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Use of firewood for artisanal ceramic production in a context of forest scarcity in Northeastern Brazil

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ABSTRACT

In this study, we sought to examine firewood use patterns in artisanal ceramic production by a quilombola community in the context of forest scarcity in Northeastern Brazil. This article aimed to answer the following questions: (1) Is the firing of ceramic products related to the perceived quality, diversity, or plant part used as firewood? (2) Does the diversity of plants used as firewood vary according to the age and gender of artisan potters? (3) What are the physical and energetic properties of the species most commonly used as firewood? Our main findings were that resource availability and accessibility seem to be the determining factors of firewood use. Exotic species were widely used. Variables commonly described as predictors of firewood diversity, such as age and gender, were not relevant in the context of forest scarcity. The most used exotic species have good physicochemical properties and can be a viable alternative to meet the firewood demand of ceramic production. However, the results showed that these species are more readily available to potters who have access to private woodlands. Therefore, in the studied context, we suggest the need for conservation strategies that foster the creation of energy forests composed of exotic species and, in parallel, promote conservation and reforestation actions aimed at native species.

Keywords: Firewood; Evolutionary ethnobiology; Human behavioral ecology.

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SIGNIFICANCE STATEMENT

We evaluated the factors that influence human decision making in the use of firewood. We evaluated whether if the firing of ceramic products related to the perceived quality, diversity, or plant part used as firewood. If plant diversity of plants used as firewood vary according to the age and gender of artisan. We arised insights for the development of biocultural conservation strategies.

INTRODUCTION

Firewood is a crucial energy source in several regions of the planet, particularly for local communities in developing countries (Ramos et al. 2008a,b). Many studies have analyzed patterns in the domestic use of firewood for cooking purposes (Ramos et al. 2008b; Specht 2012). However, firewood is used by local communities according to social needs and knowledge of its properties for many other purposes, which have been little studied. One such example is artisanal ceramic production—one of the oldest and most important human practices (Castilho et al. 2017; Ghiani Echenique et al. 2019).

In artisanal ceramic production, firewood is an essential material for the sintering process. This energy source is typically harvested from forest areas located close to production sites (Reis 2015; Silva et al. 2019). In Northeastern Brazil, extraction areas are commonly fragments of once continuous native forests that have been gradually replaced for agricultural or urbanization purposes (Silva et al. 2014; Joly et al. 2014). With the passage of time and population growth, the demand for firewood seems to have increased in poorer communities, leading to a problem of resource scarcity (Silva et al. 2018). This situation is further aggravated by legal restrictions on firewood extraction, such as occurs in the Atlantic Forest (Hirota and Ponzoni 2015).

Several research efforts have been made to assess firewood use patterns, producing relevant information for biocultural conservation strategies (Cruz et al. 2020; Morales et al. 2017). In some studies, resource availability is described as one of the main criteria for firewood selection, especially in contexts of scarcity (Silva et al. 2018; Kituyi et al. 2001). Other studies identified wood quality as the most important factor in firewood extraction, a property determined by factors such as calorific value, ash content, and moisture content, among other attributes (Ramos et al. 2008; Silva et al. 2019). Socioeconomic characteristics, such as age and gender, have also been identified as predictors of firewood use patterns (Ramos et al. 2008a). It should be noted that most studies investigated firewood consumption for cooking purposes. However, it is known that artisanal ceramic production, when integrated into the market, can be responsible for a high demand of firewood materials (Silva et al. 2019). Thus, it is necessary to improve our understanding of firewood use patterns for ceramic production in the context of forest scarcity.

In this study, we investigated firewood use patterns for artisanal ceramic production by a quilombola community in a context of forest scarcity in Northeast Brazil. We sought to answer the following questions: (1) Is the firing of ceramic products related to the perceived quality, diversity, or plant part used as firewood? (2) Does the diversity of plants used as firewood vary according to the age and gender of artisan potters? (3) What are the physical and energetic properties of the wood species most commonly used as firewood?

MATERIAL AND METHODS

Study area

The study was conducted in União dos Palmares, Serrana dos Quilombos, eastern Alagoas State, Brazil. Located 83 km from the state capital, União dos Palmares is bordered by the municipalities of São José da Lage, Ibateguara, Branquinha, Joaquim Gomes, and Santana do Mundaú (Figure 1). The municipality has a total area of 420,658 km^2, with an estimated population of 65,963 people (IBGE 2021). The region has tropical humid climate, with dry summers and rainy autumns and winters. The average temperature ranges from 18 to 28 °C, and the average annual rainfall is 1,634.2 mm, according to Mineral Resources Research Agency data (CRPM). Plant formations are part of the Atlantic Forest domain. The relief is characterized by lowlands and low plateaus with elevations between 400 and 538 m (Ferreira 2013). The economy of União dos Palmares is mainly based on livestock and crop production, with sugarcane crops having a prominent position. After an important sugar and alcohol plant ceased operations, a large part of the population began to depend on commercial activities, street markets, and jobs generated by City Hall agencies.

The tourist sector also holds great importance for the local economy, especially attractions that date back to the times of the Quilombo dos Palmares, such as ceramic crafts (Ferreira 2013). Tourism is strongly linked to the history of the municipality. Two important localities stand out, Serra da Barriga and Muquém. Serra da Barriga was the site of the most important quilombola revolution in Brazil, led by a warrior known as Zumbi (Lima 2008). Zumbi dos Palmares is widely respected as the heroic figure behind the Black warriors of the Quilombo dos Palmares, whose headquarters was located in Serra da Barriga, a sanctuary symbolizing the fight for freedom in the Americas (Tenrio and Costa 2015). In recognition of its contribution to the history of the country, Serra da Barriga was declared a historical, ecological, and landscape heritage site of the Federative Republic of Brazil under Law no. 84.017 of September 21, 1979 (Tenrio and Costa 2015). Serra da Barriga is also one of the most important archaeological sites in Brazil, where archaeologists from the Federal Universities of Minas Gerais, Bahia, and Alagoas found ceramic

remains dating back to seventeenth and eighteenth centuries (Lima 2008; Tenrio and Costa 2015). As for Muquém, it is the actual site where tourists can find remnants of the original Quilombo dos Palmares. Currently, the quilombola community (Figure 1) comprises 683 residents distributed into 180 families. Muquém is located westwards of the urban area of União dos Palmares, about 5 km from the urban center (Reis 2015).

The distance between the Muquém quilombola community and Serra da Barriga is about 15 km. In 2010, the structure of the community changed greatly as a result of a tragic flood that spread throughout the Vale do Paraíba and Mundaú region. Almost all houses were devastated by heavy rains and flood (Reis 2015). A government housing project built new houses for the community together with a crafts center, aimed at stimulating the generation of employment and income and valuing the local culture. Although the center is equipped with kilns, most crafters reported not using them because they are unsuitable for firing. According to the interviewed ceramists, they were not consulted about the necessary characteristics of pottery kilns before construction. Nevertheless, the Muquém community has been gaining prominence in the artisanal production of ceramic works, having received national and international acclaim. Local crafts are valued not only for their functionality but also for their artistic merit (Mello 2013).

Sample selection

Sampling was performed by the snowball technique, which is a non-probabilistic method. Experts were asked to indicate other people recognized as knowledge holders in the community until the saturation point was reached, that is, the point at which no new names were indicated (Baldin and Munhoz 2011). Thus, we identified 30 potters in União dos Palmares, 28 of whom were part of the Muquém community. Of the potters living in Muquém, 23 agreed to participate in the research.

Data collection

Prior to data collection, the project was approved by the Research Ethics Committee at the Federal University of Alagoas, in compliance with National Health Council Resolution No. 466 of 2012 (CAAE protocol No. 57201816.8.0000.5013). All ceramists who agreed to participate in the project signed an informed consent form declaring they were aware of the research objectives and methods and authorizing the use of information. Meetings were held with artisans, residents' associations, and school communities to explain the main research objectives, data collection process, and expected results.

Data collection started with the application of a socioeconomic questionnaire containing questions about place of birth, length of residence in the municipality, age, gender, profession, and income. Then, participants were asked about their experiences with the ceramic activity, including problems, difficulties, and challenges. Semi-structured interviews were conducted to collect information on firewood use for ceramic sintering, including resource accessibility, collection methods, distance to collection sites, transportation, collection frequency, units of measurement, local criteria for firewood classification, kiln use, firing process, and use of firewood stocks. In cases where interviewees stored firewood, stocks were measured for the calculation of the stacked wood volume (expressed in steres) by multiplying the width, length, and the average of up to five height measurements of the woodpile (Ramos et al. 2010) (Figure 2).

The woody species used by artisanal ceramists were identified by the free listing technique (Albuquerque et al. 2010). For more comprehensive results, we applied the rereading method, whereby the participant had apparently exhausted all firewood species they could remember, all species were read back to them in an attempt to improve memory retrieval (Albuquerque et al. 2010). After the list was constructed, ceramists were asked to inform the use frequency and perceived quality of each species. These responses were graded on a Likert scale ranging from one to five, with one representing the lowest grade and five the highest.

Firewood collection sites were visited on a guided tour (Albuquerque et al. 2010) led by the ceramists responsible for wood collection. On these occasions, in addition to identifying extraction sites, we collected botanical samples of the species cited by interviewees. Samples were sent for identification at the MAC Herbarium of the Alagoas Environmental Institute (IMA).

The species with the highest frequency of citations were evaluated for physical and energetic properties. Wood samples were collected directly from the firewood stocks of three randomly selected potters. One of the species with the highest frequency of citations was not found in any stock, which precluded its analysis. Thus, a total of three species were selected for analysis.

Data analysis

Socioeconomic characteristics of potters and firewood use, ceramic sintering, and wood species data were examined qualitatively and quantitatively. The data were subjected to descriptive analysis, and the

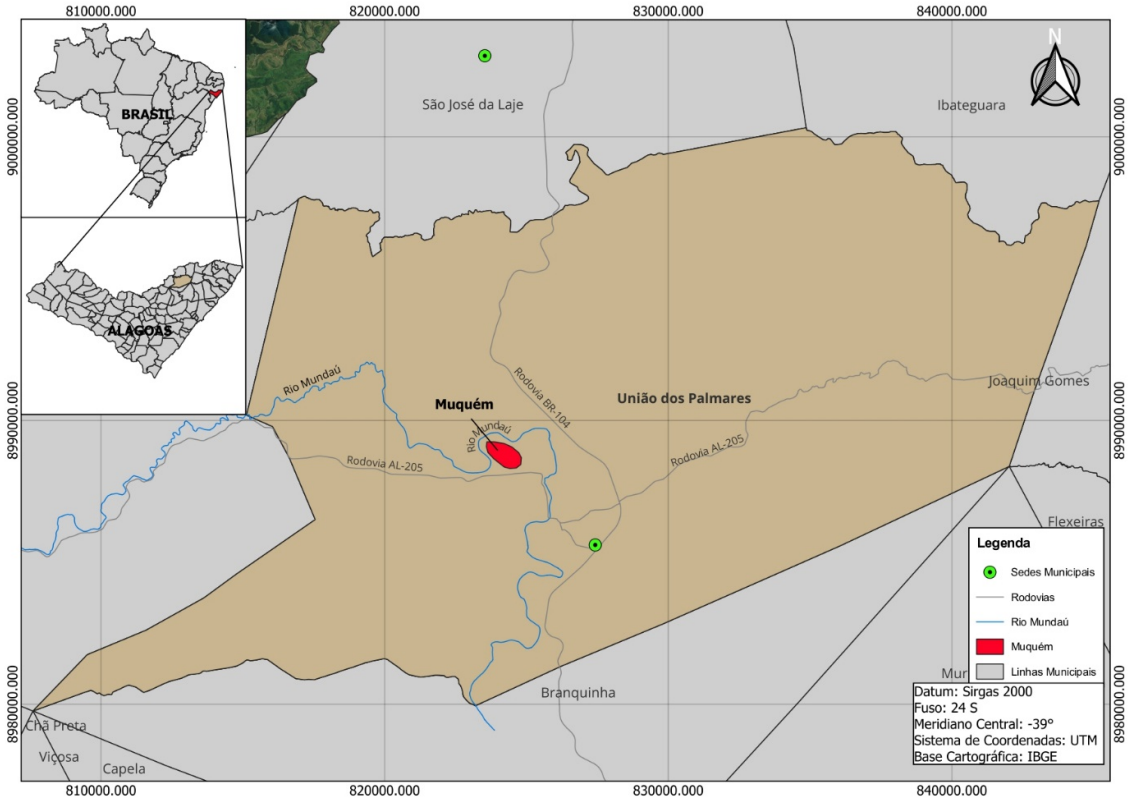

Figura 1. Location map of Muquém, União dos Palmares, Alagoas State, Brazil. Source: prepared by the author's.

Figura 2. Measurement of firewood piles. Muquém, União dos Palmares, Alagoas State, Brazil. Source: author's archive, 2017.

results are presented as frequencies and means.

To investigate whether artisanal ceramic production is influenced by potters' perception about firewood characteristics, we subjected the results of

perceived species quality at the different stages of ceramic firing to the Mann–Whitney test. Fisher's exact test was used to assess differences in the plant parts used at different stages of firing. Differences in species diversity according to stage of firing were assessed using the Wilcoxon test. Simple linear regression was used to investigate differences in the use of firewood diversity according to potter age and gender. All analyses were performed using BioStat and R software.

Wood material preparation consisted of reducing and grinding the samples in a Willey mill and sieving through a set of sieves. The material that passed through 40-mesh sieves and retained on 60-mesh sieves was used for analysis (Sá 2016). After sieving, samples were stored in plastic bags until use.

Firewood samples were analyzed for physical and energetic characteristics, including moisture and basic density, determined in triplicate, and ash and calorific value, determined using composite samples in duplicate and triplicate, respectively. Moisture was determined according to ASTM D-4442 (ASTM 2003a). Ash content determination followed ASTM D-1102-84 (ASTM 2003b). Calorific value was determined according to ASTM D-5865 (ASTM 2003c). Briefly, 1g of material was weighed (dry weight basis) and the calorific value was determined using an IKA C2000 bomb calorimeter. Basic density was determined by the immersion method, according to NBR 11941 (Associação brasileira de normas técnicas 2003), and calculated using the equation Density (g/cm^3) = Dry weight (g)/Displaced volume (cm^3).

RESULTS

Socioeconomic characterization of potters

Most of the interviewed potters stated that they had always resided in the Muquém quilombo (84.62%), and the other interviewees (15.38%) stated that they had resided in the community for more than 20 years. The age of interviewees ranged from 44 to 78 years, and most of the potters were female (78.26%).

Artisanal ceramic production was deemed an important source of income by 77.78% of interviewees. The average monthly income of 40.54% of the participants was one minimum wage (R$ 295.53 at the time of the research); 21.62% declared receiving up to three minimum wages, 35.14% declared receiving less than one minimum wage, through government subsidies, and 2.70% reported not having a fixed monthly income.

Lack of employment was indicated by 47.83% of interviewees as the main local problem. Despite this, almost half (46.15%) of the participants had stopped performing ceramic production. The reasons for abandoning the activity were difficulty in finding firewood (35.71%), health problems and advanced age (35.71%), and other factors (28.57%), such as involvement in other activities.

Lack of firewood was cited as a threat to ceramic production by 29.63% of participants. Health problems (25.93%), difficulty in obtaining clay (14.81%), and decreased sales (14.81%) were other factors hindering the performance of artisanal ceramists. Lack of interest by young people was stated by 14.81% of participants as a factor threatening continuity in the activity.

Firewood extraction for ceramic firing

Firewood was a difficult to access resource for 71.43% of the interviewed potters. According to the potters, difficulty in obtaining firewood has increased over time. Most of the potters (57.89%) attributed this increased difficulty to the decrease in forest areas, resulting from deforestation by sugar and alcohol agribusinesses in the region. Nevertheless, the majority of active potters continue to harvest firewood (68.89%). Only 11.11% of potters reported buying firewood to supplement their stock.

A considerable part of interviewees (46.67%) had small wooded areas or access to private woodlands delimited by hedges of *Mimosa caesalpiniifolia* Benth., from where they collected firewood. The distance to collection sites ranged from 1 to 5 km. All potters stated that they collected firewood on foot. In many cases, potters also used firewood for other purposes, such as cooking (37.78%). The frequency of collection varied greatly among potters, ranging from four times a month to twice a year. Dry months (September to April) represented the period with the highest intensity of collection.

The units of measurement of stored firewood used by locals were bundle (66.67% of participants) and meter (33.33% of participants). Among active potters, 42.11% had a stock of firewood at home at the time of the interview. Potters stocked firewood separately according to wood thickness. The categories were as follows: thick logs, thin logs, and woodchips. On average, firewood stocks were composed of 121.32 steres of thick logs, 18.79 steres of thin logs, and 42.79 steres of woodchips.

Some of the active potters had partnerships for the joint use of kilns for ceramic firing. Five kilns were used specifically for this process. Of these, three were shared among craftspeople. Four of the kilns were hand-built and rustic. Only one of the kilns was built in masonry, which was located in the crafts center of the Muquém quilombo.

The majority of potters (82.60%) stated that ceramic firing occurs in two stages. These steps were defined by them as heating (stage one) and candling (stage two). However, a smaller part of the informants (21.73%) mentioned a third stage, called cleaning (stage three). According to the potters, the beginning of firing (heating) is carried out using thick firewood (logs). Wood with large diameter is used to maintain the kiln at high temperatures. Stage one is the longest, lasting on average 6 h. Then, thin logs and woodchips are added, which combust easily, forming flames. Potters informed that stage two, lasting about 2 h, serves to clean the ceramics.

Species used as firewood for ceramic production

A total of 51 species were identified, distributed in 20 botanical families (Table 1). The most representative family in terms of number of species was Fabaceae (11 spp.). Four species stood out for being mentioned by more than half of the interviewees, namely Bambusa vulgaris Schrad. ex J.C.Wendl. (87.0%), *Mangifera indica* L. (69.6%), *Mimosa caesalpiniifolia* Benth. (56.5%), and *Inga edulis* Mart. (52.2%) (Table 1). Although the exotic species *B. vulgaris*, *M. indica*, and *M. caesalpiniifolia* had a higher number of users, native species were cited at a higher frequency (54.8%). Fourteen species had a high frequency of use. Those with the highest number of users were *Guazuma ulmifolia* Lam. (30.4%), camará (indeterminate 4) (30.4%), *Cordia* sp. (13.0%), *Bowdichia virgilioides* Kunth (13%), and *Croton heliotropiifolius* Kunth (13%) (Table 1).

Regarding perceived quality, 25 species received the maximum score (5.0). Of these, those with the highest number of users were *M. caesalpiniifolia* (56.5%), *I. edulis* (52.2%), *G. ulmifolia* (30.4%), camará (indeterminate 4) (30.4%), and taboca (indeterminate 9) (30.4%) (Table 1).

Tabela 1. Species used as firewood by potters in the Muquém Quilombo, União dos Palmares, Alagoas State, Brazil.

Family / Specie	Common name	Origin	No. Users	% of Users	Average frequency	Average quality
Anacardiaceae						
Anacardium occidentale L.	Cajueiro	Native	8.0	34. 8	3.0	3.5
Mangifera indica L.	Mangueira	Exotic	16.0	69.6	4.3	4.5
Spondias mombin L.	Cajá	Native	2.0	8.7	3.0	3.0
Arecaceae						
Cocos nucifera L.	Coqueiro	Exotic	5	21.7	3.4	5.0
Bignoniaceae						
Tabebuia impetiginosa (Mart. Standl.)	Pau d'arco	Native	2	8.7	5.0	5.0
Boraginaceae						
Cordia sp.	Frei Jorge	Native	3	13.0	5.0	5.0
Varronia sp.	Moleque-duro	Native	3	13.0	3.7	5.0
Combretaceae						
Terminalia catappa L.	Amendoeira	Exotic	1	4.3	-	-
Euphorbiaceae						
Croton heliotropiifolius kunth	Velame	Exotic	3	13.0	5.0	5.0
Manihot esculenta Cratz	Mandioca	Native	5	21.7	4.2	4.2
Ricinus communis L.	Carrapateira	Exotic	2	8.7	1.0	5.0
Fabaceae						
Anadenanthera colubrina (Vell.) Brenan	Angico	Exotic	8	34.8	4.0	4.5
Bowdichia virgiliodies Kunth	Sucupira	Native	3	13.0	5.0	5.0
Cassia grandis L. f.	Canafístula	Exotic	1	4.3	-	-
Hymenaea courbaril L.	Jatobá	Native	2	8.7	5.0	5.0
Inga edulis Mart.	Ingá	Native	12	52.2	4.7	5.0
Machaerium aculeatum Raddi	Mau vizinho	Native	7	30.4	3.9	3.9
Machaerium isadelphum (E.Mey.) Standl.	Espinho branco	Native	2	8.7	5.0	5.0
Macrosamanea pedicellaris DC. Kleinh	Canzenze	Native	1	4.3	-	-
Mimosa caesalpiniifolia Benth.	Sabiá	Exotic	13	56.5	4.4	5.0
Mimosa tenuiflora (Willd.) Poir.	Jurema	Exotic	2	8.7	1.0	5.0
Samanea sp.	Bordão de velho	Native	1	4.3	-	-
Lamiaceae						
Hyptis sp.	Não definido	Native	1	4.3	-	-
Vitex sp.	Maria Preta	Native	1	4.3	-	-
Malpighiaceae						
Malpighiae marginata DC.	Acerola	Exotic	1	4.3	-	-

Continues...

Family / Specie	Common name	Origin	No. Users	% of Users	Average frequency	Average quality
Byrsonima sericea DC.	Murici	Native	1	4.3	-	-
Malvaceae						
Guazuma ulmifolia Lam.	Cabotã	Native	7	30.4	5.0	5.0
Moraceae						
Artocarpus heterophyllus Lam.	Jaqueira	Exotic	9	39.1	4.1	4.1
Brosimum sp.	Quiri	Native	1	4.3	-	-
Myrtaceae						
Myrcia sp.	Guabiroba	Native	1	4.3	-	-
Psidium guajava L.	Goiaba	Exotic	2	8.7	3.0	5.0
Syzygium cumini (L.) Skeels	Azeitona	Exotic	2	8.7	3.0	3.0
Oxalidaceae						
Averrhoa carambola L.	Carambola	Exotic	1	4.3	-	-
Poaceae						
Bambusa vulgaris Schrad. ex J.C.Wendl	Bambu	Exotic	20	87.0	4.4	4.8
Saccharum officinarum L.	Cana-de-açúcar	Exotic	3	13.0	2.3	2.3
Zea mays L.	Milho	Exotic	2	8.7	5.0	5.0
Polygonaceae						
Coccoloba sp.	Cabaçu	Native	3	13.0	3.7	5.0
Rhamnaceae						
Ziziphus joazeiro Mart.	Juá	Exotic	3	13.0	3.7	5.0
Rubiaceae						
Genipa americana L.	Jenipapo	Native	1	4.3	-	-
Rutaceae						
Citrus sp.	Laranjeira	Exotic	2	8.7	5.0	5.0
Sapindaceae						
Talisia esuculenta (Cambess.) Radlk.	Pitomba	Native	5	21.7	4.2	4.2
Urticaceae						
Cecropia sp.	Embaúba	Native	1	4.3	-	-
Unidentified						
Undetermined 1	Agarrador	-	1	4.3	-	-
Undetermined 2	Cabeluda	-	1	4.3	-	-
Undetermined 3	Café branco	-	2	8.7	5.0	5.0
Undetermined 4	Camará	-	1	4.3	-	-
Undetermined 5	Cipó	-	1	4.3	-	-
Undetermined 6	Mutamba	-	4	17.4	2.0	5.0
Undetermined 7	Pirim	-	2	8.7	5.0	5.0
Undetermined 8	Santa Maria	-	2	8.7	5.0	5.0
Undetermined 9	Taboca	-	7	30.4	4.4	5.0

Does ceramic firing have any relation to the perceived quality, diversity, or parts of plants used as firewood?

There was no significant relationship between firing and perceived quality of species at different stages ($z = 0.4729$, $p > 0.05$). There were also no significant differences in plant diversity according to firing stage ($z = 1.42$, $p > 0.05$). That is, the number of plant species used did not differ between firing stages. However, firing stage significantly influenced ($p < 0.0001$) the part of plant used as firewood, whether trunks, branches, or sticks.

Does the diversity of plants used as firewood vary according to potter age and gender?

We did not identify any significant relationship between plant diversity and potter age or gender ($R2 = 0.0403$, $p > 0.05$). That is, neither of the variables (age or gender) was related to the number of plant species used as firewood by potters.

What are the physical and energetic properties of the species most used as firewood?

The three species with the highest frequency of use citations were analyzed and compared regarding moisture content, density, caloric value and ash content (Figure 3). *I. edulis* had the highest moisture content (13.1%), followed by *B. vulgaris* (9.5%). *M. caesalpiniifolia* had the highest density (0.786 g/cm^3); and *I. edulis*, the lowest (0.396 g/cm^3). The highest calorific value was observed in *M. caesalpiniifolia* (4685.3 kcal/kg) and the lowest in *B. vulgaris* (4316.7 kcal/kg). Similar results were observed for ash content. *M. caesalpiniifolia* had the lowest ash content (0.9%) and *B. vulgaris* the highest (4.9%).

DISCUSSION

The scarcity of forest areas for firewood collection is one of the main obstacles to ceramic production in the Muquém quilombo. This difficulty has contributed to abandonment of the activity, despite its economic and cultural importance in the local context. This trend of abandonment is worrisome. Insertion of artisanal ceramic products in the market could represent a strategy to promote income generation and biocultural conservation, as has occurred with other artisanal products (Martnez and Manzano Carga 2019). However, adoption of this strategy in the context of the Muquém quilombo would likely lead to an increased demand for firewood (Silva et al. 2019). Therefore, it would be necessary to establish mechanisms to increase the supply of firewood, such as restoration of forest areas for common use.

Many studies have demonstrated the importance of remnant forest areas for firewood extraction by local populations (Cruz et al. 2020). However, in the study region, these areas have become increasingly far, degraded, and subject to restrictions on resource use (Hirota and Ponzoni 2015). These factors explain the high number of potters utilizing firewood from small private woodlands. It also helps to understand the considerable wealth of exotic species (45.2% of reported species) used as firewood for pottery in the community. Such species are also the most frequently used by potters.

It seems evident that private woodlands contain more exotic species than native forest fragments. Exotic species are more frequently used by potters possibly because of their availability and accessibility. The role of exotic plants is essential to minimize the use of native plants. Depending on the firewood collection environment, its relationship with deforestation rates or the extraction of native plants, exotic plants may play an important role in the conservation of native species (Jiménez-Escobar et al. 2021). It is important to consider that the processes of invasion of exotic species are natural and social, since individuals' choices, increasingly, can reduce the probability of a species becoming invasive (Martínez and Manzano García 2019).

In a study on the domestic use of firewood in the Muquém quilombo, Silva et al. (2018) observed that the exotic species *M. caesalpiniifolia*, which serves as a hedge plant, was highly used by the population. We obtained a similar result with regard to the predominance of this species as firewood for ceramic production.

An interesting result was the use of non-woody species, such as *Manihot esculenta* Crantz, *Saccharum officinarum* L., and *Zea mays* L., as firewood. Although few potters reported using these plants, their use suggests that active potters might be choosing more available and accessible plants instead of species with better quality. The socioecological theory of maximization, more specifically, the model of maximum environmental utilization, provides an explanation (Albuquerque et al. 2019). According to the model, the resources most likely to be incorporated and used in socioecological systems are those that confer the maximum return, considering that the entry and differential use of natural resources by human populations follows a logic of reducing costs and maximizing benefits.

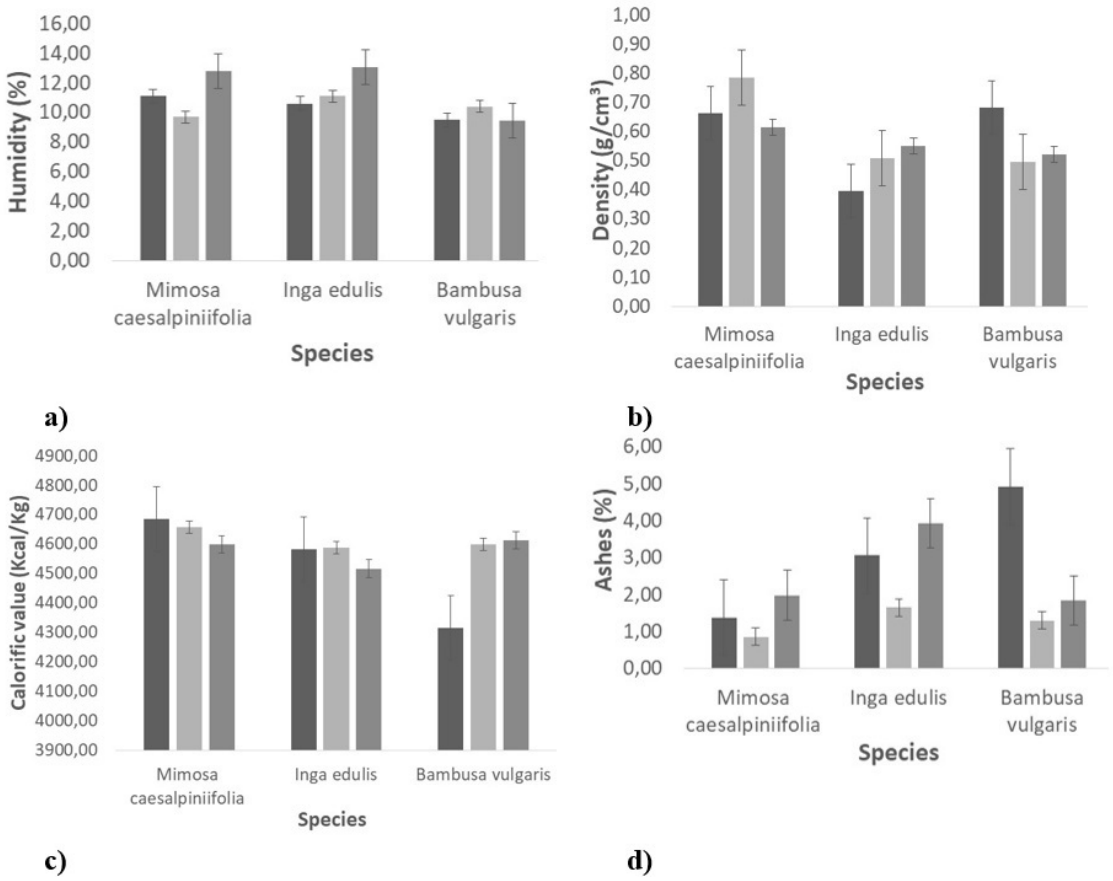

Figura 3. (a) Moisture, (b) density, (c) calorific value, and (d) ash content of sabiá (*Mimosa caesalpiniifolia* Benth.), ingá (*Inga edulis* Mart.), and bamboo (*Bambusa vulgaris* Schrad. ex J.C.Wendl.).

Does ceramic firing have any relation to the perceived quality, diversity, or parts of plants used as firewood?

The perceived quality and diversity of species used as firewood did not differ according to firing stage. These findings may be attributed to the high number of potters using the more available exotic species. Native species, on the other hand, had a higher perceived quality and frequency of use. Therefore, although they are less accessible, a greater number of native species are perceived as having better quality and are used more frequently when available. Our results reinforce the idea of biocultural adaptation in the selection and use of exotic species for firewood based on resource availability (Martínez and Manzano García 2019).

It is possible that the difficulty of access to native resources influenced the results. The need to travel longer distances to collect wood in forest remnants is a limiting factor, particularly for potters of older age. In general, factors such as availability and accessibility seem to influence extraction of wood resources (Ramos et al. 2008b). Silva et al. (2019) indicated that availability is the second most important criterion influencing the selection of plants. Although quality is important, availability can influence the first criterion. In an environment with low availability of high-quality material, preferences are reconsidered.

A similar trend was observed for species diversity in the different firing stages. Because there are few available species, potters tend to use the same type of plant for the different stages of firing, varying only the part of plants used in each stage (e.g., trunk, branches, and sticks). It should be noted that, although species diversity did not differ according to firing stage, the number of species used for this purpose was higher than that used for domestic purposes. Oliveira (2016) recorded only 27 species used as firewood for cooking in the Muquém quilombo. The higher number of species recorded here for pottery use than that reported by Oliveira (2016) may be related to the profile of interviewees. Apparently, artisanal potters use a greater repertoire of firewood plants than individuals using firewood for cooking. Silva et al. (2018) recorded a total of 39 species as firewood for domes-

tic and artisanal purposes in a community inserted in the Pernambuco agreste. According to the author, ceramic artisans may be considered "local experts" on firewood, as they knew a higher number of species used for firewood than other users.

The part of plant used as firewood differs according to the stage of ceramic firing. In the first stage, firewood is used to heat the furnace; thus, thicker firewood is used (obtained from tree trunks, for example). These parts allow the kiln to maintain constant temperature for about 4 h. In the second stage, according to the interviewees, thin logs are used (obtained from tree branches, for example). These materials generate a more intense flame, which is maintained for finalization of the process (about 2 h). It can be said that the first stage is the most harmful in terms of conservation, as it requires the use of thick wood, that is, the most critical part of plants.

Does the diversity of plants used as firewood vary according to potter age and gender?

Contrary to trends observed in the literature, our results revealed that age and gender do not influence the diversity of species used as firewood for ceramic production in the Muquém quilombo. It is expected that older individuals have greater knowledge about firewood species (Ramos et al. 2008a), as older people would have had more time to accumulate experiences about the environment. However, such a difference was not observed in the current study probably because of the advanced age of most potters. Gender is also an important factor influencing knowledge about plants for different uses. For instance, women generally have greater knowledge about medicinal and edible plants than men, attributed to the social role of women in taking care of family health and nutrition (Pinto et al. 2006). These interpretations need to be considered according to the reality of populations, as social roles vary greatly depending on the culture. Silva et al. (2019) observed that both men and women gather firewood for ceramic firing, suggesting that knowledge about wood species is shared between genders.

Physical and energy properties of the most commonly used firewood species

Our results revealed differences in the energy potential of species most frequently used as firewood during ceramic production. The quality of combustible species is assessed locally through their perceived efficiency. According to Ramos et al. (2008b), the physical and chemical characteristics of firewood may strongly influence combustion. Moisture, density, calorific value, and ash content are the most relevant aspects for assessment of energy potential (Ramos et al. 2008b). Here, the preference for firewood species did not seem to be related to these characteristics alone. For example, although *M. caesalpiniifolia* had the best results in terms of density, calorific value, and ash content, it was not the most cited species. In fact, the most cited species, *B. vulgaris*, had the worst calorific value and ash content. Given these findings, it is likely that choice of species for firewood depends on both physicochemical characteristics and availability. This hypothesis would explain the fact that, of the three most cited species, two are exotic and have greater availability in the region. It seems that exotic species serve to diversify the repertoire of fuelwood in situations of scarcity (Silva et al. 2018; Martínez and Manzano García 2019; Jiménez-Escobar et al. 2021). The good energy potential, availability, and accessibility of exotic species seem to justify their prominence in the studied context.

CONCLUSION

The scarcity of forest areas hinders access to firewood and represents a limiting factor for the strengthening of ceramic production, which has economic and cultural importance. Firewood availability and accessibility seem to be determinant factors for the choice of species, explaining why exotic species were frequently used.

Variables that usually stand out as predictors of firewood species diversity, such as gender and age, did not contribute to explaining the choice of firewood plants in the context of forest scarcity. This finding might be attributed to the specialized knowledge and advanced age of potters.

The most used exotic species have good physicochemical characteristics, representing a viable alternative to meet the demand for firewood for ceramic production. However, these species are more readily available to potters who have access to small private woodlands. Therefore, we suggest the need for conservation strategies that foster the creation of energy forests with exotic species and promote parallel actions of native species conservation and reforestation.

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DATA AVAILABILITY

Data used to support the findings of this study are available from the authors.

CONFLICT OF INTEREST

The authors have no conflicts of interest to declare.

CONTRIBUTION STATEMENT

Conceived of the presented idea: MMSS, VAS, PMM, RRVS.
Carried out the experiment: MMSS, ISF, RSC, VAS, PMM, RRVS.
Carried out the data analysis: VAS, PMM, RRVS.
Wrote the first draft of the manuscript: MMSS, ISF, RSC, VAS, PMM, RRVS.
Review and final write of the manuscript: RSC, VAS, PMM, RRVS.
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