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# UTILIZATION OF COFFEE INDUSTRY WASTE FOR BIOENERGY AND/OR BIOPRODUCTS PRODUCTION

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## ABSTRACT

Coffee holds a significant position within Brazil's agrarian economy due to its substantial demand for both domestic consumption and international trade. The country consistently achieves remarkable milestones in coffee production, thus establishing itself as a global leader in coffee cultivation. Consequently, this heightened production is accompanied by a notable increase in waste generation, which, until recently, remained underutilized in sustainable practices. This study endeavors to outline prominent avenues for repurposing coffee waste towards the production of bioproducts and bioenergy, aiming to cultivate a sustainable ecosystem for coffee cultivation and elucidate the potential economic ramifications of such endeavors on society. Noteworthy outcomes of this investigation encompass diverse bioproducts such as biofuels, biogas, applications within ceramic and flavoring industries, alongside wood panel manufacturing. Additionally, a pivotal aspect of this research lies in demonstrating the generation of bioenergy through coffee husk resources, which hold paramount importance in sustaining Brazil's populace.

**Keywords:** Coffee waste 1. Bioproduct 2. Sustainable energy 3.Economy.

## 1 INTRODUCTION

The imperative to address the challenge posed by substantial quantities of organic waste, which incur considerable burdens both environmentally and financially across all sectors of the processing industry, is evident. Consequently, there is a growing interest in seeking specific solutions to utilize raw materials more efficiently in the production process. The coffee processing process has been detailed, revealing that for every ton of coffee produced, 650 kg of waste is generated, representing approximately 65% of the total. Within the context of Brazilian agribusiness, coffee cultivation emerges as a fundamental activity, responsible for an annual production of approximately two million tons of grains. In this scenario, industry-generated waste, such as coffee husks, represents potential clean alternatives for energy generation. It is worth noting the necessity of appropriate treatment during coffee processing, as husks, as residual byproducts, may cause significant environmental impacts[1].

Regarding waste generation, it is estimated that in the production of 1 ton of green coffee, approximately 570 kg of waste is generated, which can lead to a significant environmental impact if not properly managed. This study aims to identify key strategies for the proper treatment of coffee waste, with a focus on husks, to promote the generation of various bioproducts, such as biofuels, biogas, and bioenergy. This approach may serve as an additional incentive for the expansion of coffee production. The bibliographic analysis conducted in this study underscores the extensive potential of this crop not only in reducing environmental impacts but also in socio-economic effects. It is anticipated that these benefits will extend to a broad segment of the population, especially those directly involved in the coffee production chain.

## 2 MATERIAL & METHODS

This study conducted a thorough bibliographic survey, and supported scientific articles, to explore effective methods for managing coffee husks. It aimed to generate fuels and/or bioproducts, thus adding value and reducing waste in coffee cultivation. The research involved extensive searches on platforms like Google Scholar, Scielo BDTD, web of Science, and Science Direct.

## 3 RESULTS & DISCUSSION

Data in Table (1) displayed the proximate chemical composition of the coffee husk powder[2]. The coffee husks had 10.12 g/100 g crude protein, 2.56 g/100g total fat, 18.22 g/100g crude fiber, 2.7 g/100 g ash, and 66.40 g/100g carbohydrates. In general, the chemical composition of coffee husks presents a wide range of values compared with other studies because of the differentiation in varieties, geographical location, cultivation conditions, resources in the production region, and development stage in which the coffee fruits were harvested[3].

**Table 1: Chemical composition of coffee husks (g/100 g dry weight)**

| Parameters | M ±SD |
|---|---|
| Crude Protein (g) | 10.12±0.82 |
| Fat (g) | 2.56±0.051 |
| Crude Fiber (g) | 18.22±1.22 |
| Ash (g) | 2.70±0.003 |

| | |
|---|---|
| Carbohydrates (g) | 66.40±3.45 |

The pressing global concern over energy production from non-renewable sources such as petroleum underscores the imperative for research into alternative, cleaner energy sources to mitigate pollutant emissions. Biomass emerges as a promising alternative, defined as any renewable organic matter capable of serving as an energy source. Its utilization for bioenergy purposes can take various forms, including direct combustion, thermochemical processes, or biological processes, with coffee husks being a notable candidate[4].

Exploring the potential of coffee husk for soil treatment, the utilization of coffee husk ash for clay soil stabilization was examined. The focus was on evaluating how the addition of coffee husk ash influences the physical properties of soil sourced from Vila Cot Bagie in the Aceh Province, Indonesia. This soil, sourced from a quarry used for construction projects in Banda Aceh, underwent analysis at the Soil Mechanics Laboratory of Universitas Syiah Kuala, employing rigorous scientific methodologies[5].

The experiment encompassed several stages, commencing with soil collection at a depth of approximately 0.5 meters, followed by root and stone removal. Subsequently, the soil underwent a drying process in a 105°C oven for 24 hours, followed by sieving. Soil classification using the USCS and AASHTO methods resulted in OH and A-7-5 categories, respectively. The subsequent phase involved mixing the soil with varying percentages (3%, 6%, 9%, and 12%) of coffee husk ash. Analysis of the treated soil's physical properties included specific gravity, Atterberg limit, and particle size distribution tests, following protocols established by the American Society for Testing and Material (ASTM) [5].

The results revealed noteworthy enhancements in the soil's physical properties following the incorporation of coffee husk ash. These improvements were evidenced by a decrease in both plastic limit and plasticity index as the proportion of coffee husk ash increased, accompanied by a slight reduction in the soil's specific gravity. This positive trend observed aligns with existing literature on materials derived from solid waste, which frequently emphasizes a reduction in plasticity index with the addition of such materials.

Investigating the potential use of treated coffee husk as a low-cost bio adsorbent for methylene blue (MB) adsorption, dry coffee husks were collected from a local processing unit in Bahir Dar, Ethiopia. Following collection, the husks underwent washing with distilled water to remove impurities and were subsequently dried and granulated. The resulting powder was impregnated with $H_3PO_4$ (50% v/v) and subjected to carbonization at 400-600°C to develop porosity before being stored for characterization and further experiments[6].

A solution of methylene blue (MB) was prepared by adding 0.5 g of the dye to 1 L of distilled water. Batch experiments were conducted using 250 mL of activated coffee husk in bottles containing 100 mL of MB solution. Investigated parameters included initial MB concentration, solution pH, adsorbent dosage, and contact time. Following filtration and MB concentration analysis, the adsorbed amount was calculated. Experimental data were analyzed using the Langmuir isotherm and pseudo-first and pseudo-second-order kinetic models. Physicochemical characterization involves determining moisture content, ash content, volatile matter, and fixed carbon content. Specific surface area and pore size were analyzed by BET, while FT-IR spectra provided information on functional groups.

The results indicated significant potential for activated coffee husk as a low-cost adsorbent for MB removal, with better adsorption capacities observed at pH 5 with 50 minutes of contact time. Analysis of adsorption equilibrium data showed agreement with the Langmuir model, while the pseudo-second-order kinetic model better fitted the experimental data. Thermodynamic parameters indicated that MB adsorption by activated coffee husk was a spontaneous and endothermic process. Overall, the study suggests that activated coffee husk biosorbent could serve as an effective and economical alternative for treating textile wastewater containing methylene blue[6].

The production of fuel briquettes from coffee husks involved the utilization of various materials such as metal sheets, square and round tubes, screws, flat metal plates, round bars, angular iron, and clayey soil. These materials were selected based on their cost-effectiveness and availability in the region. Research into the production process of charcoal briquettes from coffee husks was conducted at the Dagim and Dechaok coffee processing industries in Mettu. These industries were chosen due to the ample availability of coffee husks in the area. Data collection took place in the Oromia State Region, Illu Aba Bora Zone, at an altitude of 1,605 meters above sea level[1].

Coffee husks, with a moisture content of 10.03%, were gathered in Mettu and dried in the sun to facilitate combustion. Carbonization occurred in a portable cylinder measuring 100 cm in height and 66 cm in width, constructed from 2.5 mm thick metal sheets. This process was repeated four times to ensure efficient conversion of the husks into charcoal. The carbonizer used was designed as a portable cylinder with a central chimney, maintaining the carbonization temperature at 500°C to optimize charcoal quality. Following carbonization, the husks were finely ground and combined with clayey soil at a 4:1 ratio. This mixture was then molded into briquettes using a manual molder, with the clayey soil serving as a binder to reinforce the briquettes.

The process included collecting large quantities of coffee husks, sun-drying them, and carbonizing them in a portable cylinder. A manual molding machine was used to shape the briquettes, which were then sun-dried for 1-4 days before being packed in plastic bags. The sun-drying phase was crucial for removing moisture, facilitating efficient burning of the briquettes[1].

Parameters including moisture content, volatile matter, ash content, fixed carbon content, bulk density, sulfur content, and calorific value were determined through triplicate analyses for each treatment at the Geological Research Geochemical Laboratory in Addis Ababa, Ethiopia. The carbonizer developed achieved briquette charcoal with carbonization efficiency between 80% and 82%, a calorific value of 30.543 MJ/kg, and a density of 970 kg/m$^3$. The study highlighted that coffee husk briquettes offer a non-polluting and smokeless alternative, reducing respiratory health risks associated with conventional charcoal use. Moreover, their utilization contributes to deforestation prevention by substituting conventional wood fuel.

The production of briquettes not only reduces air pollution but also presents economic opportunities for local entrepreneurs, lessening dependence on international fuels. Overall, the study underscores coffee husk briquettes as a sustainable and environmentally friendly energy source with the potential to transform waste into an economical and sustainable fuel for households, restaurants, and small businesses.

In the production of seedlings for various forest species, the choice of substrate plays a pivotal role in determining growth outcomes. Research has shown that the composition of the base material significantly influences seedling development. Therefore, selecting suitable ingredients becomes imperative for achieving the desired results[7]. A study evaluating the initial growth of seedlings from species like Eucalyptus urophylla, Peltophorum dubium, and Eremanthus erythropappus employed different substrate formulations. These formulations included composted rice husk, composted coffee husk, coconut fiber, and commercial substrates. The aim was to gather data for comparative analysis and to identify the most effective substrate for promoting seedling growth.

The substrates used in the seedling production underwent a composting process, where organic matter was decomposed and stabilized biologically over 120 days. To enhance seedling growth during the initial stages, slow-release fertilizer was added to the substrate mixture. The experimental design followed a randomized approach, ensuring rigorous assessment and reliable results. Results indicated that seedlings cultivated in substrates containing composted coffee husks exhibited superior growth compared to those in other substrates. These findings highlight the potential of coffee husk as a valuable constituent in seedling production. For optimal results across different species, a recommended substrate composition includes 40% composted coffee husk, 40% commercial substrate, and 20% coconut fiber[7]. This formulation promises to provide an ideal environment for fostering healthy seedling development and contributing to forest restoration efforts.

## 4 CONCLUSION

In this study, a variety of bioproducts derived from coffee husks has been highlighted, as well as their application in energy generation. Brazil has demonstrated remarkable potential in producing these bioproducts, including bioenergy, owing to its significant coffee production. Not only benefits in terms of reducing environmental impacts but also a substantial economy has been observed, which may create a more favorable environment for coffee producers and further stimulate coffee production. The analysis of the studies conducted suggests considerable potential and feasibility for further exploration of coffee, not only in terms of food production and sales but also to benefit various economic and social sectors of the country.

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