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Energy aspects of *Eucalyptus saligna* wood in a seven-year-old plantation

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Abstract. The objective of this study was to characterize the energy parameters of wood and energy production from a seven-year-old experimental plantation of *Eucalyptus saligna*. For this purpose, information was collected from an experimental planting spaced at 3.0 m x 3.0 m in Chapadão do Sul, MS, Brazil.Values were obtained for the diameter and height of the trees, which were felled and rigorously cubed to obtain the volumes of wood. Wood and plantations were characterized in relation to: proximate chemical, calorific value, wood basic density and annual production of wood and energy.Trees and planting were able to yield satisfactory estimates of energy production in relation to annual wood production. The immediate chemical composition of the wood was 82.85%, 17.07% and 0.08% for volatile materials, fixed carbon and ash, respectively. The evaluated woods can be classified as medium basic density, and can be recommended for use with energy purposes.Therefore, the evaluated *E. saligna* woods showed results that characterize these materials as suitable for energy use, with potential for the production of energy forests. In this way, they can meet the demands of forest biomass for this purpose.
Keywords: Forest biomass, wood production, energetic forest, energy matrix

Introduction

The use of forest biomass in the Brazilian energy matrix has been increasing every year. Among renewable energy sources, in a report released by the National Energy Balance, biomass is the third most used, representing about 8.2% (EPE, 2022). In this reality, the use of agro-industrial residues has been growing, but there is an emphasis on the planting of species that serve as this raw material, especially forest stands. Among these stand out the species of the genus *Eucalyptus*.

The species *E. saligna* is characterized as an excellent raw material for the production of sawn wood, especially for use as solid pieces. In this case, the reuse of by-products from this industry can also encourage energy generation, since yields in *Eucalyptus* sawn wood are generally not higher than 50%(Ferreira et al., 2004; Juizo et al., 2014; Carvalho et al., 2019).

On the other hand, the formation of forests for the production of biomass for energy becomes one of the ways to improve the energy production derived from forest biomass. Therefore, the objective of this study was to characterize the energy parameters of wood and energy production from a seven-year-old experimental planting of *E. saligna*.

Methods

Characterization of the planting area

The trees collected came from an experimental planting with various genetic materials of *Eucalyptus* spp., developed in the municipality of Chapadão do Sul - MS, Brazil. At the time of collection, it had been implanted for seven years, with spacing of 3.0 m x 3.0 m. The climate of the region is characterized as humid tropical according to the Köppen classification, with an altitude of 820 m, annual temperature ranging from 13-29ºC and average annual precipitation of 1,850 mm (Alvares et al., 2013; Cunha et al., 2013).

Measurements and collection of trees

Three trees were sampled to carry out the characterizations. The trees were measured in diameter and height, being duly felled and rigorously cubed. Then, the measurements were used to determine the wood volumes of the trees, using the Smalian method in this process.

Collection of wood disks and determination of basic density

For each tree, a disk of approximate thickness of 5 cm was collected at the base. This material was used to determine the basic density of the wood using the hydrostatic balance method, in accordance with the standard NBR 11941 (ABNT, 2003). Each disk was separated into four wedges, the two being sampled immediately in opposite dispositions for evaluation.

Collection and energy characterization of wood

For the energetic characterization, woods were sampled in the first two meters of the trees. Then, this material was pre-dried in an oven at 65ºC and ground in a Willey knife mill, and subsequently sieved until obtaining a 60 mesh granulometry. This material was used to determine the proximate chemical of the wood, obtaining values for ash, volatile matter and fixed carbon, in accordance with the standard D1762-84 (ASTM, 2013). The lower calorific value was calculated from the equation suggested by Nock et al. (1975) and adapted by Gatto (2002), described below:

$$\mathrm{LCV} = \rho_{\mathrm{bd}} * \left[4500 - 52 * \left[\frac{\mathrm{MC}}{1 + \left(\frac{\mathrm{MC}}{100}\right)}\right]\right] * 1.162294\mathrm{E}^{-3}$$

In what: LCV = lower calorific value, in kwh.m^{-3};ρbd = basic density of wood, in kg.m^{-3}; MC = moisture content, in %.

The high calorific value was estimated from the equation described by Brand (2010), adapted as follows:

$$\mathrm{HCV} = \mathrm{LCV} + 600 * (0{,}09\mathrm{H})$$

In what: HCV = high calorific value, in kwh.m^{-3}; H = hydrogen content in biomass, in %.

In this step, the hydrogen content corresponding to 5.87% was used. According to Brand (2010), this is the average content of this element in angiosperm biomass. The values were converted into calorific energy using the relation 0.00116 kwh = 1 kcal (Santos et al., 2013).

Estimated annual energy production

To estimate the annual energy production of planting, the steps described by Lins et al. (2021) were applied. The following were determined: (i) annual wood volume (m³.ha^{-1}.year^{-1}); (ii) the annual electric energy production (kwh.ha^{-1}.year^{-1}); and (iii) the annual calorific production (Gcal.ha-1.year^{-1}).

Statistical analyzes

For each parameter, the mean, maximum and minimum values were obtained, together with the coefficients of variation. The analyzes were carried out in Microsoft Office Excel, from the Office 2019 package.

Results and discussion

Planting and woods were properly characterized. The results can be seen in Table 1. The trees developed well. More dense plantings, such as those implanted with 3.0 m x 3.0 m spacing, tend to generate trees with smaller diameters (Rezende et al., 2008; Hébert et al., 2016). However, it is observed that there was a satisfactory growth, promoting the production of biomass. Commonly, this and smaller spacings, such as 3.0 m x 2.0 m, are applied to generate a greater volume of wood per area (Silveira et al., 2014; Corrêa et al., 2020), being applied for the development initial energy forests.

Trugilho et al. (2001) characterized a seven-year-old *E. saligna* plantation in a spacing of 3.0 m x 2.0 m. The results obtained demonstrate a smaller growth than the trees evaluated in this work, with average total diameters and heights of 16.5 cm and 19.0 m, respectively.

The proximate chemical composition values behaved as expected. According to Brand (2010) and Cortez et al. (2008), the biomass of leafy species presents around 81% of volatile matter, 18% of fixed carbon and < 1% of minerals.This trend was observed for *E. saligna*wood evaluated in several works (Cordeiro et al., 2001; Almeida et al., 2010;Juizo et al., 2017; Simetti et al., 2018).

The evaluated woods can be classified as medium basic density (SFB, 2022). Due to their density greater than 500 kg.m^{-3}, these Eucalyptus woods can be recommended for use with energy purposes (Protásio et al., 2021).

The results for energy production were considerably higher than those found for charcoal production from various Eucalyptus genetic materials developed in the Brazilian semi-arid region evaluated by Lins et al. (2021). Despite these being planted at 3.0 m x 2.0 m spacing, which results in a greater number of trees per hectare compared to the spacing evaluated in this work, in addition to the different ages, the differences in the average annual increment were the main responsible by the discrepancy in energy production.

Simettiet al. (2018) evaluated the energy potential of seven-year-old Eucalyptus plantations. For energy production from *E. saligna* wood, the authors found a value of 1053.33 Gcal.ha^{-1}, corresponding to about 150.5 Gcal.ha^{-1}.year^{-1}. This value was close to that found in this work.

The evaluated trees were seven years old. *Eucalyptus* plantations aimed at energy production tend to be younger in age, generally being cut close together in age groups between five and eight years old (Lafetá et al., 2021). Reducing cutting ages can encourage rapid replanting of areas, seeking more biomass production. In addition, denser plantations encourage greater wood production per area in short cycles (Sereghetti et al., 2015; Hébert et al., 2016), which can increase the energy production of these forests.

Table 1. Estimated annual production of energy produced from a seven-year-old *Eucalyptus saligna* experimental plantation in Chapadão do Sul, MS, Brazil.

Parameters	Minimum	Average	Maximum	Coefficient of variation (%)
Diameter at 1.30 m from the ground (cm)	17.41	18.92	20.63	8.55
Total height of the tree (m)	26.30	27.40	28.20	3.59
Height of the tree trunk (m)	20.23	21.72	22.70	6.04
Volume of wood per tree (m^3)	0.246	0.284	0.315	12.27
Volume of wood per area ($m^3.ha^{-1}$)	273.61	316.00	349.72	12.27
Ash content (%)	0.05	0.08	0.14	34.67
Volatile matter content (%)	81.27	82.85	84.04	1.18
Fixed carbon content (%)	15.89	17.07	18.66	5.66
Lower calorific value ($kwh.m^{-3}$)	3258.90	3434.43	3610.56	5.12
High calorific value ($kwh.m^{-3}$)	3575.88	3751.41	3927.54	4.69
Basic density of wood ($kg.m^{-3}$)	505.28	536.71	572.18	5.76
Annual wood production ($m^3.ha^{-1}.year^{-1}$)	39.09	45.14	49.96	12.27
Annual calorific production ($Gcal.ha^{-1}.year^{-1}$)	120.49	146.36	161.54	15.38
Annual electricity production ($kwh.ha^{-1}.year^{-1}$)	139,773.0	169,775.9	187,388.8	15.38

Conclusion

The *E. saligna* wood evaluated showed results that characterize these materials as suitable for energy use, with potential for the production of energy forests.An energy production potential of around 150 $Gcal.ha^{-1}.year^{-1}$was estimated.In this way, they can meet the demands of forest biomass for this purpose.

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References

ALMEIDA, G., BRITO, J.O., PERRÉ, P. Alterations in energy properties of eucalyptus wood and bark subjectedto torrefaction: The potential of mass loss as a synthetic indicator. Bioresour. Technol. Vol. 101, p. 9778-9784, 2010. https://doi.org/10.1016/j.biortech.2010.07.026.

ALVARES, C.A., STAPE, J.L., SENTELHAS, P.C., GONÇALVES, J.L.M., SPAROVEK, G. Köppen's climate classification map for Brazil. Meteorol. Zeitschrift. Vol. 22, n. 6, p. 711-728, 2013. http://dx.doi.org/10.1127/0941-2948/2013/050.

AMERICAN SOCIETY FOR TESTING AND MATERIAL - ASTM. D1762-84 2013: Standard test method for chemical analysis of wood charcoal. West Conshohocken: ASTM, 2013. 2p.

ASSOCIAÇÃO BRASILEIRA DE NORMAS TÉCNICAS - ABNT. NBR 11941: madeira - eficiência da densidade básica. Rio de Janeiro: ABNT, 2003. 6p.

BRAND, M. A. Energia de biomassa florestal. Rio de Janeiro: Interciência, 2010. 131p.

CARVALHO, D.E., ROCHA, M.P., TIMOFEICZYK JUNIOR, R., KLITZKE, R.J. Rendimento e variedade de produtos no desdobro de toras de *Eucalyptus* spp. TECNO-LÓGICA. Vol. 23, n. 1, p. 08-13, 2019. https://doi.org/10.17058/tecnolog.v23i1.12215.

CORDERO, T., MARQUEZ, F., RODRIGUEZ-MIRASOL, J., RODRIGUEZ, J. Predictingheatingvaluesoflignocellulosicsandcarbonaceousmaterialsfromproximateanalysis. Fuel. Vol. 80, n. 11, p. 1567-1571, 2001. https://doi.org/10.1016/S0016-2361(01)00034-5.

CORRÊA, R.S., SOARES, T.S., ALVES, M.A., SOUSA, J.P., VIEIRA, E.M. Espaçamentos de plantio promovem produção distinta em híbrido de eucalipto. Adv. For. Sci. Vol. 7, n. 3, p. 1073-1079, 2020. http://dx.doi.org/ 10.34062/afs.v7i3.7887.

CORTEZ, L.A.B., LORA, E.E.S., GÓMEZ, E.O. Caracterização da biomassa. In: CORTEZ, L.A.B., LORA, E.E.S., GÓMEZ, E.O. Biomassa para energia. Campinas: Editora da Unicamp, 2008. p. 31-52.

CUNHA, F.F., MAGALHÃES, F.F., CASTRO, M.A. Métodos para estimativa da evapotranspiração de referência para Chapadão do Sul - MS. REVENG. Vol. 21, n. 2, p. 159-172, 2013.https://doi.org/10.13083/reveng.v21i2.346.

EMPRESA DE PESQUISASENERGÉTICAS - EPE. Balanço energéticonacional 2022: ano base 2021. Rio de Janeiro: Ministério deMinas e Energia, 2022. 292p.

FERREIRA, S., LIMA, J.T., ROSADO, S.C.S., TRUGILHO, P.F. Influência de métodos de desdobro tangenciais no rendimento e na qualidade da madeira de clones de *Eucalyptus* spp. Cerne. Vol. 10, n. 1, p. 10-21, 2004.

GATTO, D.A. Avaliação quantitativa e qualitativa da utilização madeireira na região da Quarta Colônia de imigração italiana no Rio Grande do Sul. 108 f. Dissertação (Mestrado em Engenharia Florestal) – Universidade Federal de Santa Maria, Santa Maria, 2002.

HÉBERT, F., KRAUDE, C., PLOURDE, P.Y., ACHIM, A., PRÉGENT, G., MÉNÉTRIER, J. Effect of tree spacing on tree level volume growth, morphology, and wood properties in a 25-year-old *Pinus banksiana* plantation in the Boreal Forest of Quebec. Forests. Vol. 7, n. 11, p. 276-292, 2016. https://doi.org/10.3390/f7110276.

JUIZO, C.G.F., LIMA, M.R., SILVA, D.A. Qualidade da casca e da madeira de nove espécies de eucalipto para produção de carvão vegetal. Revista Brasileira de Ciências Agrárias. Vol. 12, n. 3, p. 386-390, 2017. https://doi.org/10.5039/agraria.v12i3a5461.

JUIZO, C.G.F., ROCHA, M.P., BILA, N.F. Avaliação do rendimento em madeira serrada de eucalipto para dois modelos de desdobro numa serraria portátil. FLORAM. Vol. 21, n. 4, p. 543-550, 2014. https://doi.org/10.1590/2179-8087.062213.

LAFETÁ, B.O., SANTANA, R.C., NOGUEIRA, G.S., PENIDO, T.M.A., OLIVEIRA, L.F.R., VIEIRA, D. S. Biomassa e coeficiente de utilização biológico de nutrientes pelo *Eucalyptus grandis* × *E. camaldulensis*em diferentes espaçamentos de plantio. Sci. For. Vol. 49, n. 129, e3378, 2021. https://doi.org/10.18671/scifor.v49n129.13.

NOCK, H.P., RICHTER, H.G., BURGER, L.M. Tecnologia da madeira. Curitiba: UFPR- Setor de Ciências Agrarias, Departamento de Engenharia e Tecnologias Rurais, 1975. 200p.

PROTÁSIO, T.P., LIMA, M.D.R., SCATOLINO, A.B., SILVA, A.B., FIGUEIREDO, I.C.R., HEIN, P.R.G., TRUGILHO, P.F. Charcoal productivity and quality parameters for reliable classification of *Eucalyptus* clones from Brazilian energy forests. Renew. Energ. Vol. 164, p. 34-45, 2021. https://doi.org/10.1016/j.renene.2020.09.057.

REZENDE, M.A., ARONI, A.S., COSTA, V.E., SEVERO, E.T.D., LATORRACA, J.V.F. Densidade e produtividade da madeira de híbrido e seminal de *Pinus caribaea*. FLORAM. Vol. 15, n. 2, p. 08-17, 2008.

SANTOS, R.C., CARNEIRO, A.C.O., PIMENTA, A.S., CASTRO, R.V.O., MARINHO, I.V., TRUGILHO, P.F., ALVES, I.C.N., CASTRO, A.F.N.M. Potencial energético da madeira de espécies oriundas de plano de manejo florestal no estado do Rio Grande do Norte. Ciencia Florestal.Vol.23, n.2, p.491-502, 2013. http://dx.doi.org/10.5902/198050989293.

SEREGHETTI, G.C., LANÇAS, K.P., SARTORI, M.S., REZENDE, M.A., SOLER, R.R. Efeito do espaçamento no crescimento e na densidade básica da madeira de *Eucalyptus urophylla* x *Eucalyptus grandis* em florestas de ciclo curto. Energia na Agricultura. Vol. 30, n. 3, p. 257-262, 2015. https://doi.org/10.17224/EnergAgric.2015v30n3p257-262.

SERVIÇO FLORESTAL BRASILEIRO - SFB. Banco de dados de madeiras brasileiras. 2022. Available in: <https://lpf.florestal.gov.br/pt-br/madeiras-brasileiras>; Accessed: dez. 22, 2022.

SILVEIRA, E. R., REINER, D. A., SMANIOTTO, J. R. Efeito do espaçamento de plantio na produção de madeira e serapilheira de *Eucalyptus dunni* na Região Sudoeste do Paraná. Revista Técnico-Científica do CREA-PR. n. 2, p. 1-9, 2014.

SIMETTI, R., BONDUELLE, G.M., SILVA, D.A., MAYER, S.L.S., SOUZA, H.P., MUNIZ, G.I.B. Productionofbiomassandenergy stock for five*Eucalyptus*species. Ciência da Madeira. Vol. 9, n. 1, p. 30-36, 2018. https://doi.org/10.12953/2177-6830/rcm.v9n1p30-36.

TRUGILHO, P.F., LIMA, J.T., MORI, F.A., LINO, A.L. Avaliação de clones de*Eucalyptus* para produção de carvão vegetal. CERNE. Vol.7, n.2, p.104-114, 2001.