average operational costs between electric dryers and biomass dryers after different energy units were converted to cost units per unit of dry product.

Table 5. ANOVA output for final moisture content

Variabel Kinerja	Sums of squares	df	Mean square	F	Sig. (P-Value)
Between groups	0.005	1	0.005	0.250	0.650
Within groups	0.080	4	0.020		
Total	0.085	5			

Analysis of the final moisture content variable provides a P-Value (Sig.= 0.650), which is much greater than α=0.05. The decision is H_0 is accepted, which means there is no significant difference in the average final moisture content between electric drying machines and biomass drying machines. This shows that both drying technologies are equally effective in carrying out their main function, namely achieving the required moisture content quality standards by the industry of ≤12% to prevent damage and ensure shelf life.

According to the one-way ANOVA analysis, the electric dryer demonstrates superior time efficiency, shortening the drying process by 4,1 hours per batch relative to the biomass dryer. This advantage stems from its electric heating components, which allow for precise digital control and steady maintenance of ideal temperatures, optimizing the rate of mass transfer (evaporation of water) while eliminating variations. Moreover, the electric dryer sidesteps the heat inconsistencies common in biomass systems, such as the need for manual refueling and irregular burning, which often lead to sporadic temperature reductions and extended overall drying periods. As a result, the electric dryer stands out as the top option for boosting daily output and reducing the chance of spoilage in raw materials (wet cloves) queued for processing.

Biomass serves as an extremely affordable fuel source. Yet, ANOVA findings indicate no meaningful difference in operating expenses compared to electricity. To confirm this lack of significance, total costs per batch can be computed under a comparable pricing model. Assuming commercial electricity rates of Rp1.500/kWh and biomass at Rp5,000/kg, the per-batch energy expenses are as follows:

- Electricity expense = 15,36 kWh x Rp1.500/kWh = Rp23.040
- Biomass Expense = 4,3 Kg x Rp5.000/Kg = Rp21.500

The cost difference of Rp1,540 per batch numerically confirms that both machines are economically equivalent. This phenomenon is due to the high unit cost of electricity being offset by the significantly shorter operating duration of the electric machine (12.6 hours) compared to biomass. Furthermore, both drying machines proved equally effective in achieving the final moisture content standard required to maintain shelf life. Based on this economic parity and guaranteed basic quality, the electric machine is deemed superior in the time variable without sacrificing quality. This time advantage significantly boosts daily productivity and minimizes the risk of raw material damage (wet cloves) due to queuing.

The findings of this research align with the general principle found in agricultural drying studies, where a higher initial investment cost is often compensated by superior time and energy efficiency. For instance, a study comparing hybrid dryers (biomass and solar) indicated that although the fuel cost of biomass is low, the resulting thermal instability frequently leads to longer drying times (Latif & Tjiroso, 2020). Conversely, the electric machine, despite requiring a high unit energy cost, is capable of providing precise temperature control (Setiawan et al., 2021).

4. CONCLUSION

Based on the synthesis of the three drying machines with 3 performance variables, the most efficient and optimal drying machine overall is the electric drying machine for clove processing. In the industrial world, the ability to process products faster means increasing revenue and reducing the risk of losses, whose value often exceeds the additional energy costs. The electric machine also offers superior performance and achieves standard quality moisture content (11.6%) with costs that are competitive with the biomass drying machine. The electric drying machine is the most efficient and optimal because of its significant advantages in time (productivity) without sacrificing basic quality (moisture content) and with statistically equivalent costs.

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