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The Use of Saba Banana (*Musa acuminata* × *M. balbisiana*) Peel as a Charcoal Substitute

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Abstract. The use of charcoal has become a traditional part of the life of the Filipino people. However, there is always a widespread belief that the manufacturing of charcoal is completely unsustainable, damaging the environment and the lives of the people. By turning waste materials—primarily banana peelings—into charcoal, this study hopes to address these environmental problems by determining if they can replace traditional charcoal. The goal of the study is to compare commercial charcoal and banana peel charcoal in order to determine which is more advantageous, secure, and sustainable for both humans and the environment. Aside from that, this study also aimed to compare other variables like (1) longevity of burning, (2) longevity of cooking food, and (3) ash production. The banana peel briquettes were manufactured using various amounts and percentages of banana peels, wet paper, and sawdust, which served as an independent variable that influenced the quality of the briquette. The researchers followed the processes of sun drying, crushing, mixing, and molding. The material was formed into balls and allowed to dry for seven days prior to testing. After rigorous testing, the researchers came to the conclusion that banana charcoal would be a good substitute for commercial charcoal.

Keywords: Banana coal, banana peel, comparative analysis, charcoal, STEM SHS Philippines.

INTRODUCTION

The Philippines has historically relied heavily on charcoal to meet its residential and commercial energy needs. Lump charcoal is expected to produce the most demand in the Philippines' charcoal market in 2019. However, due to this, the cutting of trees has been a substantial contributor to climate change. Because of the production and manufacturing of charcoal, a large number of trees have been cut down, resulting in deforestation and environmental degradation.

Not only is deforestation and environmental degradation a problem, but so are diseases caused by the smoke used to make charcoal. The green gas houses are another problem aside from the health and ecological problems, since the smoke emissions from the production of charcoal are affecting our ozone layer. This is also one of the many negative effects of the commercial charcoal that we always use.

Several studies are being conducted to find sustainable alternatives for commercial charcoal, such as fruit peelings, coconut husks and shells, and even rice husks, which could be used as substitute materials in the production of biochar briquettes. In this case, the problem can be addressed by making use of other biomass materials such as banana peel, coconut husks and shells, and even rice husk as an alternative to the raw materials that are required in order to make charcoal because these raw substitute materials have a high production rate and are being disregarded as solid waste, so by converting them into biochar through the process of briquetting, it can be a good alternative to the traditional charcoal that is being used around the world.

Being an agricultural country, charcoal has been the primary source of energy for chargrilling and other types of cooking. The primary reason for the rise of the Philippines charcoal industry is because, throughout history, the product has been cheaper than kerosene and liquefied petroleum gas making an efficient supply for fuel. It has been cheap since there is abundant availability of low-cost feedstock, such as coconut shells and wood. The use of charcoal has become a traditional part of the life of the Filipino people.

However, there is always a widespread belief that the manufacturing of charcoal is completely unsustainable, damaging the environment and the lives of the people. Although there are new alternatives, such as fruit peels from bananas, there is still much work to be done in striving for a more sustainable environment while taking into account the limitations of global challenges. It is believed that the banana peelings that are discarded by several households are significant raw materials used in developing an alternative to banana coal.

Furthermore, the analysis will be conducted to gain insights into the efficiency of both banana coal and regular charcoal. This study is being conducted to put up a comparative analysis of banana coal and commercial coal to identify which is more beneficial, safe, and sustainable to the environment and humans.

Banana is considered one of the most important agricultural products of the Philippines, but after industrial operations, a huge volume of banana peel has been discarded. The raw material is abundant and has no commercial worth. Most developing countries look to be on the rise.

Agricultural wastes have become a source of biomass, one of their most potential sources of energy. The idea of using agricultural wastes as primary or secondary energy sources is appealing since they are available for free, indigenous, and environmentally friendly. Furthermore, due to the limited availability of firewood, efforts must be made to make efficient use of agricultural waste.

RESEARCH ELABORATIONS

Charcoal is a blackish substance made up of primary carbon that is used for cooking and several energy-intensive industrial activities. It has several applications for all types of well-known charcoals, including activated charcoal, lump charcoal, briquettes, and extruded charcoal. Lump charcoal is manufactured by burning hardwoods directly to produce ash.

In terms of medicine, gunpowder ingredients, herbal medicines, absorbent agents, water filters, and so on, wood charcoal has made a significant contribution. After learning about the significant contribution of charcoal in various fields, issues developed because the primary materials required for producing good charcoal pose a threat to the environment by hastening deforestation.

Biomass densification is defined as a process that reduces the mass volume of the material [8]. The agglomeration of build-ups is complete to make them denser for use in energy generation. This technique is known as briquetting, and it improves the quality of materials for transportation, storage, and other purposes. Waste from the wood industry, free biomass, and other combustible garbage are all mixed together in briquetting.

Additionally, charcoal production and consumption are major contributors to the loss of forest cover due to the targeting of specific tree species for charcoal production. The majority of the charcoal produced in SSA, including Kenya, is made from local tree species [10]. However, the ever-increasing rate of forest cover loss is attributed to a number of factors, including lackluster forest management, disregard or ignorance of the intrinsic value of forests, and a lack of environmental laws.

The production of traditional charcoal provides a lifeline for the expanding populations in SSA countries and less developed countries in general. One of the largest producers of charcoal in Africa, Ethiopia, supplies upward of 3 million tons of charcoal annually to its urban consumers. Due to the lack of established practices or technology, Ethiopian charcoal manufacturing has few successful case studies to share.

Despite the fact that charcoal production has a significant financial impact on families' annual total pay, it has a significant impact on the climate, such as air pollution, despite refined respiratory medical conditions. As a result, conscientious organizations and organizers should have focused on the complex impact of traditional charcoal production on ecological issues and modern medical conditions, particularly on employed workers and nearby occupants [9].

Deforestation produces greenhouse gases in addition to removing vegetation that is essential for absorbing carbon dioxide from the atmosphere [5]. According to the Food and Agriculture Organization of the United Nations, deforestation is the second-most important cause of climate change. Deforestation is responsible for almost 20% of all greenhouse gas emissions.

According to information provided by the Forest Management Bureau of the Department of Environment and Natural Resources (DENR), a report carried on PhilStar on March 4, 2018, the Philippines is losing about 47,000 hectares of forest cover each year. The country's woods totaled 7.2 million hectares in 2003, but by 2010, they had shrunk by 6.8 million hectares, or 4.6%, making up less than 24% of what they had been in the early 1900s.

Additionally, a case study by Remedio, titled "An Analysis of Sustainable Fuel wood and Charcoal Production Systems in the Philippines," indicates that there is a significant need for the production of fuel wood and charcoal. Like coconut, rice, and maize residues, biomass materials can also be used as a substitute for wood.

The biomass business in the Philippines is quickly developing, despite the fact that it is still lagging behind fossil fuel-based electricity generation [2]. The Philippines has an abundance of biomass resources, including agricultural crop leftovers, forest residues, animal waste, agro-industrial waste, municipal solid waste, and aquatic biomass. The most common agricultural wastes are coconut coir, bagasse, coconut shell husks, and rice hulls.

In the Philippines, the usage of commercially generated agricultural leftovers transformed into biofuels is growing. In a study that Israel, [6] conducted on the extraction and characterization of pectin from Saba banana peel wastes, they indicated that bananas are one of the most important tropical fruits on the international market. They said that banana fruit peels make up a significant portion of the waste generated during Saba banana manufacturing. These peels are just discarded as solid waste at a high cost and are not utilized for anything else. As a result, the industry's operation of disposing of food processing wastes now poses a significant ecological challenge as well as additional pollution to the environment.

As an agricultural country, has an abundance of agricultural goods. Sugarcane, rice, coconut, banana, and corn are the most grown crops, with the Philippines producing 2.5 × 107, 1.8 × 107, 1.5 × 107, 8.6 × 106, and 7.4 × 106 metric tons of each in 2013 [1]. Agricultural waste has long been recognized as a viable source of biomass. Biomass briquetting, which involves the densification of biomass materials using pressure, is one method for using these wastes and turning them into an alternative source of energy.

Maia [4] decided to convert waste such as banana crop and rice into biomass by converting these raw materials into briquettes and subjecting them to various types of analyses in a study. The same analyses employed in trash were applied to describe the resultant briquettes, together with their mechanical compressive strength. The waste had a moisture content that was good for briquetting and burning, ranging from 8% to 15%. At temperatures lower than those of the garbage, the briquettes released the most energy during burning.

Previous studies have shown that briquettes made from carbonized biomass are a low-cost solid fuel. The study of Carnaje [4] investigated the possibility of using molasses as a binder to turn water hyacinth (*Eichhornia crassipes*) charcoal into briquettes. In a manufactured fine biomass carbonizer, dry water hyacinth was carbonized at temperatures ranging from 350°C to 500°C. The manufacturing of briquettes with varied charcoal/molasses ratios of 40:60, 30:70, and 20:80 was done with a solution containing 80% by weight molasses.

Scanning electron microscopy was used to evaluate each briquette's bulk density, calorific value, compressive strength, proximate analysis, and microstructure. The flammability of charcoal briquettes was determined by measuring their burn rates and ignition times. The quality and features of the briquettes were altered by changing the molasses-to-charcoal ratio.

Meanwhile, it was revealed that the combustion parameters of briquettes made from dried mango leaves differ significantly from those of coconut shell and wood charcoal; nevertheless, the moisture content does not differ. The briquettes produced may not be of the same high quality as fossil fuels, but they are a viable alternative to the more expensive fuels. As a result, dried mango leaves can be used as a low-cost solid fuel source in the home.

In addition, according to the study of Romallosa [11], which focuses on a compact briquetting machine invented in the Philippines that uses a hydraulic jack to compress and manufacture cylindrical briquettes with a hole in the center and then returns to the start position semi-automatically using a pulling device, the equipment can compress 16 cylindrical briquettes in a single pressing, or 200–240 pieces per hour. The three types of briquettes made from wastepaper, sawdust, and carbonized rice husk have slightly different qualities. Bulk density, heating value, moisture, N, and S all met or exceeded DIN 51731 criteria.

Furthermore, it was found that simulating the creation of biomass briquettes from municipal garbage might lead to a feasible on-site fuel production line after establishing its usefulness, quality, and application to potential consumers [11]. Because of its simple yet durable design, the briquetting technique is simple to operate and yields promising results in terms of production rate, bulk density, and heating value of the briquettes produced. Wastepaper, sawdust, and carbonized rice husk were combined to make high-quality briquettes, making these waste streams a renewable supply of cost-effective fuels.

According to the report, an informal sector that ventures into briquette manufacture might be advantageous for small business entrepreneurs. With similar conditionality to that of the Uswag Calajunan Livelihood Association, Inc. (UCLA), the informal sector from other parts of the world could play a significant role in recovering these reusable waste materials from the waste stream and adding value to them as alternative fuels and raw materials (AFR) for household energy supply using appropriate technologies.

The fuel qualities of charcoal briquettes made from mixtures of coconut shell, corn cob, and sugarcane bagasse at specific ratios are assessed in this study by Arellano [1]. With compaction pressures of 2.2 MPa, 4.4 MPa, and 6.6 MPa, single (100), double (50%–50%), and triple (33%–33.3%–33%, 50%–25%–25%) constituent briquettes were created. With a calorific value of 19951.4 J/g, a mixture of 50% coconut shell, 25% corn cob, and 25% sugar cane bagasse was able to produce the greatest calorific value that was equivalent to coconut shell charcoal and had the maximum density and compaction ratio.

The researcher aimed to answer the following specific questions:

1. What is the effectiveness of 50% banana peel, 25% wet cardboard, and 25% sawdust in maintaining the disintegration of briquettes, duration to cook food, and ash production?

2. What is the effectiveness of 25% banana peel, 50% wet cardboard, and 25% sawdust in maintaining the disintegration of briquettes, duration to cook food, and ash production?
3. What is the effectiveness of 25% banana peel, 25% wet cardboard, and 50% sawdust in maintaining the disintegration of briquettes, duration to cook food, and ash production?
4. What is the comparison between regular coal and banana peel charcoal?

The study design should be developed since it is critical to delivering solutions to the issue statements. Because this study deals with how the number of banana peels, sawdust, and wet paper affect the various qualities of charcoal, the researchers employed an experimental research design to collect data in the most effective way possible. The amount of banana peel, sawdust, and wet paper will be the independent variables, influencing the dependent variables of heat duration, cooking time, and ash generation.

Data Gathering Procedure

Following the creation of the banana peel briquettes (bananacoal-ling) with their respective amounts and percentages of banana peels, wet paper, and sawdust, the researchers will conduct three tests in each banana peel briquette created with a different percentage of raw materials, with each test measuring the disintegration of the briquettes, cooking time, and ash production.

A briquette with a varied proportion of raw materials will be tested by disintegrating of briquettes and will be compared to conventional charcoal by igniting them both at the same time and using a timer to time how long the briquettes will burn until they are all turned into ashes.

The next test will be to determine the cooking time of each briquette that includes a different number of components, and the researchers will utilize hotdog as a meal to determine the cooking time of each briquette. The duration will be measured in minutes for how long each briquette will take to reach the cooking point of a hotdog in comparison to the ordinary charcoal that will be used.

In terms of ash production tests, each briquette that contains a different percentage of materials used in previous tests that turned into ashes will be weighed on a weighing scale by the researchers, who will weigh them in grams based on how much ash each briquette produces in order to compare the ash production of the briquettes to regular charcoal.

As shown in Table 1, the needed materials are banana peels, which contain a good amount of phosphorus and are highly flammable. Wet paper is also needed to serve as an adhesive to the briquettes, along with saw dust, water, and a mortar and pestle. To collect the necessary data, the researchers will conduct three (3) part experimentation tests for each briquette with a different degree.

Table 1. List of materials.

	Materials	Measurements or Quantities	Descriptions
1	Banana Peels	50% or 400 g 25% or 200 g	A banana skin that contains a good amount of phosphorous that is highly flammable.
2	Wet Paper	50% or 400 g 25% or 200 g	Unused paper made out of tree good adhesive when it is wet.
3	Sawdust	50% or 400 g 25% or 200 g	Pine wood sawdust is good for filling up the gaps and making the briquette hold together.
4	Water	1 liter of water for wet paper	H_2O is a chemical compound that can be seen anywhere used for making the paper an adhesive device.
5	Mortar and Pestle	2 improvise pestle and mortar	Improvise pestle wood and bamboo sticks, plastic improvise mortar used to pound and combined the materials together

Part I is the disintegration test of each briquette. In this test, it will be determined how long each briquette will last before it turns into complete ashes; this will be measured in minutes. Part II is the test to measure the cooking performance of each briquette. They will be timed, and the researchers will gather the temperature of each hotdog every minute to determine the performance of each charcoal. Part III is the test to measure the production of ashes per charcoal. In this test, each briquette will be lit in an enclosure to collect all of the ashes from each charcoal, and the ashes from each briquette will be weighed. This will determine how much ash each type of charcoal with a different magnitude can produce.

The researchers will use descriptive statistics in this experimental study. Because the study involves multiple biochar briquettes and commercial charcoal being compared, the briquettes are made with varying amounts of fillers, and there are three dependent variables to be observed, descriptive statistics will be used to determine the difference between such independent groups and commercial charcoal by describing and summarizing the data that will be gathered. The researchers will, for example, investigate how different amounts of banana peels, wet paper, and sawdust affected heat duration, cooking time, and ash output.

RESULT AND DISCUSSION

In terms of how long they burn, commercial charcoal and banana briquettes are compared on the graph. The period

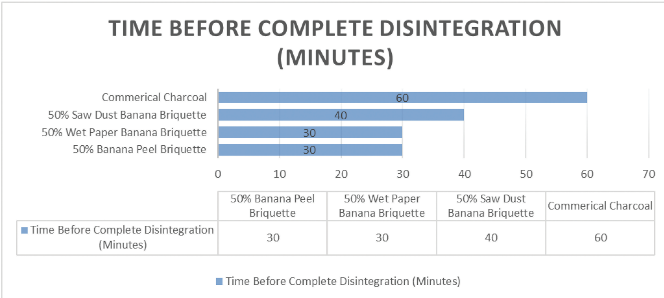

Figure 1. Disintegration test.

of time was measured from the beginning of the fire to the point at which no charcoal was still burning. According to the graph, the researchers discovered that commercial charcoal burns for 60 minutes longer than banana charcoals, while banana briquettes, which are primarily made of banana peels and wet paper, only last for 30 minutes longer.

While the briquettes with the predominant sawdust burned for a total of 40 minutes. There is a 20–30 minute time difference overall. As a result of these findings, the researchers discovered that the dominant materials were banana peels, wet paper, and sawdust, where the sawdust lasted longer compared to banana peels and wet paper in terms of disintegration time. In addition, the researchers came to the conclusion that the commercial charcoal burns longer than the rest of the banana briquettes based on the results of the data that they gathered.

In terms of how long they burn, commercial charcoal and banana briquettes are compared in Figure 1. The period of time was measured from the beginning of the fire to the point at which no charcoal was still burning. According to the graph, the researchers discovered that commercial charcoal burns for a total of 60 minutes, outlasting banana charcoal, whose primary ingredients are wet paper and banana peels, which only lasted for 30 minutes. However, the briquettes with the predominant sawdust burned for a total of 40 minutes. The total time difference is 20–30 minutes.

Therefore, through these findings, the researchers found out that there is a difference between the dominant materials, banana peels, wet paper, and sawdust, where the sawdust lasted longer compared to banana peels and wet paper in terms of disintegration time. In addition, the researchers came to the conclusion that the commercial charcoal burns longer than the rest of the banana briquettes based on the results of the data that they gathered.

As seen in Table 2, it shows the time that the testing of the briquettes lasts; each briquette has been tested for exactly thirty (30) minutes and is being checked every six (6) minutes. Based on the table in that time frame, the physical appearance of the hotdog that is being used for the test is observed to see if the briquette with different capabilities can cook food. Aside from the physical appearance, the temperature is also being checked every six (6) minutes for the researchers to see if the inside temperature is reaching the cooking point of the hotdog that is being cooked.

In every six (6) minutes, the temperature inside rose around 41°, and the test lasted for thirty (30) minutes. During the whole duration of the test, the internal temperature of the hotdog was right around 205°, and the standard cooking point of hotdogs is around 140°; therefore, the briquettes passed the test and ended up cooking all of the hotdogs in each briquette that contained different amounts of raw materials.

Figure 2 compares the ash production of commercial charcoal with briquettes made from 50% banana peel, 25% wet paper, and 25% sawdust. The researchers discovered that there is a 16 g difference in the amount of ash mass between commercial charcoal and the 50% banana peel briquette. The researchers also discovered that commercial charcoal and 50% banana peel briquettes generated the same shade of ash.

The graph compares the ash production of commercial charcoal to briquettes made from 50% paper, 25% banana peel, and 25% sawdust. In terms of ash mass, the researchers discovered that commercial charcoal had an 18-g advantage over 50% wet paper banana briquettes in

Table 2. Cooking test using the briquettes.

Briquettes	Temperature Status of the Food While Being Tested Est. 41° per 6 minutes	Remarks Food Status at the end of the Test
Banana Peel Briquette	High temperature throughout the whole 30 minutes, estimated temp. 205°	Cooked
Wet Paper Banana Briquette	High temperature throughout the whole 30 minutes, estimated temp. 205°	Cooked
Saw Dust Banana Briquette	High temperature throughout the whole 30 minutes, estimated temp. 205°	Cooked
Commercial Charcoal	High temperature throughout the whole 30 minutes, estimated temp. 205°	Cooked

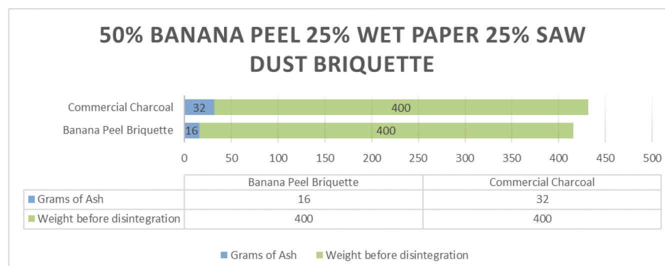

Figure 2. Ash production test for 50% banana peel, 25% wet paper, and 25% sawdust.

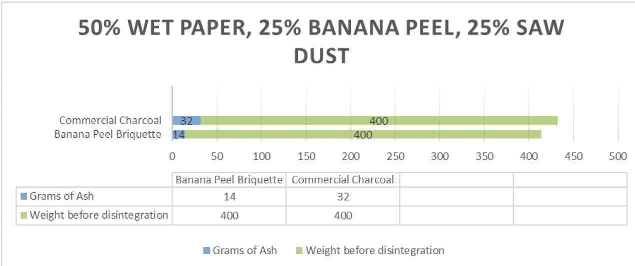

Figure 3. Ash production test for 25% banana peel, 50% wet paper, and 25% sawdust.

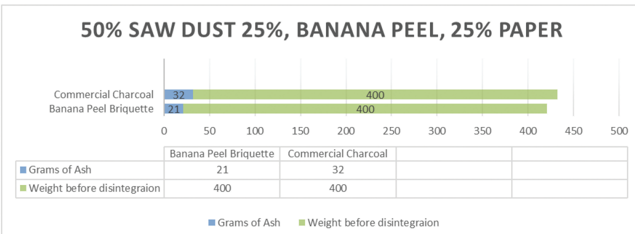

Figure 4. Ash production test for 25% banana peel, 25% wet paper, and 50% sawdust.

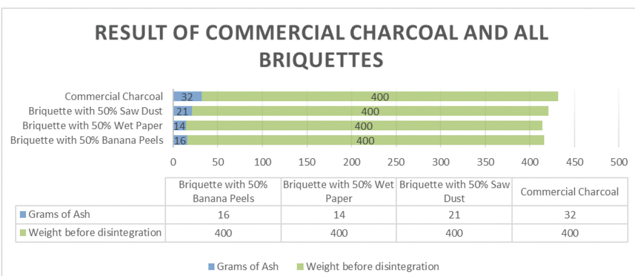

Figure 5. Ash production test for commercial charcoal and all types of briquettes.

terms of ash mass. The researchers also discovered that commercial charcoal and 50% wet paper banana briquettes both generated the same shade of ash.

The graph compares the output of ash from commercial charcoal with briquettes made from 50% sawdust, 25% banana peel, and 25% wet paper. The researchers discovered that there was an 11-g difference in the amount of ash produced by commercial charcoal and banana briquettes made with 50% sawdust. The researchers also discovered that commercial charcoal and 50% sawdust banana briquettes produced the same ash color.

In this graph, the results show that the 50% wet paper banana briquette is the most effective in terms of ash production because it produces the lowest amount of ash compared to other briquettes and commercial charcoal.

Comparison Between Commercial Charcoal and Bananacoal-Ling

According to our findings, the bananacoal-ling outperforms commercial charcoal in terms of cooking efficiency. The sample with 50% wet paper and 50% banana briquettes proves to be more effective than the regular commercial charcoal, and thus, commercial charcoal produces way more ashes than the bananacoal-ling samples.

Disintegration Test Result (Comparison Against Commercial Charcoal)

A disintegration test was performed to determine the lifetime of cooking food or how fast the charcoal breaks down into tiny particles to better analyze this alternative. The 50% wet paper banana briquette and 50% banana briquette cook the fastest, taking only 30 minutes. This was followed by a 50% sawdust banana briquette for 40 minutes and commercial charcoal for 60 minutes, respectively. This might just indicate that commercial charcoal takes a long time to degrade into tiny particles.

Cooking Test Result (Comparison Against Commercial Charcoal)

A cooking test was also performed to determine its capacity to prepare meals. The data show that there is a 41-degree rise every 6 minutes for the entire 30 minutes. The test also found that regardless of the briquette used, all hotdogs can be cooked.

Ash Production Test Result (Comparison Against Commercial Charcoal)

Lastly, an ash production test was performed to collect data on the ash mass. In the three ash production experiments conducted, commercial charcoal seemed to create a higher ash mass than banana briquettes commercial charcoal seemed to create a higher ash mass than banana briquettes. The 50% banana briquette, 50% paper banana briquette, and 50% sawdust banana briquette yielded 16 g, 14 g, and 21 g, respectively. With this in mind, the 50% paper banana briquette created the least quantity of ash. As a result, all tests conducted revealed differences between banana charcoal and commercial charcoal.

This study aimed to compare and analyze how effective bananacoal-ling is compared to the usual coals used and sold in the market. It aimed to determine how bananacoal-ling differs from those on the market, as well as the different percentages of materials used to make the coals.

CONCLUSION AND RECOMMENDATION

Conclusion

First, the level of effectiveness of the banana briquettes made with different percentages of the raw materials differs. Food cooks faster using banana charcoal with 50% banana, 25% paper, and 25% sawdust than using banana charcoal with 50% paper, 25% banana, and 25% sawdust. But overall, all the briquettes made are usable.

Then, in terms of ash production, all the charcoals that were made produced the same ash color as the commercial ones. The commercial ones have more ash mass compared to the ones made with different materials. But overall, the 50% sawdust charcoal produces the least amount of ash.

In general, all the coals made were usable and effective and could be made as alternatives for the commercial ones, but based on the outcomes of this study, the best one is the charcoal with 50% sawdust, as it almost reached the qualities of the commercial ones.

Recommendation

The researchers would like to offer the following guidance to future researchers who are interested in carrying out similar research when this study is complete:

The researchers should keep in mind that banana peelings alone aren't enough to make charcoal. The researchers should be aware that whole commercial charcoal is preferable as a comparison to briquettes because it burns properly. The researchers also suggest considering other options for testing the food in the experiment since the food testing encountered problems because of the lack of testing materials.

Furthermore, for better execution and comparison, it is recommended to use whole briquettes of commercial charcoal rather than broken down pieces of charcoal because pieces are difficult to burn as a whole and take longer to burn than banana peel briquettes.

Experiment more with various biomass materials, such as coconut shells and leaves, as alternatives to other raw materials that are used in the process of making the briquettes. In order to show that banana briquettes can be used as an alternative to commercial charcoal, it is strongly advised that the researchers visit a particular laboratory facility and carefully examine other factors that they neglected to test in this study.

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