MANUFACTURE OF BRIQUETTES WITH URBAN PRUNING RESIDUES

FABRICAÇÃO DE BRIQUETES COM RESÍDUOS DE PODA URBANA

FABRICACIÓN DE BRIQUETAS A PARTIR DE RESIDUOS DE PODA URBANA

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ABSTRACT
The residues generated from urban pruning are not used in the best way when taking into account the factor of adding value to the final product, as they are biomass in a context of urban natural capital. Thus, the objective of this work was to use urban pruning residue (UPR) generated in the urban area of Curitiba, Paraná, for the production of briquettes and characterization of quality and energy potential. The compaction of the UPR biomass was carried out in a laboratory briquette machine, with a temperature of 120ºC, with a pressure of 1200 Kgf.cm-2, compaction time of 5 minutes and cooling of 10 minutes with forced ventilation. For each briquette, 40 g of residue was used, resulting in a final briquette of approximately 4 cm in height and 3 cm in diameter. The tests carried out had the purpose of verifying the characteristics of the biomass and quality aspects of the briquettes, in accordance with current regulations. The main results obtained indicate the UPR with average values for ash content of 3.4%, volatile materials 78.5% and fixed carbon 18.1%. As for the briquettes, an average moisture content of 7.6%, higher calorific value (PSC) of 4417 Kcal/g, bulk density (DG) of 21.05 MJ/m^3, friability of 99.8% and tensile strength per diametral compress (RTCD) of 704.9 kgf, placing the briquettes in Group 1, of better quality, according to the Swedish standard SS187120. Also, the residues generated in the sawmilling of wood employees in this study can be used directly for the production of briquettes, without the need for processing, such as crushing and grinding, generating the costs associated with its energy use.

KEYWORDS
Energy; Urban Forest; Use.

RESUMO
Os resíduos oriundos de podas urbana não são aproveitados da melhor maneira quando se leva em consideração o fator de agregar valor ao produto final. O objetivo do trabalho foi utilizar o resíduo de poda urbana (RPU) gerados no meio urbano de Curitiba, Paraná, para a produção de briquetes. A compactação da biomassa dos RPU foi realizada em uma briquetadeira laboratorial, com temperatura de 120ºC, com pressão de 1200 Kgf.cm-2, tempo de compactação de 5 minutos e resfriamento de 10 minutos com ventilação forçada. Para cada briquete utilizou-se 40 g de resíduo, obtendo um briquete final de aproximadamente 4 cm altura e 3 cm de diâmetro. Os ensaios realizados tiveram como propóstio verificar se os briquetes fabricado podem ser utilizados como fonte de energia. Eles foram: teor de umidade (U%), poder calorífico superior (PCS), densidade a granel (DG), densidade aparente (DA), durabilidade (Dur), expansão volumétrica, resistência a tração por compressão diametral (RTCD) e análise granulométrica. De acordo com os resultados obtidos,

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os resíduos gerados no desdobro da madeira utilizados neste estudo podem ser utilizados diretamente para a produção de briquetes, sem a necessidade de processamento, como trituração e moagem, reduzindo os custos associados ao seu aproveitamento energético.

PALAVRAS-CHAVE
Ensaio; Floresta Urbana; Aproveitamento.

RESUMEN

Los residuos de la poda urbana no se aprovechan de la mejor manera si se tiene en cuenta el factor de valorización del producto final, ya que son biomasa en un contexto de capital natural urbano. Así, el objetivo de este trabajo fue utilizar residuos de poda urbana (UPR) generados en el medio urbano de Curitiba, Paraná, para la producción de briquetas y caracterización de calidad y potencial energético. La compactación de la biomasa UPR se realizó en una briquetadora de laboratorio, con una temperatura de 120ºC, con una presión de 1200 Kgf.cm-2, tiempo de compactación de 5 minutos y enfriamiento de 10 minutos con ventilación forzada. Para cada briqueta se utilizaron 40 g de residuo, obteniendo una briqueta final de aproximadamente 4 cm de altura y 3 cm de diámetro. Los ensayos realizados tuvieron como finalidad verificar características de la biomasa y aspectos de calidad de las briquetas, de acuerdo con la normativa vigente. Los principales resultados obtenidos indican la UPR con valores promedio para contenido de cenizas de 3.4%, materiales volátiles 78.5% y carbón fijo 18.1%. En cuanto a las briquetas, un contenido de humedad promedio de 7.6%, poder calorífico superior (PSC) de 4417 Kcal/g, densidad aparente (DG) de 21.05 MJ/m^3, friabilidad de 99.8% y resistencia a la tracción por compresión diametral (RTCD) de 704,9 kgf, ubicándose las briquetas en el Grupo 1, de mejor calidad, según la norma sueca SS187120. Asimismo, los residuos generados en el aserrado de la madera utilizada en este estudio pueden ser utilizados directamente para la producción de briquetas, sin necesidad de procesamiento, como trituración y molienda, reduciendo los costos asociados a su uso energético.

PALABRAS CLAVE
Energía; Bosque Urbano; Explotación.

1. INTRODUCTION

Briquettes are considered a form of densified fuel that can offer intriguing opportunities within the realm of renewable energy development, coupled with sustainability aspects. Currently, the vast majority of globally produced briquettes are derived from wood and/or wood waste, yet strong trends are emerging towards the utilization of various biomass residues and particularly blends of waste and wood components (SANTOS et al., 2022).

The utilization of such products exhibits a reduced environmental footprint when compared to traditional fossil fuels like coal, oil, and natural gas. Briquettes are regarded as a source of renewable energy, as they are produced from abundantly available organic materials, consequently bestowing economic benefits.

Energy stands as a pivotal factor in the economic and social advancement of a country, and according to estimates from the International Energy Agency (IEA, 2011), global energy consumption will rise by at least a third between 2010 and 2035 (CASTRO & RODRIGUES, 2023).

Numerous countries have adopted policies and programs to promote the use of briquettes as a sustainable alternative. International organizations, exemplified by the United Nations Development Programme (UNDP, 2023) and the World Bank, have endorsed briquette production projects as part of their clean energy and sustainable development initiatives. Brazil's energy matrix is considered one of the cleanest in the world, consisting of 48.4% renewable sources (FORTES, 2022). The global average, considering other countries, stands at around 13.8% (NATIONAL ENERGY BALANCE, 2021).

Briquette production offers various avenues to harness different materials as biomass feedstock. Some of the materials commonly used in briquette production include agricultural, forestry, industrial, biomass processing residues, animal-derived waste, among others.

Emerging possibilities for using diverse materials in briquette production must be intricately linked to specific properties, such as high calorific value, low ash content, and minimal generation of fines (STÅHL & BERGHEL, 2011). Consequently, the production and characterization of briquettes composed of novel feedstock materials should constitute a foundational step in the scope of prospective studies for energy recovery from waste.

In this context, the primary aim of this research was to fabricate briquettes from Residues of Urban Production (RPU) for energy purposes, and to assess the qualitative properties and calorific value of the novel material.

2. LITERATURE REVIEW

Urban landscaping holds significance for cities not solely due to its aesthetic appeal, but also due to the ecosystem services it provides, such as oxygen production, reduction of air pollution, climate regulation, and mitigation of urban noise. Maintenance of urban landscapes necessitates urban pruning, a common practice in cities worldwide. This involves the removal of diseased, damaged, or otherwise compromised parts of trees. This activity can generate a substantial amount of plant waste that, if not managed appropriately, can result in environmental issues such as soil and water pollution. Hence, the utilization of Urban Production Residues (RPU) is a practice gaining increasing importance, fostering sustainability in urban areas (GENGO & HENKES, 2012; GUSEV et al., 2023; RIBASKI et al., 2023).

The utilization of such collected material can serve purposes beyond waste reduction and resource conservation. It can generate jobs and income for the local populace (CASTRO & RODRIGUES, 2023). Waste collection and processing can be undertaken by waste picker cooperatives and other local organizations, which can sell the final products to businesses and consumers. This initiative contributes to reducing the volume of waste sent to landfills and promotes the concept of circular economy, which emphasizes more efficient resource utilization.

An example of a product derived from RPU is wood-plastic composite, which finds use in furniture, decks, and similar applications. According to Duarte et al. (2017), utilizing RPU for producing such composites is a viable and sustainable alternative, as it curbs the demand for virgin wood and helps reduce waste sent to landfills.

Another prospect is the utilization of RPU in briquette production, where fuel blocks are compressed from waste materials. Oliveira et al. (2016) posit that producing briquettes from RPU offers an economical and sustainable alternative for thermal energy generation. This aids in reducing dependence on fossil fuels and lessening waste sent to landfills.

2.1. Briquettes

Briquettes represent a method of producing and storing energy from combustible materials such as wood, sawdust, wood chips, charcoal, sugarcane bagasse, and other lignocellulosic biomass. They are solid products, resembling small blocks, generated through the compression of organic and/or inorganic residues, generally without

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the addition of chemical substances. These materials are compressed under high pressure to form a dense and sturdy structure with a high calorific value. Briquettes exhibit higher efficiency compared to other fuel forms due to more complete combustion, resulting in more intense and prolonged heat release, along with calorific value standardization.

Employing RPU in briquette production stands as an intriguing practice for reducing environmental impacts and generating clean energy. It is a sustainable alternative for thermal energy generation, aiding in reducing dependency on fossil fuels and potentially resulting in up to a 40% reduction in CO^2 emissions compared to fossil fuel usage (KOLAKOVIC et al., 2016).

According to Oliveira et al. (2016), the utilization of RPU for briquette production holds substantial energy potential, as it constitutes a renewable and abundant biomass source. Furthermore, Rueda et al. (2019) emphasize the high calorific value and low emission of polluting gases of such briquettes, making them an environmentally sustainable and efficient option for thermal energy generation.

However, each city possesses a unique floristic composition in its landscaping, implying a diversity of tree species with varying densities of the material used for briquette manufacture. This can affect the calorific value and quality of the end product.

Hence, the significance of this study lies in the valorization of underutilized resources. In numerous cases, RPU are considered undesired byproducts, discarded without proper utilization. By converting these residues into briquettes, they are elevated in value and used as a valuable energy source. This presents an opportunity to enhance the efficiency and sustainability of the natural resource lifecycle.

3. MATERIALS AND METHODS

3.1. Urban Pruning Residue Collection

The raw material employed was Urban Pruning Residue (RPU) from the city of Curitiba, Paraná, Brazil. This city harbors a blend of 122 tree species constituting its urban landscape. The three most frequent and proportionate species for the year 2010 were Lagerstroemia indica (crape myrtle), Ligustrum lucidum (broadleaf privet), and Handroanthus chrysotrichus (yellow trumpet tree) (BOBROWSKI, 2012).

The residue used in this study was obtained from the processing of this material, which was stored at the company Byocom, responsible for RPU collection in the city.

3.2. Briquette Production

The compaction of RPU biomass was conducted using a laboratory briquetting machine (Figure 1), at a temperature of 120°C, pressure of 1200 kgf.cm-2, compaction time of 5 minutes, and cooling time of 10 minutes with forced ventilation. For each briquette, 40g of shredded biomass was utilized.

According to figure 1, the provided description pertains to a laboratory-scale briquetting machine. This apparatus is employed for the compaction of biomass materials into briquettes. The machine features a compact design and is equipped with mechanisms for applying pressure and temperature control during the briquette formation process.

Figure 1: Laboratory Briquetting Machine.
Source: Authors

The temperature aimed to facilitate lignin plasticization, serving as a natural binder for the particles during compaction. For each briquette, 40 g of residue was used, with the goal of achieving a final briquette size of approximately 4 cm in height and 3 cm in diameter.

Briquetting conditions were determined through experimental trials involving pressing and cooling times. The applied pressure falls within the range used in Quirino et al. (2012) and Freitas et al. (2016). The temperature objective was to induce lignin plasticization (CHEN, et al., 2009), serving as a natural binding agent for the particles during the compaction process.

3.3. Experiments

a) Moisture Content (U%) of RPU: The moisture content of the briquette was determined for samples produced after their fabrication using Equation 1, following the ABNT NBR 14929 standard (ABNT, 2017).
b) Higher Heating Value (HHV): This was analyzed using the IKAWERKE C5003 calorimetric bomb according to the methodology established in the ABNT NBR 8633/84 standard (ABNT, 1984).
c) Bulk Density (BD): As recommended by ABNT NBR 11941.
d) Apparent Density (AD): To evaluate the apparent density of the briquettes, the stoichiometric method was used, which involves obtaining the volume from measurements using calipers and the mass of the briquette on a scale with a precision of 0.001 grams. The apparent density was then determined by dividing the moist mass (kg) by the moist volume (m^3). The energy density was calculated by multiplying the value of the higher heating value by the apparent density, as performed by Ribeiro et al. (2022).
e) Durability (Dur): For Dur analysis, the mass loss of the samples was observed. The briquettes were weighed to obtain the initial mass, then placed on a vibratory sieve for 10 minutes at 80 rotations per minute. After this procedure, the briquettes were weighed again to obtain the final mass (RIBEIRO, et al., 2022).
f) Volumetric Expansion: The volumetric expansion of the briquettes was calculated by measuring the height and diameter of the briquettes and subsequently calculating the volume at two different moments: (i) immediately after briquetting and (ii) 72 hours after briquetting (RIBEIRO, et al., 2022).
g) Diametral Compression Tensile Strength (DCTS): For DCTS, a universal testing machine EMIC – DL30000 was used with a load cell of 500 kgf and a constant speed of 0.3 mm/min, applying transverse load on the samples (PROTÁSIO et al., 2011; QUIRINO et al., 2012; RIBEIRO, et al., 2022).
h) Particle Size Analysis: Samples were classified in 20, 40, 60, and 100 mesh using a sieve shaker with intermittent tapping, as mentioned in Ribeiro et al. (2022).

4. RESULTS AND DISCUSSION

The characterization of RPU began with its particle size classification, revealing particles of varying sizes. The majority of particles were classified as 20 mesh (87%), considered as "fine" since it falls below 1 mm (RIBEIRO, et al., 2022). This classification facilitates understanding the differences in particle size distribution for optimal briquetting procedures.

The average moisture content of the briquettes was 7.6%, close to the range of 8% to 15% required for particle agglomeration (GENTIL, 2008; MORAIS, 2007). Generally, a moisture content below 10% is considered ideal for producing briquettes of good quality. Excessively high moisture content can complicate production, requiring more energy for drying, potentially increasing production time and cost. Conversely, very low moisture content might hinder the briquettes from maintaining shape and cohesion, resulting in poor-quality products. Thus, the measured moisture content falls within the expected range.

The average bulk density values obtained in this study indicate an increase in briquette density, confirming it as a viable alternative for reducing transportation costs.

The found Higher Heating Value (HHV) for the briquette was 4417.21 Kcal/kg (18.55 MJ/kg). The Swedish Standard SS 187121 specifies the tolerated minimum HHV as 16.2 MJ/kg (GENTIL, 2008), indicating that the briquettes possess good energy quality.

Regarding ash content, Gentil (2008) notes that residual ash in industrial furnaces is undesirable, making lower ash content more favorable. The results (3.35%) for the biomass exhibit relatively high ash content. The ideal ash content for briquettes may vary based on purpose and specific user requirements. Generally, "the ideal ash content for briquettes is less than 10%" according to Arinze et al. (2021). Briquettes with lower ash content are more energy-efficient, producing fewer residues and thus requiring less cleaning and maintenance.

Volatiles content falls within the range of 76% to 86%, which aligns with reality and affirms that volatiles are the primary contributors to heat generation in combustion. This characteristic also contributes to higher calorific value due to the presence of more hydrogen in the material (NAKASHIMA, et al., 2018). Depending on its use, this can confer qualitative advantages over other residues.

Concerning bulk energy density, the average values obtained (21.05 MJ/m³) indicate an increase in briquette density, confirming its viability for reducing transportation costs. Determining bulk density is essential for generating logistics and waste transport information as per Ribeiro et al. (2022).

Friability yielded a result of 99.80%, classified by Pereira (2009) as very low friability. This suggests that the briquettes are sufficiently resistant to withstand handling during production, transportation, and storage.

Mandlate (2019) mentions that volumetric expansion can impact briquette combustion efficiency by forming voids or air channels within the block, reducing material density and hindering heat transfer. Expansion can also lead to briquette breakage during combustion, generating residues and emitting pollutants. The average volumetric expansion result was 1.35%.

Rep.	Biomass			Briquettes	
	Ash Content (%)	Volatile Matter (%)	Fixed Carbon (%)	Friability (%)	Maximum Load (Kgf)
1	3,39	77,73	18,87	99,83	749,02
2	3,53	78,26	18,22	99,80	652,71
3	3,56	78,74	17,71	99,81	640,04
4	3,16	79,57	17,28	99,83	709,07
5	3,13	78,24	18,63	99,75	773,76
Average	**3,35**	**78,51**	**18,14**	**99,80**	**704,92**

Table 1: Ash Content, Volatile Matter, and Fixed Carbon Results of RPU Biomass, and Friability and Maximum Load Results of RPU Briquettes.
Source: Authors

To minimize volumetric expansion in briquettes, it's important to control material moisture and combustion temperature, along with utilizing appropriate compaction techniques. The addition of binding agents can also help reduce volumetric expansion and enhance the mechanical strength of briquettes (MANDLATE, 2019).

Tensile Strength by Diametral Compression (RTCD), as determined in Figure 2, is one of the technical specifications that briquette manufacturers must adhere to in order to ensure the quality and safety of their products.

The test was conducted based on an adaptation of the NBR 7222 standard (ABNT, 1994) for determining diametral compression tensile strength in cylindrical concrete and mortar samples, as there is no specific standard for tensile strength in briquettes (MORAES, et al., 2019).

One of the primary European standards is the Swedish Standard SS 187120, titled "Pellets - Requirements and Testing," which provides guidelines and technical requirements for the production and use of biomass pellets, and SS 18 7121 for wood briquettes. According to the Swedish standard, after determining RTCD, briquettes should be classified into three groups:

Group I: RTCD equal to or greater than 500 kgf (kilogram-force).

Group II: RTCD between 300 and 500 kgf.

Group III: RTCD less than 300 kgf.

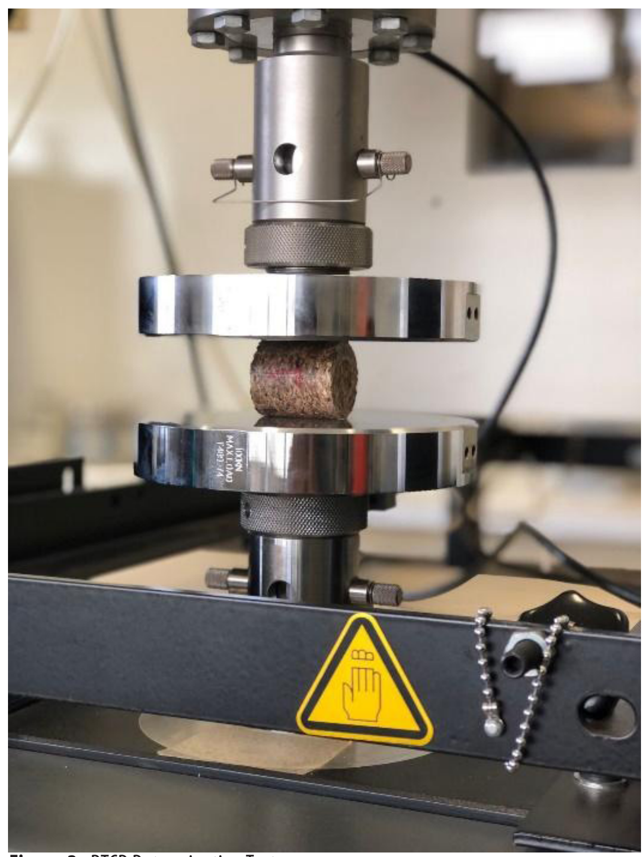

Figure 2: RTCD Determination Test.
Source: Authors

The standard establishes that Group I briquettes are of high quality and are recommended for use in high-demand industrial furnaces that require high fuel performance. Group II and III briquettes are considered lower quality and are more suitable for residential or low-demand furnaces.

The average result obtained in the tests was 704.9 kgf, classifying it as Group I and indicating high-quality briquettes.

5. CONCLUSIONS

The quality of briquettes molded on a laboratory scale in this study, using RPU, proved to be quite satisfactory. The results obtained in the characterization tests of briquettes produced from urban pruning indicated that they meet the established technical specifications. The granulometric classification revealed an appropriate particle distribution, the average moisture content of 7.6% was within the necessary range for particle agglomeration, and the bulk density of the briquettes increased, indicating a viable alternative for reducing transportation costs.

Although the ash content was considered elevated, it falls within acceptable limits for certain uses, and an adequate volatile content ensures higher heat generation during combustion. The friability of the briquettes was low, indicating suitable resistance to withstand handling during production, transportation, and storage. The volumetric expansion of the briquettes was controlled, preventing the formation of voids and loss of density during burning.

Finally, the Determination of Tensile Strength by Diametral Compression (RTCD) of the briquettes resulted in an average of 704.9 kgf, classifying them as Group I, meaning high-quality briquettes recommended for use in high-demand industrial furnaces.

The waste generated from the processing of wood from urban pruning in the metropolitan region of Curitiba-PR can be directly used for briquette production based on the obtained results, without the need for further processing such as grinding or milling, thereby reducing associated costs related to energy utilization. In other words, it is a promising and sustainable alternative for the utilization of vegetative waste. Moreover, producing briquettes from RPU can create jobs, income, and new opportunities for the local population, contributing to the socio-economic development of the region.

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