v. 4, n. 8, 2024

Journal of
Agricultural
Sciences
Research

USE OF SUGAR CANE BAGASSE, CASHEW SHELLS AND SAWDUST, FOR SOLID BIOFUEL PRODUCTION

Emanuele Rodrigues Figueiredo
Universidade Federal de Campina Grande, Centro de Ciência e Tecnologia Agroalimentar (CCTA), Campus Pombal Pombal-PB
https://orcid.org/0000-0001-8279-7639

Ravel Moreira Chaves
Universidade Federal de Campina Grande, Centro de Ciência e Tecnologia Agroalimentar (CCTA), Campus Pombal Pombal-PB
https://orcid.org/0000-0003-1267-8452

Miqueias Barbosa Formiga Alves
Universidade Federal de Campina Grande, Centro de Ciência e Tecnologia Agroalimentar (CCTA), Campus Pombal Pombal-PB
https://orcid.org/0000-0002-1222-041X

Roberlucia Araújo Candeia
Universidade Federal de Campina Grande, Centro de Ciência e Tecnologia Agroalimentar (CCTA), Campus Pombal Pombal-PB
https://orcid.org/0000-0002-6783-8794

Maíra Felinto Lopes
Universidade Federal de Campina Grande, Centro de Ciência e Tecnologia Agroalimentar (CCTA), Campus Pombal Pombal-PB
https://orcid.org/0000-0003-3331-7269

Camilo Allyson Simões de Farias
Universidade Federal de Campina Grande, Centro de Ciência e Tecnologia Agroalimentar (CCTA), Campus Pombal
Pombal-PB
https://orcid.org/0000-0002-2425-6815

Abstract: The use of waste generated in the agroindustry has been a promising and sustainable alternative. Therefore, the objective was to investigate the quality of briquets in the natura form, from different proportions of lignocellulosic biomass for energy purposes. The experimental research began with the manufacture of seven formulations of briquets with their due triplicates, standardized in mass conditions, densified under pressure of 15 tnf for 15 minutes, and then characterized by chemical physicist medium and composition of lignocellulosic materials. The results obtained revealed significant parameters for each composition, such as briquette with 100% wood residue (F3) and 50:50 of cashew nut bark and wood residue (F5) that stood out for the low concentration of ash, humidity and high calorific value. All formulations converted into briquets were energetically favorable, in addition to valuing waste in agroindustries.
Keywords: Lignocellulosic residue, Briquette, Energy composition.

INTRODUCTION

There is a continuous generation of waste in industrial production for consumer goods. These can be used in the construction of reuse alternatives, having the use of biomass as a relevant alternative in the strategic planning of economic growth in several countries (Ndumbo, 2021).

Brazil has great opportunities in the energy sector, and may have even more prominence in a low-carbon economy. Renewable sources, such as forest biomass, still have enormous potential for expansion and will be fundamental to the country's competitiveness in the future (PNE, 2020). Data from Aneel 2018 indicate that biomass represented only 1.6% of renewable energy source, while hydraulics and wind-photovoltaics represent, respectively, 74.2% and 8.3%.

Because it is a country of great agricultural and furniture production, consequently, Brazil ends up generating a high percentage of waste from various types of biomass, especially sugarcane and cashew residues (Pontes et al., 2019). The energy use of such waste becomes attractive for power generation.

One of the means of use is given by the so-called "briquettes" that are compact and dense blocks of plant biomass, considered a substitute for conventional firewood and/or charcoal due to its high calorific value (Clasen, Bonadio & Agostinho, 2022). Some research in the literature reports the energy potential of sugarcane bagasse, residues of cashew nut and wood bark in the briquetting process (Sawadogo et al., 2018; Smith et al., 2019; Santos et al., 2020). However, there are no citations of briquettes with formulations of the three biomass together.

To this end, this research combines scientific, environmental, economic and social factors related to the issue of solid waste use. generated by agro-industrial activities, especially lignocellulosic materials for conversion into solid biofuel. For example, it can promote the recovery of waste and formulated product, it reduces the problem of environmental impact, being an alternative to the agro-industrial cleaner production among other possibilities as in the social aspect, generate employment and income for local workers.

The biomasses used in this study were: sugar cane bagasse, cashew nut shell and wood residue (sawdust), because of these have prominence in national production, especially in the northeast region, with the cultivation of sugar cane and cashew nuts. In addition, some of the residues end up being discarded in dumps and/or landfills in the cities. So that this work aimed to investigate the energy quality of briquettes *in natura* form from different proportions of lignocellulosic biomass (bagasse of sugar cane, cashew nut shell and wood residue) for energy purposes, through physical chemistry and composition of lignocellulosic materials.

MATERIALS AND METHODS

The biomasses used in the manufacture of briquettes were residues from agro-industries in the northeastern sertão region, specifically sugar cane bagasse (Sousa-PB), cashew nut shells (Serra do Mel-RN) and wood residue-sawdust (Sousa-PB).

The briquettes were produced in the Solid Waste Laboratory of the Center for Agro-Food Sciences and Technology / UFCG, using a hydraulic press, Mark MARCON with capacity for 100 tnf, and a matrix made of carbon steel with the following dimensions: plate thickness 4 mm, length 25 cm, diameter 5 cm and a punch to compact the biomass used to produce the briquette.

PREPARATION OF THE BRIQUETES

The obtained lignocellulosic residues went through drying, grinding, sieving (appropriate particle size) and densification processes in a hydraulic press. The productions of the said *in natura* solid biocomposites were administered from the following biomass proportions, according to Table 1, namely:

Formulations	Composition of Briquettes (use of biomass waste)		
	Sugar Cane Bagasse	Cashew nut shells	Wood residue (Sawdust)
1	100%	-	-
2	-	100%	-
3	-	-	100%
4	50%	50%	-
5	-	50%-	50%
6	50%	-	50%
7	33%	33%	33%

Table 1: Composition for the production of briquettes

The production of briquettes occurred on a bench scale, and the amount of mass was standardized for the production of each briquette formulated to 100 g, and this compacted to 15 tnf remaining at rest in the press for 15 min, time determined from analyses in the literature already performed for the same purpose, since there is no specific methodology. Soon after, the briquette was removed *in natura* processed, stored in vacuum packaging for future characterizations to be performed.

During the production of briquettes it was not incorporated the addition of binder. From each treatment three repetitions were performed, totaling 21 briquettes. These were characterized by physical-chemical analysis and lignocellulosic materials.

CHARACTERIZATION TECHNIQUES

PHYSICOCHEMICAL ANALYSIS

The analyses of physical-chemical characterization of the produced briquettes were performed in the Chemistry Laboratory (LQ/CCTA/UFCG), except the analyses of gross calorific value that were developed in the Laboratory of Materials and Environmental Chemistry (LabMaq) of the Center for Alternative and Renewable Energy of the UFPB. All followed the parameters and methods described in Table 2.

Analysis	Methods
Moisture (U%)	ASTM D-3173
Volatile Materials (MV%)	ASTM D-3175
Ash (CZ%)	ASTM D-3174
Fixed Carbon (CF%) Apparent Density (g.cm³)	By difference: CF=100–(CZ+MV) Stoichiometric
Upper Calorific Power (PCS, J.Kg^{-1})	ABNT NBR 8633/84

Table 2: Parameters with their respective methods

DETERMINATION OF LIGNOCELLULOSIC MATERIALS

In this analysis we adopted the methodology of Morais, Rosa and Marconcini (2010). The determinations were worked out, separately, for each biomass (sugar cane bagasse, cashew nut shell and wood residue). All analyses were worked in triplicate.

DESCRIPTIVE STATISTICAL ANALYSIS

The experiment was evaluated in an entirely randomized design (DIC), using 7 formulations (briquette type) and 3 repetitions for each variable studied. To verify significant differences between the samples, the data obtained were submitted to the F Test through the analysis of variance (ANOVA). When significant differences were identified in the ANOVA, the Tukey test was applied at a 5% significance level. The data were analyzed with the help of the SISVAR software and the graphs obtained in the Excel program.

RESULTS AND DISCUSSION

PRODUCTION OF BRIQUETES

Before compacting the materials, they were submitted to sieving, with a particle size of 2.36 mm for the sugar cane bagasse and the wood residue. The cashew nut shell was thicker, with approximately 0.5 cm due to the material has high strength and high oil content (cardanol). The briquettes with the formulations proposed in this study can be seen in Figure 1. And although we have not performed mechanical tests to better understand their strength, it was possible to observe them in a macroscopic view.

Figure 1: Briquettes produced corresponding to each formulation

Legend: F1 - 100% Sugarcane Bagasse; F2 - 100% Cashew Nut Shell; F3 -100% Wood Residue; F4-50% Sugarcane Bagasse and 50% Cashew Nut Shell; F5 - 50% of cashew nut shell and 50% of wood residue; F6 - 50% of sugar cane bagasse and 50% of wood residue; F7 - 33% of sugar cane bagasse, 33% of cashew nut shell and 33% of wood residue.

Source: Own authorship (2022).

All formulations had satisfactory briquetting without apparent cracks, except the formulation F2 (100% of cashew nut shell) proved to be prone to fragment more easily since 100% of the composition of the material contains oily and acidic substance, such as source of long-chain unsaturated phenols, such as anacardic acids, cardols and their isomers (Yuliana et al., 2014), hindering the agglutination of the particles in the briquette formulation in question.

Another factor that may have influenced the compaction process in F2, was the granulometry of the material, because, according to Fernandez et al. (2016), the larger the granulometry the smaller the contact area between the particles, hindering the bonding between the particles. And, corroborating this understanding, the cashew nut shell waste was not worked at a particle size equal to or less than 2.36 mm, due to the release of the oleaginous liquid and acid contained in the material while grinding and then hindered in the screening process, and therefore, particles above 2.36 mm were adopted in the briquetting process in question.

PHYSICO-CHEMICAL ANALYSIS

The data obtained from the immediate analysis corresponding to the seven formulations of briquettes produced are shown in Table 3.

It can be seen that the moisture values were very close, ranging between 5.78 and 7.13%, and the statistical values showed no significant difference. Formulations F2 and F5 presented, respectively, higher and lower moisture content, with 7.13% and 5.78%, corresponding to a difference of 1.35%. Among the formulations, there was a low oscillation of values. The decrease in moisture content is favorable both to reduce the proliferation of fungus during storage (Madalena, 1999), and in the gain of efficiency in steam production, and consequently, in energy production (Alves et al 2022a). Therefore, moisture contents between 5 and 10 % are ideal for the material to develop better burning, and below 5% moisture content the briquette can become brittle (Petricoski, 2017; Carvalho et al., 2019).

Thus, all formulations proposed in Table 3 showed adequate moisture index, and it can be evidenced that formulations with the presence of agricultural residue (sugar cane bagasse and cashew nut shell) adds to the product more moisture than the forest residue (sawdust) and, therefore, when mixed allow hygroscopic balance reducing this parameter. Such a statement can be verified in Costa et al. (2019) in which he worked roasted formulations of sugar cane and Eucalyptus Sawdust with moisture concentration values ranging between 6.52 and 7.59%. And, Ifa et al. (2020) who studied the feasibility of some biomasses and among them the cashew nut shell obtaining 5.3% of moisture suitable for energy source purposes.

Formulations	U (%)	CZ (%)	MV (%)	CF (%)
F1	6.99 ± 0.37a	2.77 ± 0.26 ab	79.20 ± 1.30 a	18.03 ± 1.13 ac
F2	7.13 ± 0.4a	1.33 ± 0.23 ce	79.50 ± 0.80 a	19.17 ± 0.64 ab
F3	6.92 ± 0.30a	0.25 ± 0.15 e	79.12 ± 1.91 a	20.63 ± 1.90 a
F4	6.43 ± 0.24ab	2.96 ± 0.88 a	81.14 ± 0.47 a	15.91 ± 0.58 ac
F5	5.78 ± 0.23b	0.49 ± 0.36 de	80.90 ± 0.20 a	18.62 ± 0.20 c
F6	6.54 ± 0.18ab	1.72 ± 0.18 bc	79.28 ± 0.55 a	19.01 ± 0.72 ac
F7	6.38 ± 0.55ab	1.52 ± 0.18 cd	81.77 ± 1.54 a	16.72 ± 1.60 bc

Table 3: Mean values and standard deviation referring to the immediate analysis of the samples of briquettes

Legend: F1 - 100% Sugarcane Bagasse; F2 - 100% Cashew Nut Shell; F3 -100% Wood Residue; F4- 50% Sugarcane Bagasse and 50% Cashew Nut Shell; F5 - 50% of cashew nut shell and 50% of wood residue; F6 - 50% of sugar cane bagasse and 50% of wood residue; F7 - 33% of sugar cane bagasse, 33% of cashew nut shell and 33% of wood residue.

The means followed by the same letter are not statistically different at 5% probability by Tukey's test.

Source: Own authorship (2022).

In the other parameters, it can be seen that all formulations showed the same behavior which were low ash content (variation between 0.25 and 2.96%), high content of volatile materials (variation between 79.20 and 81.77%) and moderate fixed carbon (variation between 15.91 and 20.63%).

Table 4 presents the compiled data corresponding to the analyses of density and gross calorific value (GCV) of each formulation proposed in this study.

Formulations	Apparent Density ($g.cm^3$)	PCS ($MJ.kg^{-1}$)
F1	0,753	15.961
F2	1,242	21.167
F3	0,809	22.101
F4	0,916	22.292
F5	0,965	24.254
F6	0,804	20.781
F7	0,955	22.128

Table 4: Mean values for the immediate analysis of the samples of briquettes

Legend: F1 - 100% Sugarcane Bagasse; F2 - 100% Cashew Nut Shell; F3 -100% Wood Residue; F4- 50% Sugarcane Bagasse and 50% Cashew Nut Shell; F5 - 50% of cashew nut shell and 50% of wood residue; F6 - 50% of sugar cane bagasse and 50% of wood residue; F7 - 33% of sugar cane bagasse, 33% of cashew nut shell and 33% of wood residue.

The means followed by the same letter are not statistically different at 5% probability by Tukey's test.

Given this general context, it suggests that all the proposed formulations assume pertinent characteristics for a bioenergy product of quality and burning power, and such statement also follows corroborated by Nikiema et al. (2022), when investigating some biomass mixtures in the production of non-carbonized briquette.

Observing the behavior of each composition evaluated, it can be verified that F1 presented the lowest PCS, with 15.961 J/G, confirming the result obtained for the moisture content of the sugarcane bagasse biomass. The F5 formulation, on the other hand, obtained the highest concentration of PCS with 24.254 J/G, believing that the molecular chemical composition for this briquette aggregated better performance in the burning power, because of the two biomasses involved have high concentrations of lignins (as verified in Table 5).

Formulation F4 presented the highest value of ash (2.96%), followed by F1, F6 and F7, which contain decreasing proportions of sugarcane bagasse in the bioproduct composition, suggesting that as the ash are inert materials in the biomass, high concentrations can influence the pyrolysis of the material (Alves et al., 2022b). At high volume is considered an unfavorable characteristic, as it increases the availability of toxic dust in the atmosphere and can cause damage to equipment (boilers, for example) with the creation of crusts that decrease their useful life (Sawadogo et al., 2018; Silva, 2021). For Dionizio et al., (2019) high percentage of ash is common in agroforestry residues, and may be related to the fertilization of agricultural crops.

Formulation F3 stood out both in low ash content and high fixed carbon content when compared to the other formulations. Although, the ash values presented in all formulations were less than 4%, not compromising during the burning process, the management operations and the useful life of boilers and furnaces by corrosion according to Magalhaes, Silva & Castro (2019).

Formulation F7 stood out among the formulations as the most reactive (faster burning), due to the high concentration of volatile materials, followed by F4 and F5, although statistically no significant difference can be seen. It is noticed that the formulations that contain the presence of the cashew nut shell add to the composition of the briquette better development in the pyrolysis process, besides also resulting in lower concentration of inert material at the end of this process. Opposite to this raw material is the sugar cane bagasse that promotes slower burning, and greater inert residue at the end of pyrolysis.

Regarding the calorific value and fixed carbon, it is observed that F5, followed by F4 and F7 showed slow pyrolysis and longer combustion time, corroborating the understanding of Soares (2014) and Alves et al (2022a) in which they argued that high concentrations of fixed carbon and lower rates of moisture and ash, generate more heat for longer during combustion.

Statistically, Table 4, the ash concentrations showed significant difference between each other in all formulations. While for the volatile materials parameter there was no significant difference among the samples. The fixed carbon also presented significant difference among some materials, less between F1, F4 and F6. It is considered that the low ash content of F3 and F5 and their respective carbon content values indicate formulations with good burning performance and energy efficiency.

One point to consider about the ash residue, resulting after the pyrolysis process, is that if not handled properly, it can become an environmental liability. However, Belini (2022), in a recent study, points out the use of the remaining ash as a substrate enhancer for the germination of cucumber seeds. According to the same author, the ash positively influenced seedling size and concentration, mainly, of macronutrients.

The sugarcane bagasse obtained 18.03% of fixed carbon and 79.20% of volatile materials different from that found by Nalevaiko (2021) who verified for ash, fixed carbon and volatiles, respectively, 5.06%, 13.96% and 80.92%.

For Chungcharoen & Srisang (2020) in a study of cashew nut shell briquettes found 20,180J/G calorific value similar to the present study (21,167J/G). Santos et al. (2020) on the other hand obtained 1.34% for ash content, 70.44% volatiles, 28.22% fixed carbon and 27,469J/G calorific value. Similar to that found in this study only for ash content.

CHEMICAL COMPOSITION OF THE LIGNOCELLULOSIC MATERIAL OF BIOMASSES

The in natura residues were characterized as to the chemical composition of the lignocellulosic material for the raw materials sugar cane bagasse, cashew nut shell, and wood residue, as shown in Table 5.

Parameters	Sugar Cane Bagasse	Cashew Nut Bark	Wood Residue (Sawdust)
Extractives (%)	12.30	9.33	4.42
Lignin (%)	13.40	13.46	23.38
Holocellulose (%)	48.41	45.05	54.73
Alphacellulose (%)	31.80	28.92	41.77
*Hemicellulose (%)	16.61	16.13	12.96

Table 1: *Chemical composition of lignocellulosic material of raw materials in natura*

*Hemicellulose consists of the difference between holocellulose and alphacellulose.

Such parameters correspond to the following understandings (Ogata, 2015), namely:

I) extractives include some salts, sugars and polysaccharides (water soluble) and fatty acids or esters, long-chain alcohols, waxes, resins, steroids, phenolic compounds and glycosides (soluble in organic solvents);

II) holocellulose determines the amount of carbohydrates present in a plant sample, in this case cellulose and a set of pentoses, or hemicellulose;

III) alphacellulose reveals the amount of cellulose and hemicellulose contained in a plant sample, relative to the holocellulose content;

IV) the lignin content is an important parameter in the study of materials with energy potentials because it presents, in its molecular composition, from 60 to 64% of elemental carbon (Foelkel, 2016). And, the higher the carbon content, the greater its energy potential (Pompêu, 2019). For this reason, lignin is responsible for increasing the calorific value.

It can be seen that the wood residue and the sugar cane bagasse presented higher and lower lignin content with, respectively, 23.38% and 13.14%. What was already expected since the wood residue (forest residue) exceeds that of agricultural crops (Selvarajoo et al., 2022; Liu, Han 2015), corroborating also with the calorific value (Table 4).

Faced with the formulations of briquettes composed of 100% of each residue, F3 stood out with respect to the calorific value, corroborating with the data regarding the constitution of lignocellulosic material, Table 5, especially lignin. Therefore, the presence of wood residue in the other blends will positively influence the burning power.

The chemical composition of the lignocellulosic material (cellulose, hemicellulose, and lignin) are also important characteristics because they influence from physical-mechanical-energy quality, such as waste densification (presence of "green" binders, i.e., lignin) to pyrolysis, calorific power of the bioproduct. Higher calorific values are related to a higher percentage of lignin because this chemical constituent contains less oxygen content and higher carbon content than polysaccharides (Setter, Oliveira, 2022).

CONCLUSIONS

All formulations can be used as feedstock for briquette production, showing favorable for combustion for energy generation. By the immediate analysis it was verified a high volatile content, low ash content and moisture content suitable for burning. These factors indicate formulations with good ignition, low content of residues generated during burning, and a gain in energy efficiency in steam production and, consequently, in energy release.

However, among the formulations, the briquette 100% of Wood Waste (F3) and 50% of Cashew Nut Bark and Wood Waste (F5) were the ones that presented better energy efficiency due to the low concentration of ash, moisture and high calorific value, and besides the presence of high concentrations of residues generated during the burning, the briquette had a higher energy efficiency.

However, among the formulations, the briquette 100% of Wood Waste (F3) and 50% of Cashew Nut Bark and Wood Waste (F5) were those that presented the best energy efficiency due to the low concentration of ash, moisture and high calorific value, and the presence of high concentrations of lignin in its composition. On the other hand, although F4 with 50% of sugar cane bagasse and cashew nut shell and F7 with 33% of sugar cane bagasse, cashew nut shell and wood residue have higher calorific value than F3, they presented higher ash content, which reduces the efficiency when compared with the other formulations.

REFERENCES

Alves, M. F. B; Candeia, R. A.; Leite, J. C. A.; Santos, A. F. Produção e caracterização de biocombustível sólido a partir de resíduos orgânicos sem tratamento térmico. **Brazilian Journal of Development**, Curitiba, v.8, n.2, p. 8925-8945, 2022a.

Alves, M. F. B; Chavesa, R. M.; Saraiva, T dos S.; Silva, E. K. S da; Candeia, R. A. Perfil físico-químico e energético de briquetes composto por cascas de coco, cascas de banana, e/ou serragem. **Brazilian Journal of Development**, Curitiba, v.8, n.2, p. 8893-8909, 2022b.

ANEEL. Agência Nacional de Energia Elétrica. 2018. Disponível em: < https://www.aneel.gov.br/documents/656877/14854008/Boletim+de+Informa%C3%A7%C3%B5es+Gerenciais+-+4%C2%BA+trimestre+de+2018/36e91555-141a-637d-97b1-9f6946cc61b3 >. Acesso em: 20 ago. 2021.

Belini, G. B. ***Cinzas de caldeira de biomassa: caracterização, diagnóstico e alternativa para aplicação.*** 2022. 129P. Tese (Doutorado em Planejamento e Uso de Recursos Renováveis), Universidade Federal de São Carlos, campus Sorocaba, Sorocaba, SP, 2022.

Carvalho, A. H. S.; Santos, C. A dos; Farah, S. P. dos S.; Farah, A. F. Influência da umidade do bagaço da cana-de-açúcar no sistema de cogeração de energia. **Simpósio de Tecnologia Falco.** 2019. Disponível em: https://sitefa.fatecsertaozinho.edu.br/index.php/sitefa/article/view/48/71.

Chungcharoen, T; Srisang, N. Preparation and characterization of fuel briquettes made from dual agricultural waste: Cashew nut shells and areca nuts. **Journal of Cleaner Production,** Netherlands, v. 256, p. 120434, 2020.

Clasen, A. P.; Bonadio, J. C.; Agostinho, F. Briquettes production from green coconut shells: technical, financial, and environmental aspects. **Engenharia Sanitária e Ambiental** [online]. v. 27, n. 3, 2022. Available from: <https://doi.org/10.1590/S1413-415220200364>.

Costa, S. E. de L.; Santos, R. C dos; Castro, R. V. O.; Castro, A. F. N. M.; Magalhães, M. A de; Carneiro, A de C. O.; Santos, C. P. de S; Gomes, I. R. F.; Rocha, S. M. G. Briquettes quality produced with the macauba epicarp (Acrocomia aculeata) and Pinus sp. Wood. **Revista Árvore** [online]. v. 43, n. 5 2019, [Accessed 11 July 2022], e430501. Available from: <https://doi.org/10.1590/1806-90882019000500001>. Epub 25 Nov 2019. ISSN 1806-9088. https://doi.org/10.1590/1806-90882019000500001.

Dionizio, A. F.; Vale, A. T do; Moreira, A. C. de O; Galvão, L. G. O.; Chaves, B. S.; Costa, M. de A. Agregação de valor a resíduos agroindustriais para fins energéticos. **Revista de Ciências Agrárias**, v. 42, n. 2, p. 528-538, 2019. DOI: https://doi.org/10.19084/rca.15129.

Foelkel, C. E. B. Utilização da Biomassa do Eucalipto para Produção de Calor, Vapor e Eletricidade Parte 1: Biomassa Florestal & Florestas Energéticas. **Eucalyptus Online Book & Newsletter**, 2016.

Ifa, L.; Yani, S.; Nurjannah, N.; Darnengsih, D.; Rusnaenah, A; Mel, M.; Mahfud, M.; Kusuma, H.S. Techno-economic analysis of bio-briquette from cashew nut shell waste. **Heliyon***, v*. 6, 2020, e05009.

Liu, Z.; Han, G. Production of solid fuel biochar from waste biomass by low temperature pyrolysis, **Fuel**, v.158, p. 159e165, 2015. https://doi.org/10.1016/ j.fuel.2015.05.032.

Madalena, L. C. de S. ***Análise físico-química e energética de briquetes de feijão guandu (Cajanus cajan) SILG.*** *2009 submetidos à torrefação*. 2019. 90f. Dissertação (Mestrado em Dissertação em Engenharia de Energia na Agricultura). Universidade Estadual do Oeste do Paraná, Cascavel, PR, 2019.

MAGALHÃES, A. S; SILVA, T. M. M. da; CASTRO, V. G. de. Produção e caracterização de briquetes a partir de resíduos sólidos e prensagem semi-manual. **Adv. For. Sci.,** Cuiabá, v.6, n.3, p.705-710, 2019.

Morais, J. P. S; Rosa, M. de F.; Marconcini, J. M. Procedimentos para análise lignocelulósica. Campina Grande: ***Embrapa Algodão***, Documentos, 236, 2010. 54 p.

Nalevaiko, J. Z; Teleken, J. G; Cremonez, P. A. Use of agroindustrial by-products in the production of briquettes. **Revista Brasileira de Engenharia de Biossistemas,** Tupã, São Paulo, Brazil, v. 15, n. 1, p. 1–26, 2021. DOI: 10.18011/bioeng2021v15n1p1-26. Disponível em: https://seer.tupa.unesp.br/index.php/BIOENG/article/view/980. Acesso em: 5 mai. 2022.

Ndumbo, M. ***Processo integrado para produção de xilana, briquetes e açúcares fermentáveis.*** 2021.60p. Dissertação (mestradoem Ciências Biologicas) - Universidade Estadual Paulista (Unesp), Instituto de Biociências, Rio Claro. 2021.

Nikiema, J.; Asamoah, B.; Egblewogbe, M. N. Y. H.; Akomea-Agyin, J.; Cofie, O. O.; Hughes, A. F.; Gebreyesus, G.; Asiedu, K. Z.; Njenga, M. Impact of material composition and food waste decomposition on characteristics of fuel briquettes. **Resources, Conservation & Recycling Advances,** v. 15, 2022, 200095

Ogata, B. H**. *Caracterização das fraçoes cellulose, hemicelulose e lignin de Diferentes genótipos de cana-de-açucar potencial de uso em biorrefinarias.*** 2013. 108p. Dissertação (Mestrado em Biotecnologia). Escola Superior de Agricultura "Luiz de Queiroz". USP. Piracicaba, SP, 2013.

Petricoski, S. M. ***Briquetes produzidos com mistura de podas urbanas, glicerina e resíduos de processamento de mandioca.*** 2017. 83 f. Dissertação (Mestrado em Engenharia de Energia na Agricultura), Universidade Estadual do Oeste do Paraná, Cascavel, PR.

PNE – Plano Nacional de Energia. 2020. Disponível em: http://antigo.mme.gov.br/web/guest/servicos/consultas-publicas?p_p_id=consultapublicammeportlet_WAR_consultapublicammeportlet&p_p_lifecycle=0&p_p_state=normal&p_p_mode=view&p_p_col_id=column-1&p_p_col_count=1&_consultapublicammeportlet_WAR_consultapublicammeportlet_view=detalharConsulta&resourcePrimKey=1197115&detalharConsulta=true&entryId=1197117. Acesso em: 19 jul. 2021.

Pompêu, G. C. S. ***Estudo do conteúdo calorífico de ligninas extraídas de diferentes fontes de biomassa vegetal.*** 2019. 54p. Dissertação (Mestrado em Biocombustível), Instituto de Química, da Universidade Federal de Uberlândia, Uberlândia. Disponível em: < https://repositorio.ufu.br/bitstream/123456789/24830/1/EstudoConte%C3%BAdoCalor%C3%ADfico.pdf > Acesso em: 28 jul. 2022.

Pontes, M. R.; Gadelha, A. M. T.; Machado, Y. de L.; Lopes, A. A. S.; Malveira, J. Q.; Mazzeetto, S. E.; Lomanaco, D.; Rios, M. A. de S. Blendas de bagaço de cana-de-açúcar, podas de mangueira e cajueiro: caracterização das propriedades e investigação de seus potenciais energéticos. **Matéria** (Rio de Janeiro). v. 24, n. 2, 2019. Disponível em: <https://doi.org/10.1590/S1517-707620190002.0687>. Acesso em 20 ago. 2022.

Fernandez, B. O.; Gonçalves, B. F.; Pereira, A. C. C. ; Hansted, A. L. S.; Pádua, F. A.; Da Róz, A. L.; Yamaji, F. M. Características Mecânicas e Energéticas de Briquetes Produzidos a partir de Diferentes Tipos de Biomassa**. Revista Virtual de Química**, v. 9, n. 1, 2016.

Santos, M. C. B; Silva, Y.B.R. da; Martin, T.; Soares, E.C.V.; Oliveira, F.D.B de; Moura, J. J de; Santos, M. do S.F dos. ***Aproveitamento de biomassa em uma indústria moveleira para geração de energia.*** VIII Congresso Brasileiro de Energia Solar – Fortaleza, 2020. Disponível em: < https://anaiscbens.emnuvens.com.br/cbens/article/view/961/961>. Acesso em: 05 ago. 2022.

Sawadogo, M; Tchini Tanoh, S; Sidibé, S; Kpai, N; Tankoano, I. Cleaner production in Burkina Faso: Case study of fuel briquettes made from cashew industry waste. **Journal of Cleaner Production**, v. 195, p.1047-1056. 2018. DOI: 10.1016/j.jclepro.2018.05.261.

Selvarajoo, A.; Wong, Y. L.; Khoo, K. S.; Chen, W. H.; Show, P. L. Biochar production via pyrolysis of citrus peel fruit waste as a potential usage as solid biofuel, **Chemosphere**, v. 294, 133671, 2022. https://doi.org/10.1016/ j.chemosphere.2022.133671

Setter, C.; Oliveira, T. J. P. Evaluation of the physical-mechanical and energy properties of coffee husk briquettes with kraft lignin during slow pyrolysis. **Renewable Energy**, v. 189, p. 1007e1019, 2022.

Smith, A. K. de. G; Alesi, L. S.; Varanda, L. D.; Silva, D. A. da; Santos, L. R. O; Yamaji, F. M. Production and evaluation of briquettes from urban pruning residue and sugarcane bagasse. **Revista Brasileira de Engenharia Agrícola e Ambiental,** v. 23, n. 2, Feb, p. 138, 2019. DOI: http://dx.doi.org/10.1590/1807-1929/agriambi.v23n2p138-143.

Soares, V. C.; Bianchi, M. L.; Trugilho, P. F.; Pereira, A. J.; Hofle, J. Correlações entre as propriedades da madeira e do carvão vegetal de híbridos de eucalipto. **Revista Árvore** [online] v. 38, n. 3, p. 543-549, 2014. Disponível em: <https://doi.org/10.1590/S0100-67622014000300017>. ISSN 1806-9088.

Yuliana, M.; Nguyen-Thi, B. T.; Faika, S.; Hunynh, L. H.; Soetarejo, F. E.; Ju, Y. Separation and purification of cardol, cardanol and anacardic acid from cashew (*Anacardium occidentale* L.) nut-shell liquid using a simple two-step column chromatography. **Journal of the Taiwan Institute of Chemical Engineers**. v.45, p. 2187-2193,2014.