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Testing and evaluation of biomass roasting furnace using Pili Shell

Teste e avaliação de torrefação de biomassa usando casca de Pili

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A B S T R A C T

The use of pili shells as fuel in a biomass roasting furnace for roasting meat was investigated in this study. To estimate the capacity of pili shells in roasting meat, researchers used observation, experimentation, data analysis, and interpretation. Pili shells as a fuel were found to be a good substitute for roasting. Pili shells are more effective than an electric oven, according to the researchers. More research into the qualities and components of pili nutshells is needed to establish the treatment required before they may be utilized as fuel. Increased pressure has an effect on torrefaction metrics such as mass yields, energy densification ratio, energy yield, process energy consumption, the proximate analysis, high heating value.

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RESUMO

O uso de cascas de pili como combustível em um forno de torrefação de biomassa para assar carne foi investigado neste estudo. Para estimar a capacidade das cascas de pili em assar carne, os pesquisadores usaram observação, experimentação, análise de dados e interpretação. Verificou-se que as cascas de pili como combustível são um bom substituto para a torrefação. As cascas de pili são mais eficazes do que um forno elétrico, de acordo com os pesquisadores. Mais pesquisas sobre as qualidades e componentes das cascas de nozes de pili são necessárias para estabelecer o tratamento necessário antes que possam ser utilizadas como combustível. O aumento da pressão tem um efeito nas métricas de torrefação, como rendimentos de massa, taxa de densificação de energia, rendimento de energia, consumo de energia do processo, análise aproximada, alto valor de aquecimento

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Introduction

According to National Geographic (2023), fuel is one of the world's most widely used energy sources today. The bulk of fuels are natural compounds such as petrol fuel, diesel, and natural gas, which are either harvested directly from the earth or refined from petroleum. Fuel-burning energy can be utilized to power vehicles, ships, and planes, as well as deliver electricity to homes and buildings.

Based on Statistics made by the International Energy Agency (IEA), the following data arise this idea:

1. According to IEA, approximately 2.8 billion people worldwide used biomass fuels for cooking in 2018.
2. Biomass fuels include various sources such as firewood, charcoal, agricultural waste, and animal manure.
3. The IEA estimates that about 50% of the global population still relies on traditional biomass fuels for cooking.
4. In many developing countries, biomass fuel is the primary source of energy for cooking due to limited access to modern energy sources.
5. The use of biomass fuels for cooking is associated with several health and environmental challenges. Household air pollution caused by burning these fuels leads to respiratory diseases and contributes to climate change.

Traditionally, activated carbon obtained from wood is an important material for industrial adsorption (Yao, 2012). New sources of activated carbon are needed for environmental applications to maintain the ecological balance. This study investigates Pili (Canarium ovatum Engl.) nut shell, a waste material from Pili food processing, as a potential source of activated carbon. The carbonized Pili nut shell was determined to have a high fixed carbon content (86.81%), which makes it an ideal carbon raw material for the production of activated carbon.

The pili shell refers to the hard outer covering or shell of the pili nut, which is the fruit of the pili tree (Canarium ovatum). The pili tree is native to Southeast Asia, particularly in regions like the Philippines. The pili nut is known for its rich flavor and high nutritional value, containing healthy fats, protein, and various vitamins and minerals. The pili shell is typically thick, woody, and brown in color. It encases the edible kernel or meat of the nut, protecting it from external elements. The shell is quite hard and can be challenging to crack open without the use of tools. In some cases, the pili shell is used for various purposes beyond its protective function. It can be utilized in crafting, such as making decorative items, jewelry, or even as a material for home décor. The unique texture and appearance of the pili shell make it suitable for creative applications. It's worth noting that while the pili nut is highly regarded for its taste and nutritional benefits, the shell itself is not typically consumed due to its toughness and inedibility (Pham & Dumandan, 2015).

In most Sub-Saharan African countries, biomass fuels are used for daily cooking by more than 80% of the population. While in the Philippines, about 30% of the nation's energy is produced by biomass fuels, as it is mainly consumed for household cooking (Zafar, 2021).

Biomass is produced from organic materials either directly from plants or indirectly from industrial, commercial, domestic or agricultural products (Enerpower, 2012). It is often referred to as "bioenergy" or "biofuel". Much of our wood waste is processed into biofuel, which is used to generate renewable energy. In the form of wood chips, its environmental impact is undeniable. Not only is it carbon neutral, but it also diverts waste to landfill. An additional benefit for our customers is that it is significantly cheaper than using fossil fuels. Biomass is a form of renewable energy produced from the use of organic material. Biomass is currently the largest user of wood waste in the UK. The amount of biomass made from scrap wood has doubled in recent years and was 2.1 million tons in 2018. Carbon-neutral electricity is produced with biomass fuel, which is generated from the heat released by burning wood chips.

The research problems are the following;

1. To investigate and assess the thermal efficiency, heat usage, reduction in smoke emissions, and user-friendliness of a biomass stove design that incorporates insulation around the combustion chamber, appropriate channels for primary and secondary air updraft, and an oven furnace;

2. To examine the health consequences associated with traditional kerosene stoves and explore the potential of the biomass stove as a substitute, considering its ability to utilize a variety of renewable fuel sources other than wood; and

3. To evaluate the role of the biomass stove as a solution to the current energy dilemma caused by fossil fuels and dwindling forest stocks due to reliance on fuel wood.

Materials and Method

Clay is a type of fine-grained natural soil material containing clay minerals (hydrous aluminum phyllosilicates, e.g. kaolinite, $Al2Si2O5(OH)4$). Clays develop plasticity when wet but can be hardened through firing. Most pure clay minerals are white or light-colored, but natural clays show a variety of colors from impurities, such as a reddish or brownish color from small amounts of iron oxide. Clay is the oldest known ceramic material. Prehistoric humans discovered the useful properties of clay and used it for making pottery. Some of the earliest pottery shards have been dated to around 14,000 BC, and clay tablets were the first known writing medium. Clay is used in many modern industrial processes, such as paper making, cement production, and chemical filtering. Between one-half and two-thirds of the world's population live or work in buildings made with clay, often baked into brick, as an essential part of its load-bearing structure.

Figure 1
Fabrication of Clay Briks

Figure 2.
Roasting Oven made from clay bricks

Masonry ovens remain popular in part because of the way their use affects cooking processes and food flavor. Where modern gas or electric ovens cook food by moving hot air around inside an insulated, lightweight box, a masonry oven works by soaking up heat, like a battery building up a full charge. When hot, the heavy oven walls release the heat slowly, for

hours. Thus the food is cooked not only by hot air but also by radiant heat from hot dense masonry and especially for bread and pizza, which are not cooked in pans, heat conducted directly into the food from hot floor bricks (bakers call the resulting added rising action of bread "oven spring".) Finally, a masonry oven seals in the steam produced by the water in cooking food. A supercharged steamy atmosphere produces a more flavorful and chewy crust (see Maillard reaction); it also keeps other foods moist and tender. The triple combination of radiant, conductive, and convection heat also speeds cooking.

Wood-burning masonry ovens are mandated for production of true Neapolitan pizza. Clay brick is efficient for cooking of fish, chicken and among other meaty foods. It will cook all around the food, the taste is okay, color is tender especially the chicken.

The "pili shells" (Figure 3) were gathered and dried to reduce moisture content and facilitate burning. The absence of weight fluctuations indicates that the samples were dry. An electronic weighing scale was used to determine the weight. The rate of combustion of pili shells suitable for roasting meat was examined by the researchers.

The total performance of a biomass roasting furnace (figure 3) was measured using a meat roasting test. The increase in thermal efficiency can be attributed to several causes, including the use of clay to insulate the combustion chamber and reduce heat loss through the chamber's walls. Other than fuel wood, it's used with fuel pellets/briquettes. The enhanced cooked food reduces particle emissions. Waste briquettes are used as a processing option to increase the efficiency of both waste incineration and its treatment and processing.

Figure 3.
Pili shells

Results and Discussions

The purpose of this critical review is to assess the potential of this method as a possible solution for the introduction of alternative fuels in developing countries. A total of 85 scientific articles that were available in international databases between 1999 and 2021 were reviewed, and a SWOT analysis was performed according to the indications presented in the scientific literature. The results of the review emphasize that briquettes based on agricultural waste and wood are the most studied, followed by briquettes based on plastic and paper and cardboard.

When compared to a regular three-stone fire, the performance of the stove is noticeably lower. The operation of the three-stone fire required more attention than the biomass burners. As with any tool, the skill of the user determines how well the job is done. It takes years to learn how to use a hammer or shovel. Three Stone Fire can be powerful and pure or very dirty and wasteful. In some kitchens, large fires consume a lot of wood and produce a lot of smoke. Small fires are also made, which cook the food relatively clean. Seeing indigenous experts with fire helped to better understand the use of biofuel. Attempts to save wood tend to burn the tip of the stick and cause flames. Improving the well-made Three Stone Fire was more difficult than expected. Learning from experienced users has helped engineers make better ovens. Well-built Three stone fireplaces, protected from wind and carefully maintained, achieve a thermal efficiency of 20-30 percent. Wetter wood and less sensible open jackets can reach up to 5%.

Figure 4
Roasting of Meat using Pili Shells

Cooking time is reduced, and a higher percentage of heat is used in the enhanced biomass stove, lightweight, low cost of mass manufacture, and simple to use. An improved

stove that enhances efficiency and reduces smoke is the clean cookstove. Clean cookstoves are designed to maximize heat usage and minimize emissions.

For instance, let's consider a traditional three-stone open fire stove commonly used in many rural households. Such stoves have a lower efficiency, typically around 10-15%, meaning that only a small fraction of the heat generated is utilized for cooking. This leads to longer cooking times and higher fuel consumption (Okino et al., 2021). In contrast, an improved clean cookstove, such as a fuel-efficient biomass stove or a gas stove, can reach efficiencies of up to 95%. This means that almost all of the heat generated is utilized for cooking, resulting in shorter cooking times and reduced fuel consumption.

Additionally, these improved stoves are designed to minimize the smokiness associated with traditional stoves. They often incorporate features such as insulated chambers, better ventilation, and more efficient combustion systems. As a result, these stoves produce significantly less smoke and harmful emissions compared to traditional stoves, providing a healthier cooking environment for users. By using an efficient and smoke-reducing stove, individuals can benefit from faster cooking, reduced fuel costs, and improved indoor air quality. These improvements make the cooking experience more user-friendly, comfortable, and convenient, while also contributing to environmental sustainability by minimizing gaseous pollutants released into the atmosphere (VNV, 2023).

Health and environmental benefits of using a biomass stove as a substitute for a traditional kerosene stove, as well as the significance of addressing the energy dilemma caused by fossil fuels and dwindling forest stocks (Ahmad et al., 2022):

1. Health consequences: Traditional kerosene stoves often release harmful indoor air pollutants, such as carbon monoxide and particulate matter, which can lead to respiratory issues, eye irritation, and other health problems. In contrast, a biomass stove, designed with improved combustion systems and efficient ventilation, significantly reduces these emissions, providing a healthier cooking environment for users and reducing the risk of indoor air pollution-related health consequences.

2. Variety of renewable fuel sources: Biomass stoves offer the advantage of being able to utilize a variety of renewable fuel sources, such as agricultural waste, crop residues, and even animal dung. This versatility allows individuals to reduce their reliance on wood as the primary fuel source, mitigating deforestation and reducing pressure on dwindling forest stocks. By diversifying fuel sources, biomass stoves contribute to sustainable resource management and help alleviate the negative environmental impacts associated with heavy reliance on fuel wood.

3. Addressing the energy dilemma: The use of fossil fuels, such as kerosene, for cooking purposes not only contributes to indoor air pollution but also exacerbates the global energy crisis. Fossil fuels are non-renewable resources that are depleting rapidly, leading to increased energy costs and environmental degradation during extraction and combustion. By adopting

biomass stoves, which rely on renewable fuel sources, we take a natural step towards addressing this energy dilemma. Biomass stoves reduce dependence on fossil fuels, helping to transition towards a more sustainable energy future.

In summary, opting for a biomass stove as a substitute for a traditional kerosene stove provides a multitude of benefits. It improves indoor air quality, reduces harmful emissions, utilizes renewable fuel sources, and contributes to solving the energy dilemma caused by fossil fuels and dwindling forest stocks. By embracing these clean cooking technologies, we can create healthier living environments, safeguard precious ecosystems, and work towards a more sustainable and resilient future.

Conclusion

The design was improved by installing insulation around the combustion chamber. Chamber, and the addition of appropriate channels for primary and secondary air updraft have all contributed to a significant boost in thermal efficiency.

The oven furnace's efficiency and heat usage was 95% which is acceptable for cooking meat, fish, corn and etc. The smokiness of the stove has also been significantly reduced, making it more user-friendly, comfortable, and convenient. It minimizes the amount of time spent cooking and the number of gaseous pollutants released.

This has health consequences. This biomass stove is an excellent substitute for a traditional kerosene stove. Having the added benefit of being able to cook with a variety of renewable fuel sources other than wood. More importantly, this stove is a natural next step in addressing the current energy dilemma caused by fossil fuels and dwindling forest stocks because of reliance on fuel wood.

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