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Comparative analysis of LPG and rice husk biomass as energy sources for drying food materials for small farmers

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Abstract

Drying is a post-harvest process with high energy requirements; choosing an energy source a crucial factor, especially for smallholder farmers. This study aims to analyze the comparative use of LPG (Liquefied Petroleum Gas) and rice husk biomass as energy sources for drying food through a literature review. The study results show that LPG has higher energy efficiency, faster drying times, and produces more uniform product quality due to stable temperature control. Conversely, rice husk has lower efficiency and longer drying times, but excels in terms of very low operational costs, abundant availability, and its renewable nature. The use of rice husks also has the potential to increase the added value of agricultural waste and support energy independence in rural areas. Overall, LPG is superior from a technical perspective, while rice husks are superior from an economic and sustainability perspective. Therefore, the choice of energy source needs to be tailored to local farmer conditions, with the potential for developing hybrid systems to optimize efficiency and costs.

Keywords: LPG (Liquefied Petroleum Gas); Rice husk biomass; Food drying; Drying energy; Small-scale farmers

1. Introduction

Drying is a crucial step in post-harvest food processing, especially for small-scale farmers. Solar drying is widely used by small-scale farmers because it requires no fuel costs and is easy to implement. However, solar drying has major drawbacks, including a high dependence on weather conditions, a relatively long drying time, difficulty in controlling temperature and humidity, the risk of environmental contamination, the need for extensive land, and inconsistent product quality. Drying in sunlight can reduce product quality because it causes the product to become dusty and hard, damages the physical structure (pores, volume, porosity, texture), and reduces sensory properties and nutritional content, especially in heat-sensitive ingredients such as fruit and vegetables [1, 2, 3].

Drying aims to reduce the moisture content of food, thereby extending shelf life, maintaining product quality, and increasing sales value. However, drying methods used by smallholder farmers still face various challenges, such as dependence on weather in traditional drying methods and limited access to modern drying technology. To improve energy efficiency and independence, the use of alternative energy sources for food drying is crucial. One of the commonly used energy sources is LPG (Liquefied Petroleum Gas), which is known to have high efficiency, is easy to control, and produces stable heat. LPG (Liquefied petroleum gas) has a calorific value of 46-51 MJ/kg, NIST [4], and 46607 MJ/kg, GREET [5]. In addition, LPG is easily available in the market as a result of LPG being a primary need in household activities, especially for cooking [6]. The use of LPG in the drying process tends to require less energy than coal, thus resulting in smaller pollutant emissions into the atmosphere [7]. However, LPG use is often hampered by its relatively high price and uneven availability in some rural areas. On the other hand, biomass is a potential alternative

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energy source, particularly in agricultural areas. Biomass can be utilized through a thermal conversion process, one of which uses a heat exchanger. Biomass energy conversion technology into thermal energy, using a heat exchanger to flow hot air into the drying chamber, can increase the drying temperature [8]. The drying process using a biomass dryer is faster than using sunlight [9]. One biomass that is easy to obtain and utilize is rice husks.

Rice husk biomass is used as an energy source due to its abundant availability as an agricultural waste, its very low or almost free cost, and its renewable and environmentally friendly nature. Furthermore, utilizing rice husk can reduce waste, increase the efficiency of local resource utilization, and support energy independence for smallholder farmers. Rice husk has a calorific value of approximately 11–15.3 MJ/kg, which is about half the calorific value of coal. Furthermore, its maximum combustion temperature reaches approximately 560°C when directly fired and 556.5°C when using a stove. Meanwhile, its main content is cellulose, lignin, and silica, making it suitable as a source of heat energy [10, 11, 12]. Rice residues such as husks and straw can be used as biofuels to complement or replace fossil fuels because they have adequate calorific value, good thermal properties, and produce relatively low gas emissions both in oxidative and inert conditions, so they have the potential to be a sustainable biomass source that supports economic growth and environmental sustainability [13, 14]. Rice husk is a waste product from rice milling, which is abundant and relatively cheap, and is often not utilized optimally.

Utilizing rice husks as drying fuel not only reduces operational costs but also supports sustainability principles through the utilization of agricultural waste. Rice husks are a byproduct of rice processing, accounting for approximately 20% of the total weight of unhulled rice [15, 16]. Rice husks pose an ecological problem due to their abundant production, but their use as biomass can provide added value, reduce energy dependence, and improve the economic well-being of smallholder farmers [17, 18]. In addition, the abundant availability of rice husks can be utilized to reduce waste by using them as a drying energy source. The vast area of rice fields also shows the great potential for utilizing rice husks as a biomass raw material to support renewable energy [19]. The abundant potential of rice husks, such as on *Lombok* Island as an agricultural region, rice production in 2024 was recorded to reach 785,918 tons of dry milled rice based on data from the Central Statistics Agency in 2024 [20]. So theoretically, the potential for rice husks on Lombok Island for 2024 is 157,184 tons [21]. The use of biomass also has challenges, such as lower combustion efficiency, less stable temperature control, and the potential for higher emissions.

The differences in characteristics between LPG and rice husk biomass indicate that each has its own advantages and disadvantages as a drying energy source. Therefore, a comprehensive comparative analysis is needed to evaluate the two energy sources, particularly in the context of the needs and limitations of small-scale farmers. This study aims to analyze the comparison of LPG and rice husk biomass as energy sources for drying food based on efficiency, cost, availability, environmental impact, and quality of the drying results. The results are expected to provide appropriate recommendations for smallholder farmers in selecting effective, economical, and sustainable energy sources.

2. Scope and Methodology

This study uses a literature review with a descriptive-comparative approach to analyze the use of LPG and rice husk biomass as energy sources for drying food products among small-scale farmers. The data types and sources used are secondary data obtained from various sources, including national and international scientific journals, seminar proceedings, reference books, and reports from relevant institutions (e.g., the FAO, the Ministry of Agriculture, and energy research institutions). This study used inclusion criteria to determine the characteristics required for inclusion in the study. The following are some of the inclusion criteria.

- Published within the last 10–15 years.
- Discusses the use of LPG or rice husk biomass in food drying.
- Contains technical data (efficiency, drying temperature, energy consumption, etc.).
- Relevant to small-scale farmers or appropriate technology.

Data collection techniques were carried out through literature selection based on the relevance and quality of the sources. In addition, data were collected through searches of scientific databases (Google Scholar, ScienceDirect, *Sinta*, etc.), as well as the use of keywords such as LPG drying, rice husk biomass drying, food drying energy, and small-scale farmers' drying technology. Data were analyzed using descriptive comparative analysis, by comparing LPG and rice husk biomass based on several key parameters, including energy efficiency and fuel consumption, operational costs and equipment investment, fuel availability and accessibility, ease of use of the technology, environmental impacts (emissions, waste), and quality of drying results (moisture content, colour, product quality). The research was conducted through the following stages: problem formulation and research objectives, literature collection and selection, data classification based on analysis parameters, comparative analysis of LPG and rice husk biomass, and discussion and conclusion drawing. The research approach used a descriptive qualitative approach to explain the characteristics of each energy source. Furthermore, a comparative approach aimed to identify the advantages and disadvantages of LPG and rice husk in the context of smallholder farmers.

3. Results and discussions

Based on the results of a literature review, the use of LPG and rice husk biomass as energy sources for drying food products shows significant differences in several key aspects, namely energy efficiency, cost, availability, environmental impact, and drying quality. LPG has higher energy efficiency than rice husk. This is due to LPG's higher calorific value and a more complete combustion process, resulting in more stable and easily controlled heat generation. Thus, drying time using LPG tends to be shorter and produces a more uniform final moisture content. Research conducted on drying corn in a rotary dryer showed a difference in drying time between the use of LPG energy and rice husks. The use of LPG in drying using a rotary dryer requires 60 minutes to reach a moisture content of 12.3% based on testing of a 10 kg corn sample [22]. Meanwhile, the use of rice husks requires 258 minutes to reach a water content of 12% based on testing a sample of 4 kg of corn for a heat exchanger pipe diameter of 0.5 in [23]. The results of the study indicate that the use of LPG energy provides a shorter time compared to the use of rice husk energy.

The turmeric drying process carried out in a rotary dryer with LPG energy showed that the drying process carried out for 360 minutes at a hot air flow rate of 9.1 m/s reached a water content of 43.97% from the initial water content of 8.98% [24]. In contrast to the use of rice husk energy in a vertical rack dryer, it was found that the water content of white turmeric after drying was 6.335% from the initial water content of 79.6% within a period of 600 minutes [25]. Although rice husks have lower efficiency than LPG, applying a heat exchanger can increase efficiency and temperature stability during the drying process. The use of rice husk energy in rotary dryers, such as in cherry coffee drying, is not dependent on environmental temperature, which results in shorter drying times [26]. Although LPG and rice husks have differences in temperature and drying time when applied, both energy sources are relevant for application as a substitute for solar drying, which is highly dependent on weather conditions. Utilizing rice husks as an energy source can increase the economic value of waste while reducing pollution. Biomass utilization has the potential to meet the energy needs of rural communities in developing countries, improve economic welfare, and reduce dependence on firewood [18, 27]. Drying is a post-harvest unit operation that plays a crucial role and requires relatively high energy consumption [28].

LPG (Liquefied Petroleum Gas) is a gaseous fossil fuel that is liquefied under pressure, and generally consists of a mixture of light hydrocarbons such as propane (C_3H_8) and butane (C_4H_{10}). LPG is widely used as an energy source because it has a high calorific value and efficient combustion characteristics. In the drying process, LPG has lower energy consumption than coal, with a drying productivity index that is also lower, which is around 0.27 dollars/quintal compared to biomass, which reaches 1.4 dollars/quintal. In addition, LPG can be used to meet energy shortages due to low solar radiation in the initial and final stages of drying, and is able to produce a more even heat distribution as an alternative to solar drying [7, 29, 30, 31]. Based on the comparison results, LPG and rice husks show different characteristics as energy sources for drying food materials. LPG is a fossil energy source with a high calorific value (±46–50 MJ/kg), so it has better energy efficiency compared to rice husks, which only have a calorific value of around 11–15 MJ/kg. The high calorific value of LPG allows for a faster drying process at a stable and easily controlled temperature, resulting in a more uniform final moisture content. This comparison is shown in Table 1.

Table 1 Comparison of LPG and rice husk as drying energy

Aspects	**LPG**	**Rice Husk (Biomass)**
Types of energy	Fossils (non-renewable)	Renewable (agricultural waste)
Calorific value	High (±46–50 MJ/kg)	Moderate (±11–15 MJ/kg)
Energy efficiency	High	Lower (depending on technology)
Temperature control	Stable and easy to control	Less stable
Drying time	Faster	Longer
Operational costs	High	Very low / almost free
Availability	Depends on distribution	Abundant in agricultural areas
Ease of use	Practical	Requires special handling

Environmental impact	Cleaner emissions	More environmentally friendly (renewable)
Pollutant emissions	Relatively low	Higher (smoke & particulates)
Residues	None	Produces ash
Product quality	More uniform and better	Varies
Equipment investment	Medium–high	Low-moderate
Smallholder suitability	Limited (due to cost)	Highly suitable

In contrast, rice husk, as a renewable biomass, has relatively lower efficiency due to its unstable combustion process. This results in longer drying times and more variable product quality. However, rice husk utilization can be improved through the application of technologies such as biomass furnaces or indirect drying systems. From an economic perspective, rice husks offer significant advantages due to their very low, even near-zero, operating costs, given their abundant availability as agricultural waste. Meanwhile, LPG is more expensive and dependent on distribution systems, making it less economical for smallholder farmers, particularly in rural areas. In terms of environmental impact, LPG produces cleaner emissions with relatively low levels of pollutants, but it still contributes to carbon emissions because it is derived from fossil fuels. On the other hand, rice husks are more environmentally friendly because they are a renewable energy source and potentially carbon neutral, although their combustion can produce smoke and ash residue if not managed properly. Technically and operationally, LPG is superior in terms of ease of use, produces no residue, and provides a better and more uniform product quality. Conversely, rice husks require special handling and produce ash residue, but they have advantages in terms of availability and suitability for small-scale farmers.

Overall, LPG is superior in terms of efficiency and drying quality, while rice husks are superior in terms of economics and sustainability. Therefore, the choice of energy source needs to be tailored to local conditions and farmer capabilities, with the possibility of developing a hybrid system as an optimal solution. An alternative that can be considered is the use of a hybrid system that combines LPG and biomass to optimize efficiency while reducing costs.

4. Conclusion

Based on the study results, LPG (Liquefied Petroleum Gas) and rice husks each have their own advantages and limitations as energy sources for drying food. LPG excels in energy efficiency, temperature stability, shorter drying times, and better quality results. However, its use is limited by its relatively high cost and dependence on fossil fuels. Conversely, rice husks as biomass have the advantages of availability, low cost, and environmental friendliness, although they have lower efficiency and less consistent results. Thus, rice husks are more suitable for small farmers with limited financial resources, while LPG is suitable for drying needs that require high efficiency and quality. Developing a hybrid drying system is a potential solution to combine the advantages of both energy sources.

Compliance with ethical standards

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Disclosure of conflict of interest

The authors declare no conflict of interest.

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