

**UTILIZATION OF SPENT COFFEE GROUNDS (SCG)
AS BIO-BRIQUETTE FUEL**

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An Undergraduate Thesis Submitted to the Faculty of the Department of Agricultural
and Biosystems Engineering, College of Engineering, Central Luzon State University,
Science City of Muñoz, Nueva Ecija, Philippines
in Partial Fulfillment of the Requirements
for the Degree of

**BACHELOR OF SCIENCE IN AGRICULTURAL AND
BIOSYSTEMS ENGINEERING
(AB Process Engineering)**

JUNE 2023

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ABSTRACT

DUMELOD, JEZIAH ALEXIS A., FERNANDEZ, CHESKA V., Department of Agricultural and Biosystems Engineering, College of Engineering, Central Luzon State University, Science City of Muñoz, Nueva Ecija, Philippines, **June 2023, UTILIZATION OF SPENT COFFEE GROUNDS (SCG) AS BIO-BRIQUETTE FUEL.**

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The coffee industry produces a large amount of waste in the form of coffee grounds, which is about 45% of the processed coffee beans. This study aims to produce the spent coffee grounds (SCG) and cassava starch (CS) binder as an environmentally friendly alternative fuel in the form of biomass briquettes. It also aimed to determine the best binder mixture proportion through analysis of bio-briquette's physical and thermal properties.

There are 3 treatments in this study — T_1 (10:3:10) has a proportion of 100% spent coffee ground and 30% cassava starch as binder with 100% water, T_2 (10:3:12.5) has a proportion of 100% spent coffee ground and 30% cassava starch as binder with 125% water and T_3 (10:3:15) has a proportion of 100% spent coffee ground and 30% cassava starch as binder with 150% water.

Based on the analysis of physical and thermal properties of the bio briquettes, the best treatment is T_3 . It has a density of 0.553 g/cc, an abrasive resistance value of 1.73 %, a shatter resistance value of 39.14% and a compressive strength of 548.0 N. It has the highest calorific value of 4,974.21 cal/g, energy density of 2763.19 kcal/cc. It also has a thermal efficiency of 73.50% and burning rate 10.27 g/min with no significant difference with other treatments.

Bio-briquettes from T₃ were considered as the best among other treatments. The cost of production for one (1) kg of T₃ bio briquette was Php 39.00 and a per piece price of Php 1.95.

LITERATURE CITED

- Al-Hamamre, Z., Foerster, S., Hartmann, F., Kröger, M., & Kaltschmitt, M. (2012). Oil extracted from spent coffee grounds as a renewable source for fatty acid methyl ester manufacturing. *Fuel*, *96*, 70–76. <https://doi.org/10.1016/j.fuel.2012.01.023>
- Akowuah, J. O., Kemausuor, F., & Mitchual, S. J. (2012). Physico-chemical characteristics and market potential of sawdust charcoal briquette. *International Journal of Energy and Environmental Engineering*, *3*(1), 20. <https://doi.org/10.1186/2251-6832-3-20>
- American Society of Agricultural and Biological Engineers [ASABE]. (2012). *ASAE S269.5 OCT2012 Densified Products for Bulk Handling - Definitions and Method* (5th ed.).
- ASTM International. (2012). Standard Test Method of Drop Shatter Test for Coal. *ASTM Standards*, *13*. <https://www.astm.org/d0440-07.html>
- Awasthi, A., Dhyani, V., Biswas, B., Kumar, J., & Bhaskar, T. (2019). Production of phenolic compounds using waste coir pith: Estimation of kinetic and thermodynamic parameters. *Bioresource Technology*, *274*, 173–179. <https://doi.org/10.1016/j.biortech.2018.11.073>
- Ballesteros, L. F., Teixeira, J. A., & Mussatto, S. I. (2014). Chemical, Functional, and Structural Properties of Spent Coffee Grounds and Coffee Silverskin. *Food and Bioprocess Technology*, *7*(12), 3493–3503. <https://doi.org/10.1007/s11947-014-1349-z>
- Blinová, L., Sirotiak, M., Bartošová, A., & Soldán, M. (2017). Review: Utilization of Waste From Coffee Production. *Research Papers Faculty of Materials Science and Technology Slovak University of Technology*, *25*(40), 91–101. <https://doi.org/10.1515/rput-2017-0011>
- Brand, M. A., Balduino, A. L., Junior, Nones, D. L., & Gaa, A. Z. N. (2019b). Potential of bamboo species for the production of briquettes. *Pesquisa Agropecuária Tropical*, *49*. <https://doi.org/10.1590/1983-40632019v49s4178>
- Brunerová, A., Roubík, H., Brožek, M., Van Dung, D., Phung, L. D., Hasanudin, U., Iryani, D. A., & Herák, D. (2020). Briquetting of sugarcane bagasse as a proper waste management technology in Vietnam. *Waste Management & Research: The Journal for a Sustainable Circular Economy*, *38*(11), 1239–1250. <https://doi.org/10.1177/0734242x20938438>

- Chaney, J. (2010). *Combustion Characteristics of Biomass Briquettes* [PhD Thesis]. University of Nottingham.
- Corpuz, M. G. A., Tuates Jr., A. M., & Aguinaldo, T. G. (2017). Development of corn cob-based fuel briquettes. *CIGR Journal*, 19(3). <https://cigrjournal.org/index.php/Ejournal/article/view/4089>
- De Melo, M. S. T., Barbosa, H., Passos, C. P., & Silva, C. A. (2014). Supercritical fluid extraction of spent coffee grounds: Measurement of extraction curves, oil characterization and economic analysis. *Journal of Supercritical Fluids*, 86, 150–159. <https://doi.org/10.1016/j.supflu.2013.12.016>
- De Oliveira Maia, B. G., Souza, O., Marangoni, C., Hotza, D., De Oliveira, A. P. N., & Sellin, N. (2014). Production and Characterization of Fuel Briquettes from Banana Leaves Waste. *Chemical Engineering Transactions*, 37, 439–444. <https://doi.org/10.3303/cet1437074>
- Fithratullah, R. (2020). The Study of Making Biomass Briquettes from Spent Coffee Ground. *Journal of Environmental Engineering and Waste Management*, 7(1), 34–35. <http://dx.doi.org/10.33021/jenv.v7i1.1522>
- Gengania, R. P. (2018). Production of Fuel Briquettes from Goat Manure and Sawdust.
- Giroto, F., Alibardi, L., & Cossu, R. (2015). Food waste generation and industrial uses: A review. *Waste Management*, 45, 32–41. <https://doi.org/10.1016/j.wasman.2015.06.008>
- Habib, U., Habib, M., & Khan, A. U. (2013). Factors Influencing the Performance of Coal Briquettes. *Walailak Journal of Science and Technology (WJST)*, 11(1), 1–5. <https://doi.org/10.2004/wjst.v11i1.417>
- Hardgrove, S. J., & Livesley, S. J. (2016). Applying spent coffee grounds directly to urban agriculture soils greatly reduces plant growth. *Urban Forestry & Urban Greening*, 18, 1–8. <https://doi.org/10.1016/j.ufug.2016.02.015>
- Jamradloedluk, J., & Wiriyaumpaiwong, S. (2012). Production and Characterization of Rice Husk Based Charcoal Briquettes. *Engineering and Applied Science Research*, 34(4), 391–398. <https://www.tci-thaijo.org/index.php/easr/article/view/1830>
- Kansai, N., Chaisuwan, N., & Supakata, N. (2018). Carbonized Briquettes as a Tool for Adding Value to Waste from Rain tree (*Samanea Saman*) and Coffee Ground/Tea Waste. *Engineering Journal*, 22(6), 47–63. <https://doi.org/10.4186/ej.2018.22.6.47>

- Kookos, I. (2018). Technoeconomic and environmental assessment of a process for biodiesel production from spent coffee grounds (SCGs). *Resources, Conservation and Recycling*, *134*, 156–164. <https://doi.org/10.1016/j.resconrec.2018.02.002>
- Li, X., Mupondwa, E., Panigrahi, S., Tabil, L., Sokhansanj, S., & Stumborg, M. (2012). A review of agricultural crop residue supplies in Canada for cellulosic ethanol production. *Renewable and Sustainable Energy Reviews*, *16*(5), 2954–2965. <https://doi.org/10.1016/j.rser.2012.02.013>
- Low, J. H., Rahman, W. a. W. A., & Jamaluddin, J. (2015). The influence of extraction parameters on spent coffee grounds as a renewable tannin resource. *Journal of Cleaner Production*, *101*, 222–228. <https://doi.org/10.1016/j.jclepro.2015.03.094>
- Major Non-Food and Industrial Crops Quarterly Bulletin (October-December 2022) (ISSN 2094-6198). (2023). Philippine Statistics Authority (PSA). <https://psa.gov.ph/content/major-non-food-and-industrial-crops-quarterly-bulletin>
- Mani, S., Tabil, L. G., & Sokhansanj, S. (2006). Effects of compressive force, particle size and moisture content on mechanical properties of biomass pellets from grasses. *Biomass & Bioenergy*, *30*(7), 648–654. <https://doi.org/10.1016/j.biombioe.2005.01.004>
- Mussatto, S. I., Carneiro, L. M., Silva, J. P., Roberto, I. C., & Teixeira, J. A. (2011). A study on chemical constituents and sugars extraction from spent coffee grounds. *Carbohydrate Polymers*, *83*(2), 368–374. <https://doi.org/10.1016/j.carbpol.2010.07.063>
- Mussatto, S. I., Machado, E. M. S., Martins, S. S., & Teixeira, J. A. (2011). Production, Composition, and Application of Coffee and Its Industrial Residues. *Food and Bioprocess Technology*, *4*(5), 661–672. <https://doi.org/10.1007/s11947-011-0565-z>
- Narzary, A., & Das, A. K. (2022). Study of effects of addition of charcoal and binder derived from taro on physiochemical properties of briquettes made from tree leaves. *Sustainable Energy Technologies and Assessments*, *52*, 102119. <https://doi.org/10.1016/j.seta.2022.102119>
- Nasir Ani, F. (2016). Utilization of bioresources as fuels and energy generation. *Electric Renewable Energy Systems*, 140–155. <https://doi.org/10.1016/b978-0-12-804448-3.00008-6>

- Nosek, R., Tun, M. M., & Juchelkova, D. (2020). Energy Utilization of Spent Coffee Grounds in the Form of Pellets. *Energies*, 13(5), 1235. <https://doi.org/10.3390/en13051235>
- Obi, O. F., Pecenka, R., & Clifford, M. N. (2022). A Review of Biomass Briquette Binders and Quality Parameters. *Energies*, 15(7), 2426. <https://doi.org/10.3390/en15072426>
- Okike, I., Wigboldus, S., Samireddipalle, A., Naziri, D., Adeshinwa, A. O. K., Adejoh, V. A., Amole, T., Bordoloi, S., & Kulakow, P. (2022). Turning Waste to Wealth: Harnessing the Potential of Cassava Peels for Nutritious Animal Feed. *Root, Tuber and Banana Food System Innovations*, 173–206. https://doi.org/10.1007/978-3-030-92022-7_6
- Olamide A. Adesanya, Kayode A. Oluyemi, S. J. Josiah, R.A. Adesanya, Lukeman Shittu, David A. Ofusori, Bankole, & G.B. Babalola. (2008). Ethanol Production By *Saccharomyces Cerevisiae* From Cassava Peel Hydrolysate. *The Internet Journal of Microbiology*, 5(1). <https://doi.org/10.5580/4f1>
- Rathore, N. S., Panwar, N. L., & Kurchania, A. K. (2008). *Renewable Energy Theory & Practice* (1st ed.). Himanshu Publication.
- Richards, S. (1990). Physical testing of fuel briquettes. *Fuel Processing Technology*, 25(2), 89–100. [https://doi.org/10.1016/0378-3820\(90\)90098-d](https://doi.org/10.1016/0378-3820(90)90098-d)
- Sahu, S. K., Chakraborty, N., & Sarkar, P. (2014). Coal–biomass co-combustion: An overview. *Renewable & Sustainable Energy Reviews*, 39, 575–586. <https://doi.org/10.1016/j.rser.2014.07.106>
- Tamilvanan, A. (2013). Preparation of Biomass Briquettes using Various Agro- Residues and Waste Papers. *Journal of Biofuels*, 4(2), 47. <https://doi.org/10.5958/j.0976-4763.4.2.006>
- Tuates, A. M., Ligisan, A. R., & Caparino, O. A. (2016). Physico-chemical and Thermal Properties of Fuel Briquettes Derived from Biomass Furnaces as By-Products. *Nihon Enerugi Gakkaishi*, 95(9), 859–867. <https://doi.org/10.3775/jie.95.859>
- Wondemagegnehu, E. B., Gupta, N. K., & Habtu, E. (2019). Coffee parchment as potential biofuel for cement industries of Ethiopia. *Energy Sources, Part A: Recovery, Utilization, and Environmental Effects*, 44(2), 5004–5015. <https://doi.org/10.1080/15567036.2019.1656682>

Woodyard, D. (2009). *Pounder's Marine Diesel Engines and Gas Turbines: and Gas Turbines* (9th ed.). Butterworth-Heinemann.

Zubairu, A. (2014). Production of Briquette Charcoal from Agro-Waste. *ResearchGate*.
<https://doi.org/10.5923/j.ep.20140402.03>