

Techno-Economic Analysis of Energy Conversion from a Diesel Motor to an Electric Motor in a Hot Air Blowing Fan for Rice Drying

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ABSTRACT

A rice drying machine with biomass fuel is an alternative in the rice drying process to reduce dependence on conventional drying using sunlight. To achieve this objective, a dryer has been developed to dry rice with a better efficiency and high economic value. The experiment was conducted by optimizing the drying machine capacity of 5,000 kg/process using a diesel motor and an electric motor in a hot air blowing fan. The test results showed that a drying machine using an electric motor for a driver of hot air blowing fan is better than using a diesel engine. The economic value is directly proportional to the efficiency value of the rice drying machine, where the use of electric motor is more economical than the use of diesel motor engine.

Keywords: Rice drying machine, Efficiency, Electric motor, Diesel engine, Economical analysis

INTRODUCTION

Indonesia, as an agriculture country, has various staple food sources, including rice, a well-known staple food. Rice production in Indonesia has soared in the first half of 2025, with the production reaching the highest level in a 7-year period, driven by abundant

harvests in provinces in Java, which is expected to remain stable at approximately 95%. On the demand side, a slowing population growth rate and a food diversification trend will cause a decrease in the per capita consumption level. Rice imports decreased approximately 92% in first quarter of 2025 because the domestic production exceeded domestic consumption in the same period [1]. Therefore, in order to maintain the harvest, a drying machine is required to maintain the harvest in good condition by considering the yield losses.

An effort to increase energy efficiency in the drying process is important because of higher energy consumption levels (10-25% of total energy in developed countries) and low thermal efficiency (25–50%) [2]. Renewable energy sources can help reduce costs and increase efficiency, particularly in the drying system. Various renewable drying techniques applied include solar drying, solar light drying, greenhouse drying, and biomass drying. Biomass drying can be a better alternative, especially when Indonesia gets high rainfall. In biomass drying, biomass is used as the main fuel, burned in the combustion chamber, and the hot air produced circulates through convection with the help of a blower. This hot air is used to dry rice to the desired moisture content [3].

Kaaya and Kyamuhangire [4] examined that the impact of biomass drying on drying time can significantly increase the efficiency of drying time, reducing the drying time to 6 hours compared to direct solar light drying. Mohapatra and Mahanta [5] examined the effectiveness of drying rate in drying rice using biomass to increase the drying efficiency in overcoming the threat of an energy crisis.

MATERIALS & METHODS

The researcher converted the use of a motor in a hot air blowing fan for a drying machine, which initially used an 11hp diesel motor into a 7.5hp electric motor. The testing process was carried out by drying 5,000 kg of rice with a drying time of 7 hours. Materials for the drying process used rice with an initial wet-basis moisture content of 23%, harvested the day before the drying process. The heater furnace fuel was rice husk. The experiment process was conducted in Kudus, Indonesia.

The first testing was conducted using a hot air blowing fan driven by a diesel motor. Data collection was conducted with a time interval of 1 hour. Sampling of the material pile temperature and material temperature was conducted at 27 points, including 9 points on the surface layer of the rice pile, 9 points on the middle layer, and 9 points at the bottom layer. The drying process was conducted for 7 hours with a final wet-basis moisture content of 13.8%.

The second testing was conducted using a hot air blowing fan driven by an electric motor. Data collection was conducted with a time interval of 1 hour. Sampling of the material pile temperature and material temperature was conducted at 27 points, including 9 points on the surface layer of the rice pile, 9 points on the middle layer, and 9 points at the bottom layer. The drying process was conducted for 7 hours with a final wet-basis moisture content of 13.8%.

Calculating the drying efficiency used the Equation (1):

$$\eta_p = 100 \frac{(m_g \times c_{pg} \times (T_t - T_0)) + (W \times L)}{(m_u \times c_{pu} \times \Delta T \times \theta)} \quad (1)$$

where:

- η_p : drying efficiency (%)
- m_g : weight of material to be dried (kg)
- C_{pg} : specific heat of the dried material (kJ/kg°C)
- T_t : average temperature of material pile during the drying process (°C)
- T_0 : average temperature of material pile before the drying process (°C)
- W : weight of evaporated water (kg)
- L : latent heat of water evaporation (kJ/kg)
- m_u : mass flow rate of hot air (kg/second)
- C_u : specific heat of hot air (kJ/kg°C)
- ΔT : the difference between hot air temperature and ambient temperature (°C)
- θ : drying process time (seconds) [7].

The calculation for Break Even Point (BEP) used a fixed cost ratio approach with the difference between drying results and variable costs as it is shown in Equation (2). Fixed cost for this test was the investment cost for a rice drying machine using either a diesel motor or an electric motor in a hot air blowing fan. It is assumed that 25% of the net profit generated from the rice drying process is allocated as a return to the drying machine. Variable costs included the production cost of rice drying, including fuel, labor, and the use of rice husk (biomass) as the heating fuel source of the rice drying machine.

$$BEP = \frac{F}{((S-V) \times 25\%)} \quad (2)$$

where:

- BEP : Break Event Point (%)
- F : Fixed cost (USD)
- S : Drying results (USD)
- V : Variable cost (USD).

RESULTS

The first experiment set up was conducted using a hot air blowing fan driven by a diesel motor, and it gave the results as:

- m_g : weight of material to be dried (5,000kg)
- C_{pg} : specific heat of the dried material (1.79kJ/kg°C)

T_t : average temperature of material pile during the drying process (33.8°C)
 T_0 : average temperature of material pile before the drying process (28°C)
 W : weight of evaporated water (533.64kg)
 L : latent heat of water evaporation (2306.44kJ/kg)
 m_u : mass flow rate of hot air (2.66kg/second)
 C_u : specific heat of hot air (1.037kJ/kg°C)
 ΔT : the difference between hot air temperature and ambient temperature (26.2°C)
 θ : drying process time (25,200 seconds).

Thus, the drying efficiency value was 70.4%. The second experiment set up was conducted using a hot air blowing fan driven by an electric motor, and it gave results:

m_g : weight of material to be dried (5,000kg)
 C_{pg} : specific heat of the dried material (1.79kJ/kg°C)
 T_t : average temperature of material pile during the drying process (34.8°C)
 T_0 : average temperature of material pile before the drying process (28.2°C)
 W : weight of evaporated water (533.64kg)
 L : latent heat of water evaporation (2306.44kJ/kg)
 m_u : mass flow rate of hot air (2.66kg/second)
 C_u : specific heat of hot air (1.037kJ/kg°C)
 ΔT : the difference between hot air temperature and ambient temperature (26°C)
 θ : drying process time (25,200 seconds).

Then, the drying efficiency value was 71.4%.

Drying Efficiency	%
Diesel Motor	70.40
Electric Motor	71.40

The amount of diesel motor fuel used in the rice drying process in the first test was 18.9

liters for 7 hours using a hot air blowing fan driven by a diesel motor. The total energy used was 189 kWh, assuming that 1 liter of diesel fuel is equivalent to 10 kWh. The amount of electrical energy used in the rice drying process in the second test was 54.81 kWh for 7 hours using a hot air blowing fan driven by an electric motor.

The amount of energy used	kWh
Diesel Motor	189
Electric Motor	54.81

The initial investment for a rice drying machine using the configuration of a hot air blowing fan driven by a diesel motor was USD 10,545, and for a rice drying machine using the configuration of a hot air blowing fan driven by an electric motor was USD 10,848.

The Amount of Rice Drying Machine Investment	USD
Diesel Motor	10,545
Electric Motor	10,848

Variable costs included the production cost of rice drying, consisting of fuel, labor (two people), and the use of rice husk as a fuel for heating the rice drying machine. During the first test process, it was carried out using a hot air blowing fan driven by a diesel motor, consuming 18.9 liters of diesel fuel, two workers, and 172 kg of rice husks, with a total cost of USD 27.55. During the second test process, it was carried out using a hot air blowing fan driven by a diesel motor, consuming electrical energy of 7.83kW for 7 hours, 2 workers, and 168 kg of rice husks, with a total cost of USD 24.44.

The amount of rice drying machine production	USD
Diesel Motor	27.55
Electric Motor	24.44

The result of the drying process obtained from the rice drying machine was USD 331.15. The calculation of Break Event Point (BEP) in the first experiment using a hot air blowing fan driven by a diesel motor, gave the following results:

F : Fixed cost (USD 10,545)
 S : Drying results (USD 331.15)

V : Variable cost (USD 27.55).
 Thus, the BEP obtained was 138.93 periods.
 The calculation of Break Event Point (BEP) in the second experiment, using a hot air blowing fan driven by an electric motor gave the following results:

F : Fixed cost (USD 10,848)
 S : Drying results (USD 331.15)
 V : Variable cost (USD 24.44).
 Thus, the BEP obtained was 141.48 periods.

Break-Even Point	cycle
Diesel Motor	138.93
Electric Motor	141.48

DISCUSSION

The Figure 1 shows the test results which is obtained a drying efficiency value of 70.4% using a diesel motor and 71.4% using an electric motor. The results show that the conversion from a diesel motor to an electric motor can increase the efficiency value by 1%, and these results is in accordance with the study conducted by Mohapatra and Mahanta [5]. The experimental results using the electric motor obtained an efficiency value of 71.4%, and it exceeded the minimum threshold required by the Indonesian National Standard with the number of SNI 4412:2015 about Rice Dryer for Flat-Bed Type with the quality requirements and test methods above 50% [7]. Thus, the process of converting the 11hp diesel motor to a 7.5hp electric motor on the hot air blowing fan has met the standards.

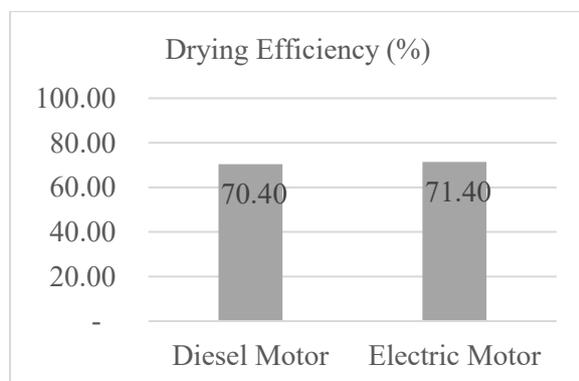


Figure 1 Comparison of Drying Efficiency

The increase in energy efficiency is reflected in the reduced energy consumption of a hot air blowing fan using a diesel motor, from

189 kWh with a diesel motor to 54.81 kWh after conversion to an electric motor as it is shown in Figure 2.

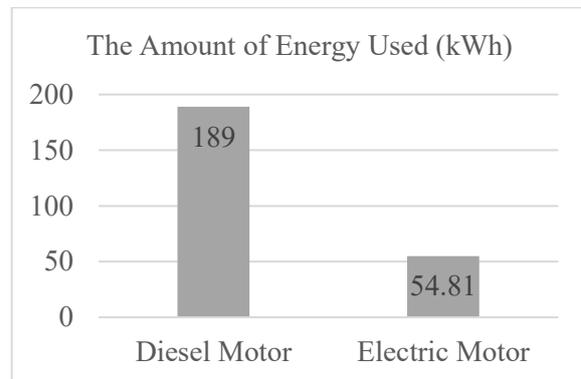


Figure 2. Comparison of The Amount of Energy Used

The increase in drying efficiency value and the use of more efficient energy result in a higher initial investment cost, where using a diesel motor requires an investment of 10,545 USD, and increases to 10,848 USD after being converted to an electric motor as it is shown in Figure 3.

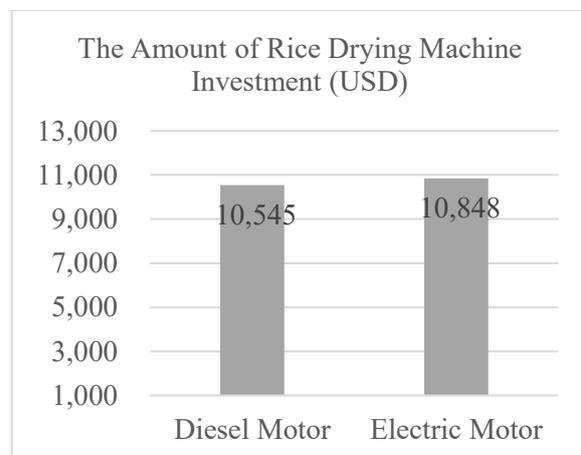


Figure 3 Comparison of Drying Machine Investment

Figure 4 shows the comparison of the experimental result of the reduction in operational drying costs, from 27.55 USD per drying cycle to 24.44 USD per drying cycle after being converted to an electric motor.

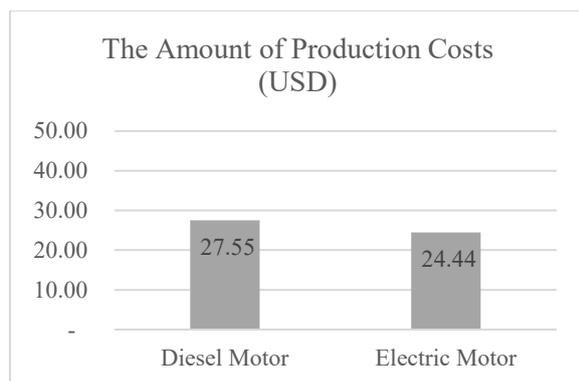


Figure 4. Comparison of Production Cost

The Break-Even Point in Figure 5 shows the increment from 138.93 drying cycles to 141.48 drying cycles after being converted to an electric motor.

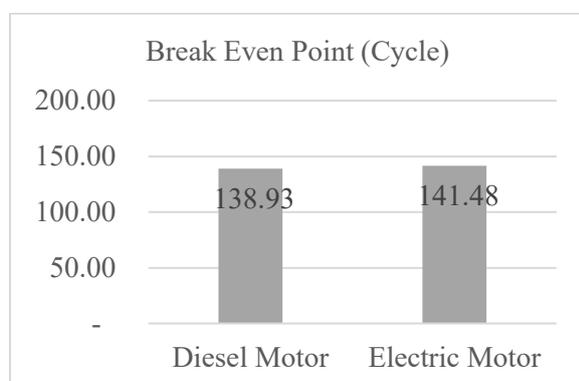


Figure 5. Comparison of Break-Even Point

CONCLUSION

Based on the experimental results of the rice drying machine, the conversion of driver for the hot air blowing fan, which initially used 11hp diesel engine to a 7.5hp electric motor, can increase the energy efficiency by 134.19kWh and give the drying efficiency value by 1%. However, the conversion process from diesel engine to electric motor increases initial investment costs of USD 303, and gives the higher break-even point (BEP) by 2.54 periods.

Declaration by Authors

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