

**UTILIZATION OF WATER HYACINTH (*Eichhornia crassipes*) AND  
COCONUT (*Cocos nucifera*) SHELL AS A BIO-BRIQUETTE**

**JULIE FE B. PALTAO**

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**

## TABLE OF CONTENTS

	PAGE
LIST OF TABLES	x
LIST OF FIGURES	xi
LIST OF APPENDICES	xii
INTRODUCTION	1
Background of the Study	1
Statement of the Problem	3
Objectives of the Study	5
Significance of the Study	5
Scope and Limitation of the Study	6
Time and Place of the Study	6
REVIEW OF RELATED LITERATURE	7
Biomass Utilization	7
Water Hyacinth	7
Briquette	8
Coconut Shell	9
Biomass Briquettes	9
Philippines Charcoal Demand	10
Advantages of Biomass Briquettes Compared to Other Solid Fuels	11
Fuel Properties of Biomasses	12
Calorific Value (CV)	13
Moisture Content (MC)	13
Ash Content	13
Volatile Matter (VM)	13
Charcoal Briquetting Process	14
Carbonization	15
Densification	16
Biomass Carbonization Process	17
Pre-drying	18

	PAGE
Drying	18
Post drying	18
Torrefaction	18
Low-temperature carbonization	19
High-temperature carbonization	20
Char Yield	21
Binder	22
Cassava Starch as a Briquette Binder	22
Briquetting Technology	23
Screw Press and Piston Press Technologies	23
Briquette Storage	23
Physical Properties of Briquettes	24
Density	24
Compressive Strength	24
Shatter Resistance	24
Thermal Properties	25
Thermal Efficiency	25
Burning Time	25
Ash Content	26
METHODOLOGY	27
Conceptual Framework of the Study	28
Briquetting Process	28
Collection and Preparation of Raw Materials	28
Carbonization Process	29
Briquette Production	30
Particle Size Reduction	30
Preparation of Binder and Formulation	30
Densification	31
Drying	31

	PAGE
Briquette Analysis	32
Physical Properties	32
Density	32
Compressive Strength	33
Shatter Resistance	33
Combustion Properties	34
Thermal Efficiency	34
Calorific Value Computation	35
Burning Time	36
Ash Percentage Determination	36
Experimental Design	38
Cost of Production	39
Machine Rental Cost	39
Binder Cost	39
Labor Cost	39
Power cost	39
RESULTS AND DISCUSSION	40
Coconut Shell-Water Hyacinth Charcoal Briquettes	40
Charcoal Yield of Coconut Shell and Water Hyacinth	41
Physical Properties of Coconut Shell-Water Hyacinth Briquette	42
Density	42
Compressive Strength	43
Shatter Resistance	44
Combustion Properties of Coconut Shell-Water Hyacinth Briquette	47
Thermal Efficiency	47
Burning Time	48
Ash Content	49
Optimum Mixing Ratio of Coconut and Water hyacinth Fuel Briquette	51
Cost Analysis	53

	PAGE
SUMMARY, CONCLUSION AND RECOMMENDATIONS	55
Summary	55
Conclusion	58
Recommendations	58
LITERATURE CITED	59

## LIST OF TABLES

TABLE		PAGE
1	Char yield of different biomass	20
2	Treatment of composition between water hyacinth and coconut shell with binder	31
3	Treatment of composition between water hyacinth and coconut shell	37
4	Experimental layout of the study	38
5	Mean density of water hyacinth and coconut shell fuel briquettes (g/cc)	41
6	Mean compressive strength of water hyacinth and coconut shell fuel briquettes (N)	43
7	Mean shatter resistance of water hyacinth and coconut shell fuel briquettes (%)	44
8	Computed thermal efficiency of charcoal briquettes	46
9	Mean burning time of water hyacinth and coconut shell fuel briquettes (min)	47
10	Ash content of water hyacinth and coconut shell fuel briquettes (%)	48
11	Physical and combustion properties of the sample coconut shell-water hyacinth fuel briquettes bind with cassava starch	50
12	Production cost of briquettes	52

## LIST OF FIGURES

FIGURE		PAGE
1	Process flow in the production of briquettes	15
2	Carbonization process including its products	17
3	Conceptual framework of the study	27
4	Experimental layout and design	36
5	Charcoal briquettes with different biomass ratio	40

## APPENDIX TABLES

APPENDIX TABLE		PAGE
1	ANOVA for computed density of water hyacinth and coconut shell fuel briquettes	64
2	ANOVA for computed compressive strength of water hyacinth and coconut shell fuel briquettes	64
3	ANOVA for computed shatter resistance of water hyacinth and coconut shell fuel briquettes	65
4	ANOVA for computed ash content of water hyacinth and coconut shell fuel briquettes	66
5	ANOVA for computed burning time of water hyacinth and coconut shell fuel briquettes.	66
6	Rental rate of briquetting machine	67
7	Rental rate of a 1.1 horsepower mechanical mixer	68
8	Rental rate of the hammer mill	68
9	Rental rate of the carbonizer	69
10	Production of briquettes/day	70
11	Physical properties of bio-briquettes	70
12	Density of bio-briquettes of different ratios	70
14	Burning time of bio-briquettes of different ratios	72
15	Charcoal yield of coconut shell	73
16	Charcoal yield of water hyacinth	73

		PAGE
17	Drop test of bio-briquettes of different ratios	73
18	Shatter resistance of bio-briquettes of different ratios	74
19	Compressive strength test of bio-briquettes of different ratios	74

## APPENDIX FIGURES

APPENDIX FIGURE		PAGE
1	Collection of water hyacinth at Brgy. Población North, Science City of Munoz	75
2	Collection of coconut shells at Munoz public market	75
3	Sun-dried water hyacinth for 15 days	76
4	Sun-dried coconut shell for 5 days	76
5	Checking the moisture content of the coconut shell and water hyacinth using a moisture analyzer	77
6	Weighing of dried water hyacinth and coconut shell using a weighing scale	77
7	Loading the biomass into the carbonization drum	78
8	Carbonization of water hyacinth (right) and coconut shell (left) in a drum-type carbonizer.	78
9	Sorting of carbonized coconut shell	79
10	Sorting of carbonized water hyacinth	79
11	Pulverizing the charcoal using hammer mill	80
12	Weighing the final weight of water hyacinth and coconut shell after hammer milling	80
13	Weighed biomass, cassava starch, and water for the preparation of binder	81
14	Mixing the water-binder ratio and formulating the binder	81
15	Mixing the binder and carbonized char in a mechanical mixer	82

	PAGE	
16	Pouring the mixture into zip-lock bags to maintain moisture	82
17	Weighing of the mixture before subjecting it to the briquetting machine	83
18	Pouring of the mixture in a briquetting machine	83
19	Molding of briquettes using a manual briquetting machine	84
20	Densified briquettes	84
21	Sun-drying of briquettes	85
22	Checking for moisture using a moisture analyzer	85
23	Sampling and density determination of the produced bio-briquettes	86
24	Compressive strength test using the universal testing machine	86
25	Shatter resistance test of bio-briquettes	87
26	Burning time test of bio-briquettes	87
27	Density of different ratio of charcoal briquettes	88
28	Compressive strength of different ratio of charcoal briquettes	88
29	Shatter resistance of different ratio of charcoal briquettes	89
30	Thermal efficiency of different ratio of charcoal briquettes	89
31	Burning time of different ratio of charcoal briquettes	90
32	Ash content of different ratio of charcoal briquettes	90

## ABSTRACT

**PALTAO, JULIE FE B.**, Department of Agricultural and Biosystems Engineering, College of Engineering, Central Luzon State University, Science City of Munoz, Nueva Ecija, Philippines, **June 2023, UTILIZATION OF WATER HYACINTH (*Eichhornia crassipes*) AND COCONUT (*Cocos nucifera*) SHELL AS A BIO-BRIQUETTE**

Adviser: CAROLYN GRACE G. SOMERA, Ph.D.

The general objective of the research was to produce charcoal briquettes from water hyacinth and coconut shell using cassava starch as a binder. The specific objectives of the study were to: determine the charcoal yield of water hyacinth and coconut shell; determine the optimum water hyacinth and coconut shell mixing ratio; bind with cassava starch for the production of charcoal briquettes; and estimate the unit cost of production of water hyacinth and coconut shell charcoal briquettes. For the production of bio-briquettes, water hyacinth and coconut shell undergo various processes such as drying, carbonizing, shredding, combining in various proportions of biomass, binding, and densifying. Physical characteristics such as density, compressive strength, abrasive strength, and shatter resistance were assessed, as were chemical properties such as thermal efficiency, calorific value computation, burning time, and ash percentage. An analysis of variance was used to determine the significant difference between treatments, and the least significant difference was used to compare the means. Each treatment was replicated three times. For each water hyacinth and coconut shell mixture, four distinct composition ratios were used: 80:20, 60:40, 40:60, and 20:80.

The highest computed mean density, highest compressive strength, highest mean burning time, and lowest ash percentage were obtained in Treatment 1 (80:20), with a value of 2.02 g/cc, 6843.76 N, 227.75 minutes, and 8.75%, respectively. On the other hand, Treatment 4 (20:80) has the least computed compressive strength, the least mean shatter resistance, the lowest mean burning time, and the highest ash content. with a value of 1499.34 N, 65.95%, 114.57 minutes, and 27.72%, respectively. Hence, it can be inferred that Treatment 1 (80:20) is the optimum mixing ratio of coconut shell and water hyacinth bound with cassava starch.

Keywords: Charcoal yield; Optimum mixing ratio; Physical property; Combustion property; Cost analysis.

## LITERATURE CITED

- Afra, E., Abyaz, A., & Saraeyan, A. (2021). The production of bagasse biofuel briquettes and the evaluation of natural binders (LNFC, NFC, and lignin) effects on their technical parameters. *Journal of Cleaner Production*, 278, 123543.
- Ahmad, K. K., Sazali, K., & Kamarolzaman, A. A. (2018). Characterization of fuel briquettes from banana tree waste. *Materials Today: Proceedings*, 5(10), 21744-21752.
- Ajith, K. J., Vinoth, K. K., Petchimuthu, M., Iyahraja, S., & Vignesh, K. D. (2020). Comparative analysis of briquettes obtained from biomass and charcoal. *Mater. Today Proc.*10.1016/j.matpr.2020.02.918
- Asian Charcoal Briquettes Market Research Report. (2020). Asia Charcoal Briquettes Market Overview.
- Bailey, R. T. & Blankenhorn, P. R. (1982). Calorific and porosity development in carbonized wood. *Wood Science*, 15(1): 19 -28.
- Chen, H. (2015). Lignocellulose Biorefinery Engineering: Lignocellulose biorefinery product engineering. *Woodhead Publishing*, 125-165.
- Chirchir, D. K., Nyaanga, D. M., & Githeko, J. M. (2013). Effect of Binder Types and Amount on Physical and Combustion Characteristics. *Int. J. Engg. Res. and Sci. and Tech.* 2(1).
- Corpuz, M. G. A., Tuates Jr., A. M., Aguinaldo, T. G., Villota, E. M., Mateo, W. C., & Caparino, O. A. (2017). Development of corn cob-based fuel briquettes. *Agricultural Engineering International: CIGR Journal*, 19(3), 92–96.
- Davies, R. M., & Davies, O. A. (2013). Physical and Combustion Characteristics of Briquettes Made from Water Hyacinth and Phytoplankton Scum as Binder. *Journal of Combustion*, 2013, 7.
- Gani, A. & Naruse, I. (2007). Effect of cellulose and lignin content on pyrolysis and combustion characteristic for several types of biomasses. *Renew. Energy*, 32, 649–661.
- Go, A. W., Conag, A. T., Igdon, R. M. B., Toledo, A. S., & Malila, J. S. (2019). Potentials of agricultural and agro-industrial crop residues for the displacement of fossil fuels: A Philippine context. *Energy Strategy Reviews*, 23, 100-113.

## LITERATURE CITED

- Afra, E., Abyaz, A., & Saraeyan, A. (2021). The production of bagasse biofuel briquettes and the evaluation of natural binders (LNFC, NFC, and lignin) effects on their technical parameters. *Journal of Cleaner Production*, 278, 123543.
- Ahmad, K. K., Sazali, K., & Kamarolzaman, A. A. (2018). Characterization of fuel briquettes from banana tree waste. *Materials Today: Proceedings*, 5(10), 21744-21752.
- Ajith, K. J., Vinoth, K. K., Petchimuthu, M., Iyahraja, S., & Vignesh, K. D. (2020). Comparative analysis of briquettes obtained from biomass and charcoal. *Mater. Today Proc.* 10.1016/j.matpr.2020.02.918
- Asian Charcoal Briquettes Market Research Report. (2020). Asia Charcoal Briquettes Market Overview.
- Bailey, R. T. & Blankenhorn, P. R. (1982). Calorific and porosity development in carbonized wood. *Wood Science*, 15(1): 19 -28.
- Chen, H. (2015). Lignocellulose Biorefinery Engineering: Lignocellulose biorefinery product engineering. *Woodhead Publishing*, 125-165.
- Chirchir, D. K., Nyaanga, D. M., & Githeko, J. M. (2013). Effect of Binder Types and Amount on Physical and Combustion Characteristics. *Int. J. Engg. Res. and Sci. and Tech.* 2(1).
- Corpuz, M. G. A., Tuates Jr., A. M., Aguinaldo, T. G., Villota, E. M., Mateo, W. C., & Caparino, O. A. (2017). Development of corn cob-based fuel briquettes. *Agricultural Engineering International: CIGR Journal*, 19(3), 92–96.
- Davies, R. M., & Davies, O. A. (2013). Physical and Combustion Characteristics of Briquettes Made from Water Hyacinth and Phytoplankton Scum as Binder. *Journal of Combustion*, 2013, 7.
- Gani, A. & Naruse, I. (2007). Effect of cellulose and lignin content on pyrolysis and combustion characteristic for several types of biomasses. *Renew. Energy*, 32, 649–661.
- Go, A. W., Conag, A. T., Igdon, R. M. B., Toledo, A. S., & Malila, J. S. (2019). Potentials of agricultural and agro-industrial crop residues for the displacement of fossil fuels: A Philippine context. *Energy Strategy Reviews*, 23, 100-113.

- Huang, J. (2014). Calorific value of pressed fuel briquettes.
- Idowu, A., Ayodeji, I., & Musa, A. (2020). Combustion Quality Evaluation of Briquettes Produced from Sesame Hull as Source of Sustainable Energy. *Asian Journal of Energy Transformation and Conservation*, 4(1), 30-39.
- Ikelle, I. I., Nworie, F. S., Ogah, A. O., & Ilochi, N. O. (2017). Study on the Combustion Properties of Bio-Coal Briquette Blends of Cassava Stalk Chem. *ChemSearch Journal*, 8(2), 29 – 34.
- Kaliyan, N., & Morey, R. V. (2009). Factors affecting strength and durability of densified biomass products. *Biomass and Bioenergy*, 33(3), 337-359. doi: 10.1016/j.biombioe.2008.08.005
- Kaliyan, N., & Morey, R. V. (2010). Densification characteristics of corn cobs. *Fuel Processing Technology*, 91(5), 559-565.
- Kaliyan, N., & Morey, R. V. (2010). Natural binders and solid bridge type binding mechanisms in briquettes and pellets made from corn stover and switchgrass. *Bioresource technology*, 101(3), 1082-1090.
- Kaur, A., Kumar, A., Singh, P., & Kundu, K. (2017). Production, Analysis and Optimization of Low-Cost Briquettes from Biomass Residues. *Adv. Res*, 12, 1-10.
- Kimutai, S. K., & Kimutai, I. K. (2019). Investigation of physical and combustion properties of briquettes from cashew nut shell and cassava binder. *International Journal of Education and Research*, 7(11).
- Köser, H. J., Schmalstieg, G., & Siemers, W. (1982). Densification of water hyacinth basic data. *Fuel*, 61(9), 791-798.
- Kpalo, S. Y., Zainuddin, M. F., Manaf, L. A., & Roslan, A. M. (2020). A Review of Technical and Economic Aspects of Biomass Briquetting. *Sustainability*, 12(11). doi: 10.3390/su12114609
- Macabebe, E. Q. B., Dumlao, S. M. G., & Perez, T. R. (2016). Waste to Energy: A Look into Community-Based Charcoal Briquetting in the Philippines. *International Proceedings of Chemical, Biological and Environmental Engineering*, 93. doi: 10.7763/IPCBE. 2016. V93. 9
- Mengesha, T. T., & Ramayya A. V. (2017). Performance Evaluation of Pyrolysis Cookstove Using Water Boiling Test. *American Journal of Modern Physics*, 6(5), 108-116. doi: 10.11648/j.ajmp.20170605.15

- Mitchual, S.J., Frimpong-Mensah, K., & Darkwa, N. A. (2013). Effect of species, particle size and compacting pressure on relaxed density and compressive strength of fuel briquettes. *Int J Energy Environ Eng*, 4, 30.
- Nasrin, A. B., Ma, A. N., Choo, Y. M., Mohamad, S., Rohaya, M. H., Azali, A., & Zainal, Z. (2008). Oil palm biomass as potential substitution raw materials for commercial biomass briquettes production. *American Journal of Applied Sciences*, 5(3), 179-183.
- Nyakuma, B. B., Johari, A., Ahmad, A., & Abdullah, T. A. T. (2014). Comparative analysis of the calorific fuel properties of Empty Fruit Bunch Fiber and Briquette. *Energy Procedia*, 52, 466-473.
- Obi, F. O., Ugwuishiwu, B. O., & Nwakaire, J. N. (2016). Agricultural waste concept, generation, utilization and management.
- Olugbade, T., Ojo, O., & Mohammed, T. (2019). Influence of Binders on Combustion Properties of Biomass Briquettes: A Recent Review. *Bioenerg. Res.*, 12, 241–259. <https://doi.org/10.1007/s12155-019-09973-w>
- Onukak, I. E., Mohammed-Dabo, I. A., Ameh, A. O., Okoduwa, S. I. R., & Fasanya, O. O. (2017). Production and Characterization of Biomass Briquettes from Tannery Solid Waste. *Recycling*, 2, 17. doi:10.3390/recycling2040017
- Pachaiyappan, S., Seshadri, S., Sugumaran, P., Susan, V. P., Ravichandran, P., & Seshadri, S. (2012). Production and characterization of activated carbon from banana empty fruit bunch and *Delonix regia* fruit pod microbial inoculants view project bio-char production view project production and characterization of activated carbon from banana empty fruit bu. *J. Sustain. Energy Environ*, 3, 125-132.
- Ranada, P. (2014). New pest fast destroying coconut trees in Luzon. *Nation*, 31.
- Rathore, N. S. & Panwar, N. L. (2008). *Renewable Energy Theory and Practice*. Himanshu Publication, New Delhi, p. 273.
- Rezania, S., Din, M. F. M., Kamaruddin, S. F., Taib, S. M., Singh, L., Yong, E. L., & Dahalan, F. A. (2016). Evaluation of water hyacinth (*Eichhornia crassipes*) as a potential raw material source for briquette production. *Energy*, 111, 768-773.
- Rotich, P. K. (1998). Carbonization and briquetting of sawdust for use in domestic cookers. Retrieved from <http://erepository.uonbi.ac.ke/handle/11295/21571>

- Sengar, S. H., Mohod, A. G., Khandetod, Y. P., Patil, S. S., & Chendake, A. D. (2012). Performance of Briquetting Machine for Briquette Fuel. *International Journal of Energy Engineering*, 2(1), 28-34. doi: 10.5923/j.ijee.20120201.05.
- Shuma, R., & Madyira, D. M. (2017). Production of loose biomass briquettes from agricultural and forestry residues. *Procedia Manufacturing*, 7, 98-105.
- Sluiter, A., Hames, B., Ruiz, R., Scarlata, C., Sluiter, J., & Templeton, D. (2008). Determination of Ash in Biomass: Laboratory Analytical Procedure (LAP). Retrieved from <https://www.nrel.gov/docs/gen/fy08/42622.pdf>
- Speight, J. G. (2020). The Refinery of the Future: Production of fuels from nonfossil fuel feedstocks. *Gulf Professional Publishing*, 2, 391-426. <https://doi.org/10.1016/B978-0-12-816994-0.00011-7>.
- Steiner, C., Bayode, A. O., & Komang Ralebitso-Senior, T. (2016). Biochar Application: Feedstock and Production Parameters: Effects on Biochar Properties and Microbial Communities. *Elsevier*, 41-54.
- Sundaram, E. G., & Natarajan, E. (2009). Pyrolysis of coconut shell: An experimental investigation. *The Journal of Engineering Research [TJER]*, 6(2), 33-39.
- Supatata, N., Buates, J., & Hariyanont, P. (2013). Characterization of fuel briquettes made from sewage sludge mixed with water hyacinth and sewage sludge mixed with sedge. *International Journal of Environmental Science and Development*, 4(2), 179.
- Téllez, T. R., López, E. M. D. R., Granado, G. L., Pérez, E. A., López, R. M., & Guzmán, J. M. S. (2008). The water hyacinth, *Eichhornia crassipes*: an invasive plant in the Guadiana River Basin (Spain). *Aquatic Invasions*, 3(1), 42-53.
- Tesfaye, A., & Girma, A. (2017). Phytochemistry, pharmacology and nutraceutical potential of enset (*Ensete ventricosum*). *African Journal of Basic & Applied Sciences*, 9(3), 112-117.
- Turkenburg, W. C., & Faaij, A. (2000). *Renewable energy technologies* (pp. 219-72). UNDP/UNDESA/WEC: Energy and the Challenge of Sustainability. World Energy Assessment. New York: UNDP, 219-272.
- Zakari, I. Y., Ismaila, A., Sadiq, U., & Nasiru, R. (2013). Investigation on the effects of addition of binder and particle size on the high calorific value of solid biofuel briquettes. *J. Natural Sci. Res.*, 3(12), 30-34.

Zheng, C., Ma, X., Yao, Z., & Chen, X. (2019). The properties and combustion behaviors of hydrochars derived from co-hydrothermal carbonization of sewage sludge and food waste. *Bioresource technology*, 285, 121347.