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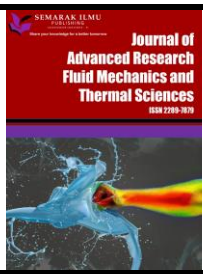

Environmental Analysis of Power Generation from Pineapple Waste

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ABSTRACT

Malaysia's manufacturing and transportation sectors are largely reliant on fossil fuels. In 2009, fossil fuels such as natural gas, coal, diesel oil, and palm oil were used to produce 94.5 percent of electricity. Concerns about energy security, crude oil price volatility, and climate change are all driving major changes in how energy, specifically electricity, is produced, distributed, and consumed. In this regard, renewable energy resources are becoming more appealing in Malaysia for long-term energy growth. There is because Malaysia has an abundance of renewable energy sources, the most important of which are biomass and solar. This article presents the potential use of pineapple wastes as one of renewable sources of energy (biomass) in Malaysia and their impacts towards environment.

1. Introduction

Ananas comosus, or pineapple, is one of Malaysia's most popular tropical and economic fruits with boosting global market potential [1]. It is categorized as a major fruit group because it has great potential to generate income for both farmers and countries. Its popularity is due to its consumption of multiple forms. This fruit juice is the third most preferred worldwide after orange and apple juices [2]. The plant can reach a height of 75-150 cm and a width of 90-120 cm. It's a short plant with a stout stump and narrow, fibrous, spiny leaves. The plant produces a juicy, fleshy cone-shaped fruit with a crown at the top. It is primarily grown commercially as canned fruits and is consumed worldwide [2]. It is also used to make juices, concentrates, and jams. Pineapple slices can also be frozen and stored [3]. Furthermore, bromelain, the proteolytic enzyme present in the stem of the pineapple, is finding wide applications in pharmaceutical and food uses [4]. Costa Rica, Brazil, the Philippines, Thailand, and Indonesia led the global pineapple producers producing about 10 million tons of pineapple. By the year 2017 Malaysia was ranked 19th in the world's pineapple producing country [5]. Since Malaysia is among the largest pineapple producer in the world, the incineration process of the pineapple biomass should be reduced by converting the biomass to something useful [6].

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Recently, the agricultural waste management problem has become a hotly debated issue, with around 1.2 million tonnes of agricultural waste disposed of each year in Malaysia following the agricultural sector [7]. After harvesting, most pineapple residue is normally disposed of or burnt in an open field. However, this method is not effective and also contribute to air pollution [8]. According to Selvarajoo and Hanson [9], the optimum condition for pineapple peel was at 4250 C with a heating value of 27.2 MJ kg^{-1}. This potentially can be used as fuel in the boiler. The pineapple peel is discarded in the pineapple cannery industry, and only the pulp is processed into the can. As a result of this operation, a pile of pineapple peel waste is produced on a regular basis, and without a plan to reuse the waste, it is discarded as domestic waste [10]. These wastes (peel, core, stem, crown and leaves) generally account for 50% (w/w) of total pineapple weight [11]. Related to these, in 2016 Malaysia generate about 195,857 tonnes of pineapples waste. Utilization of pineapple waste as fuel could potentially generate approximately 20.8 MW. This research will explore the potential use of pineapples waste related to energy production. Pineapple waste will be utilized in this analysis in power generation. This study will also investigate the environmental impact of power generation by using life cycle assessment of pineapple waste approach.

2. Literature Review

2.1 Pineapple Waste

Huge waste generation has resulted from the increased production of pineapple-processed items. This is mostly due to the selection and removal of components that are unfit for human consumption. Furthermore, rough handling of fruits and exposure to harsh environmental conditions during transportation and storage can result in up to 55% product waste [4]. These wastes are normally susceptible to microbial spoilage, restricting their use. Furthermore, the cost of drying, storing, and shipping these wastes is low, so their reliable, low-cost, and environmentally friendly use is becoming increasingly important.

Most of pineapples are eaten fresh or as canned goods, with the exception of high-quality fruits selected for shipment. Low-quality fruits, on the other hand, do not sell and are left on fields. Furthermore, a large amount of unusable waste material is produced during pineapple processing [2]. According to reports, 40-80% of pineapple fruit is discarded as waste because it has a high biological oxygen demand (BOD) and chemical oxygen demand (COD) value [4].

Fruit residues, which accumulate in agro-industrial yards without having any significant or commercial value, may cause severe environmental problems. Since disposal of these wastes is costly due to high shipping costs and a scarcity of landfills, they are disposed of in an unethical manner, causing environmental concerns. In addition, regulatory limits exacerbate the issue of disposing of by-products. Pineapple wastes have a high BOD and COD content, which complicates disposal further. Recently, composting of pineapple wastes using earthworm is reported [12]. They found that vermicomposting decomposes about 99 percent of pineapple pulp wet mass, while the peel loses almost 87 percent of its weight. During composting, the pH of the waste changed from acidic to neutral to alkaline. Cost effectiveness, on the other hand, has yet to be investigated.

It is expected that discarded fruit, as well as waste material, will be used in industrial processes such as fermentation, bioactive component extraction, and so on. Several studies have been conducted on the use of waste from the fruit and vegetable, dairy, and meat industries. Several attempts have been made in this regard to use pineapple wastes collected from various sources. Since pineapple cannery wastes are a potential source of sugars, vitamins, and growth factors, they have been used as a substrate for bromelain, organic acids, ethanol, and other compounds [4]. Several experiments have been conducted over the years to look at the feasibility of using these wastes. Sugar was previously extracted from pineapple effluent using ion exchange and then used in syrup to can pineapple slices [3]. The waste management of pineapple leaves constitute an effective alternative pulping raw material, because pineapple leaves fibres can be produced to get a paper sheet while the exploitation of pineapple residues as food for ruminants has been emphasized in several studies where the pineapple skin and core of the pineapple and leaf planting industries are used as ruminants [3,13]. This paper would try to collect and gather information regarding the utilization of pineapple wastes in power or electricity generation.

2.2 Renewable Energy in Malaysia

Malaysia is a country that has abundance renewable energy such as solar, small hydro biogas and biomass but the electricity industries is dominated by fossil fuel as primary resources. This is because most of these renewable energy resources are not fully explored and exploited. Studies from many researches had showed which the combustion of fossil fuel for electricity generation will produces greenhouse gas emission, until give a big impact in extreme changes in global climate [14].

An alternate source of renewable energy is biogas. Anaerobic digestion is used to create it rather than a geological process using fossil fuels. Because biogas contains methane and has enough energy to produce both heat and power, it can lessen reliance on fossil fuels and replace them [15]. About 55 to 70 percent of the biogas is methane, 30 to 45 percent is carbon dioxide, and the other trace gases include oxygen, carbon monoxide, and hydrogen sulphide. When organic waste is disposed of in an environment without oxygen, it decomposes and produces biogas. Anaerobic digestion is the procedure in question. Additionally, biogas is carbon neutral because it is made from organic waste that has had its carbon dioxide from the environment repaired. Thus, even if carbon dioxide will be released during the burning of biogas, the level of carbon dioxide won't rise. Furthermore, the organic wastes will continue to develop and be available, making it extremely sustainable [15].

Table 1 below presents the renewable energy potential in Malaysia identified by a recent research study. However, study of pineapple waste as potential source of energy is still lacking and hard to be found especially in Malaysia.

Table 1
Renewable energy potential

Renewable Energy Resources	Energy Value in RM (Annual)
Forest residues	11,984
Palm oil biomass	6,379
Solar thermal	3,023
Mill residues	836
Hydro	506
Solar PV	378
Municipal waste	190
Rice husk	77
Landfill gas	4

2.3 Pineapple Waste as Renewable Energy in Malaysia

Establishment of the Malaysia Pineapple Industry Board (MPIB) in 1957 oversee the growth of the Malaysian pineapple production industry and to be fully empowered to make decisions. Nowadays, MPIB continues support the fresh fruit of the pineapple and pineapple processing industries by finding agronomic research regarding pineapple industry, market price controlling of pineapple, quality control of the nation's pineapple product and documenting or reporting pineapple industry in related statistic.

The Malaysian economy can also provide an example of a viable nation as a result of the plantation and pineapple industry. With more pineapple harvested and processed, more pineapple waste will be generated. Figure 1 shows the relatively stable and positive trends of pineapple and its biomass production in Malaysia from 2000-2012.

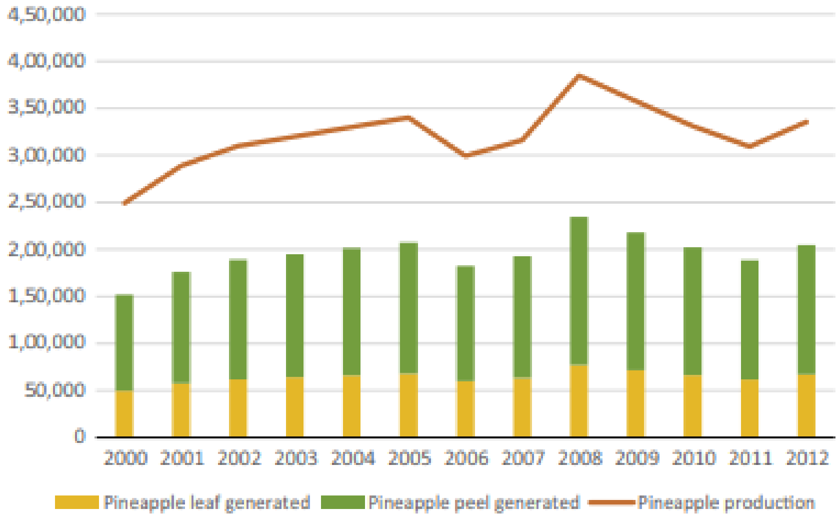

Fig. 1. Malaysia's pineapple production and its biomasses production year 2000-2012

Pineapple fruit will usually produce skin and leaves (crown) as a waste, the amount of pineapple biomass seen about half of fresh fruit is produced annually (Figure 2). The data were collected from the composition of the basin based on the weight of ordinary fresh fruit reported by Medina and García [16], which is described as 20% of the leaves and 41% of the skin. As many as 335,488 tonnes of pineapple were produced in Malaysia in year 2012, with crowned fruit producing 67,098 tonnes and 137,550 tonnes of peeled skin. The amount of pineapple fluctuated throughout the year, with 2008 being fresh pineapple, leaf, and skin production with data of 384,673, 76,935 and 157,716 tonnes respectively.

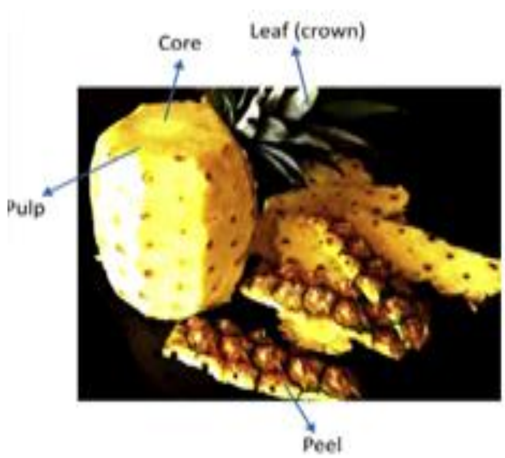

Fig. 2. Pineapple fruit and its biomasses

2.3.1 Model of rice husk as renewable energy in Malaysia

Malaysia has officially used rice husk as a source of biomass material to generate electricity. As such, pineapple waste also has the potential to become a source of alternative substances such as rice husks which is currently operating in Sungai Petani, Kedah. All technologies, methods, emissions can be related as future references. Table 2 shows the technologies and methods used in rice husk energy generation which also can be used for pineapple waste.

Table 2
Methods in rice husk renewable energy

Title	Description
Combustion Technology	Use this technology in co-firing and biomass (Rice Husk/pineapple waste). The purpose of using this technology is to reduce the cost of modifying or retrofitting in new technologies in existing systems.
Method of Firing	Method of firing also utilise, purpose to safer and much less space than the bin system. Most coal-fired power plants in Malaysia are also incorporated in this method.
Fuel Consideration	By using Abok Coal, the forced draught can be achieved through electricity consumption because it produces adiabatic of closer to the optimal temperature. 95:5 and 90:10 fuel blend, low fuel mixtures require more use to supply higher flow rates of air into the combustion chamber.
Excess Air	About 2000k to 2100k in the optimal temperature in combustion chamber or furnace. To lower the adiabatic flame temperature, excess air can be pumped to the combustion chamber.
Emission	The most important aspect of the power plant is to consider the release of contaminants that have been produced. Among the major pollutants in the power plant are CO2, NOX, and SOX.
Modelling	In this model, the Abok coal is assumed to be the target for the standard for 95: 5 mixed rice paddies to be achieved.
Economy Aspect of Co-firing	Only 5% of the total amount of coal used to be utilisation in rice husk. Therefore, the supplementation of risk was being saved up in an amount of cost there exist.

The technology used in the biomass process of pineapple skin waste is direct combustion. Direct combustion methods are more extensive in solid biomass than gasification and Pyrolysis which are still under development. Where it is contributes to 97% of bio-energy production in the world. Generally, direct combustion is carried out inside a furnace, steam turbine, or boiler at a temperature range of 800–1000°C. This process is suitable for all types of biomasses, which has low moisture content (<50%) [17]. Burning theoretically can be used on any kind of raw materials of biomass but it can only be done to moisten the content of less than 50%. The main combustion system is divided into three types, namely combustion of fluid beds, fixed bed fires and dust combustion. All of these systems can be distinguished by their unique properties.

Among the technology used for pineapple waste processing is the Solid-State Fermentation (SSF) method to produce ethanol. SSF is a simple, more energy-efficient fermentation method than Liquid State Fermentation (LSF) technology, which is fermentation in liquid media that requires agitation, aeration, and foam control. The method of fermentation is the use of yeast. In this process there are also several factors that determine the amount of ethanol concentration produced. Among them, method, yeast type, the amount of yeast addition until the period of fermentation. Various types of pineapple provide ethanol yield for each fruit are different.

The importance of bioethanol is also to substitute for reduced fuels such as fossil fuels that produce reduced electricity. Bioethanol with a rate of 95-99% can be purchased as premium substitution material (gasoline), while 40% rate is used as kerosene substitution substance [18].

3. Research Method

One of the approaches used in the design of qualitative research is the case study. A case study is intended to capture the essence of a particular case, and the methodology that allows for this has evolved in the social sciences, such as psychology, anthropology, and economics, as well as in practice-oriented fields like climate studies, social work, education, and business studies [19]. A pineapple plantation and processing company located in Sungai Petani, Kedah has been chosen for this study since this business not only grows pineapples, but also makes fresh pineapple products like pineapple juice, pineapple cordial, pineapple paste, pineapple jelly, rojak and fruit dipping sauces, and hot pineapple and pineapple dipping sauce.

3.1 Research Design

Qualitative study using Interviews and document review were conducted to obtain information and to investigate the current state of pineapple in Malaysia. The government agencies involved are the LPNM/MPIB of the Kedah and Johor Branches (Malaysia Pineapple Industry Board), the State Department of Kedah Agriculture (JPNK) and Kedah Farmers' Organization Board (LPP) to obtain the valid information.

The overall design of this research is shown in Figure 3 below. This study focuses on analyzing the use of pineapple waste in Malaysia. There are three perspectives on the environment, energy, and economy under the LCA scheme. There are two ways to get this pineapple residue, the first is directly from the pineapple cultivation area, and the second is from the industrial/milling area after certain grade pineapple is delivered to the factory. Example of the by-product from pineapple is pineapple canning, pineapple juice, pineapple jams and others. The pineapple waste is taken to the power plant to produce the next process of electricity. The most critical part of both methods is the logistics problem, and the optimal design output with minimum cost and release is identified.

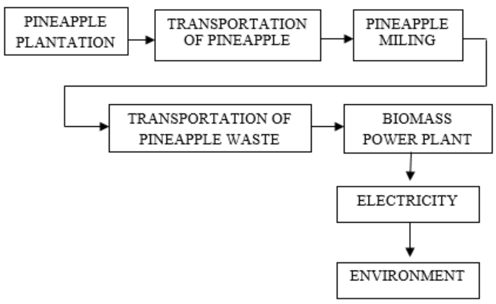

Fig. 3. Overall Outline of Research

3.2 Data Collection Method

The primary data for this analysis was collected through a semi-structured interview. Many researchers prefer this approach because semi-structured interview questions can be planned of time. In addition, this approach gives informants the right to express themselves in their own words

[20]. According to Yaacob *et al.,* [21], the qualitative data gathered must be shared using analytical or interpretation methods. A series of interviews were conducted on the so-called organizations as they deal with the onset of pineapple cultivation so that pineapple can be commercialized in their area. For the overall findings, this study uses rice waste as a substitute for future strategies for developing power generation in Malaysia. This is because pineapple residues have yet to be commercialized in Malaysia, but pineapple residues have a great potential as rice residues.

The study's respondent is a manager at the organisation under investigation, and the interview session yielded a wealth of useful knowledge. To supplement the primary data, secondary data was used. To supplement the primary data, secondary data was used. This type of data was obtained from reviewing official website such as MIPB, Nanas Merbok (NM) and Energy Commission website, the company’s report, as well as from the reviewed of previous literatures.

4. Results

4.1 Potential of Electricity Generation

Pineapple waste like (skin, crown, pulp, stem,) is produced by Nanas Merbok (NM) every year can be converted to fuel to generate electricity. Eq. (1) is used to calculate the potential of electricity generation every year for pineapple waste in NM.

$$\text{Electricity Generation} = \text{Pineapple waste (kg)} \times \text{High heating value of pineapples} / \text{Net plant heat} \quad (1)$$

Table 3 shows the amount of pineapple waste that has been recorded by Nanas Merbok from year 2012 to 2018. The amount of pineapple waste seems to increase significantly in these six years. This amount forecasted will increase in coming years since the Malaysia government have good initiative plan in encouraging agriculture sector and its supply chain including pineapple plantation. Figure 4 shows the amount of electricity that can be generated from pineapple for example in 2018, where 9857.6 tonnes of pineapple waste can generate 9918177.4 kWh of electricity.

Table 3
Amount of pineapple waste from Nanas Merbok

Years	Waste (kg)
2012	588000
2013	588000
2014	656801
2015	645600
2016	3487600
2017	4875672
2018	9857600

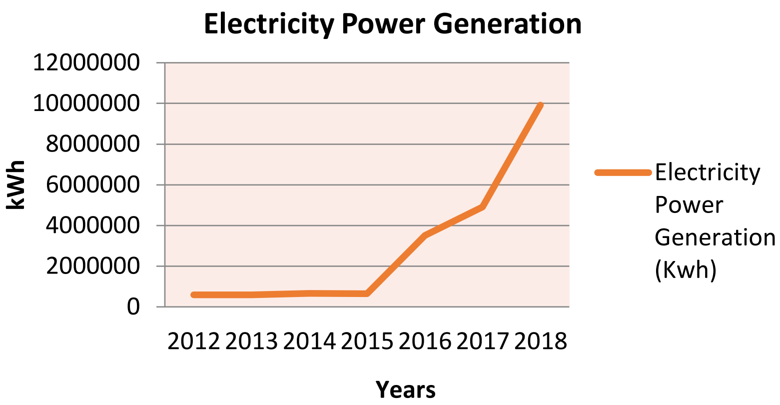

Fig. 4. Electricity power (kWh) produced by pineapple waste

4.2 Environmental Impact

The life cycle assessment (LCA) of pineapple waste toward power generation has impacted the environment from the initial stage until final (from cradle to grave).

4.2.1 Global warming potential include biogenic CO_2

Since the CO_2 released by biomass combustion is a one-time pulse and remains in the atmosphere for many years, the global warming potential of biogenic CO_2 production from biomass combustion may have a climate change effect to some degree. Biogenic CO_2 exist when had the plant or pineapple waste in every stages. If pineapple wastes are not collected, it will decompose slowly and emit CO_2 into the atmosphere over the following years. In this study, stages of pineapple LCA plantation shows the highest produced of CO_2, followed by lorry/trucking transportation, and milling.

4.2.2 Global warming potential exclude biogenic CO_2

Essentially there is no different of excluded or include biogenic CO_2 because it is getting the same result. Both not giving a big negative impact to environment but just produced the CO_2 of emission. Transportation by truck and power plant operation have zero emission results because not had a pineapple waste produce in these stages.

4.2.3 Particulate matter impact

The highest particulate matter to air produced in milling stages than lorry transportation. The most hazardous air pollution will cause respiratory problems. This is also cause to human toxicity in cancer.

4.2.4 Ionising radiation impact

Most of environmental impacts occur/exist in power plant, because at this stage there is sufficient energy in the radiation to release electrons from molecules or atoms and thus ionize them. Ionizing radiation consists of energetic subatomic ions, particles or atoms that move at high speed and electromagnetic waves at the high end of the electromagnetic spectrum. High exposure to ionizing radiation will cause damage to living tissue. But not as high as radiation in other power plantation like nuclear.

4.2.5 Ozone depletion potential impact (steady state)

The impact of ODP came from power plant stages because had several types of gases / substances that are released into the air to the ozone layer but in steady state in unit kg R11-Equivalent.

4.2.6 Ecotoxicity impact (fresh water)

Ecotoxicity occurs at the milling stage because the residual chemicals that are not used will simply be thrown away example pineapple boiled water and so on. This will pollute fresh water in the surrounding area, and this also give an impact to human toxicity.

4.6.7 Human toxicity impact (cancer effect)

This impact exists on milling stages only which is the emission of some substances can have impact on human health like cancer. A little use of chemicals used in the production of pineapple juice as a preservative and flavour. So, humans are exposed to chemicals. Addition, process cutting crown and remove the excess pineapple skin from fresh pineapple in manually will be effect to the hand workers when their hand suddenly cramp, prickly thorn from the pineapple skin and got hurt, and any injuries that occur.

5. Discussion and Conclusion

5.1 Discussion

The finding of this study prove that pineapple waste can be a substitute for fossil fuel electricity generation, this study also shows that the LCA of pineapple produced less emission towards environment compared to conventional power generation (fossil fuel) [19].

Five types of environmental impact have been identified from life cycle assessment (LCA) of pineapple waste toward power generation, which are global warming potential include and excluded biogenic CO_2, particulate matter impact, ionising radiation impact, ozone depletion potential impact (steady state), ecotoxicity impact (fresh water) and Human toxicity impact (cancer effect). The highest environmental impact in this study is global warming potential include and excluded biogenic CO_2 in climate changes, because had 3 stages involved where are in plantation stages, milling stages and lorry transportation. But, the highest dangerous impact to environment is particulate matter impact and ionising radiation impact because the effect to environment and human can be seen faster than others [22].

In a nutshell, the crown, leaves, flesh, peel, stem and core of pineapple waste can be reused without having a harmful effect on the environment, even though it has been used in several ways. It is possible to minimise CO_2 emissions by using a good strategy at every point of LCA [23]. Overall, the environmental impact of pollution was lower than traditional power generation (fossil fuel) in Malaysia. This research also shows that sustainable energy can be accomplished using renewable energy and energy efficiency.

5.2 Recommendation

Finding from Sahid and Sin [24] clearly provides a signal to the policy makers to take further action to address energy security concerns with regard to the success of renewable energy implementation in Malaysia. Malaysia is rich with variety of agriculture products, hence, agriculture waste in Malaysia also increasing every year including pineapple waste. Therefore, studies on how to manage this agricultural waste should be enhanced to reduce its impact on the environment.

In the Philippines, the use of pineapple waste in electricity generation has been widely implemented. Therefore, Malaysia should emulate the Philippines to realize the goal of Malaysian sustainable energy. The use and production of advance environmentally friendly technologies to generate electricity from biomass power in Malaysia is needed to replace the declining fossil fuels. Environmental protection is very important in developing a country, studies on reducing environmental pollution and sources of pollution need to be further established. Hopefully, this research will enable stakeholders to create or improve a new biomass energy policy for penetration strategy.

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