EUCALYPTUS GLOBULUS AND THE EUCALYPTUS NITENS AS ENERGY CROPS

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Abstract.

The objective of this work has been to evaluate the power potential of fast growth forest species, which could be operated in Cantabria (North Coast of Spain). This region has a forest surface of 145,000 hectares with no plantation.

The use of forest species as energy crops implies high density of plantation, and very short rotations (2-3 years). Therefore, it is the tree youthful stage the one that will be the focus of attention on this work.

The *Eucalyptus* is the fast growth species that has demonstrated the greatest biomass production, by hectare, in the region. Two varieties of *Eucalyptus* have been planted for years in our region in order to supply the paper industry. These species are *Eucalyptus Globulus* and *Eucalyptus Nitens*.

The great experience accumulated in the use of these forest species and their great productivity, make of them good candidates to join the set of suitable trees for being used as energy crops. In this work a power characterization of the young stages of the species *Eucalyptus Globulus* and *Eucalyptus Nitens* has been carried out.

The power characterization has been carried out in an adiabatic high accuracy calorimeter, IKA C 5000. The work was made in the four seasons of the year, which has allowed studying the influence of the seasonality in the calorific power of the species. In addition, the influence that the implantation of these species would have on the CO_2 emissions and in the greenhouse effect has been evaluated

Key words

Eucalyptus Globulus, *Eucalyptus Nitens*, energy crops, calorific value, greenhouse effect.

1. Introduction

The energy of the biomass plays an important role as one of the power sources of the future. This is due to two characteristics: (1) neutrality in the emissions of CO_2, and (2) relative abundance and uniformity to a world-wide level. It could provide from the 14 to the 50 percent of the total energy consumed in the world [1].

On the other hand, it is necessary to consider the environmental benefit of the use of the biomass like primary source of energy, mainly by his effectiveness in the reduction of the greenhouse effect [2].

Vegetal species of fast growth are one of the suitable ways to take advantage of the potential power of the biomass. This allows us to avoid the operation of native forest of high ecological value. These species are commonly called energy crops and they must meet mainly two premises: (1) to adapt to the territory in that they are cultivated, and (2) to have a good energy efficiency.

Cantabria is a region located in the North of Spain at a latitude of 43º28'N, and a length of 3º48'W. Due to its climatology, this area has a great forest potential [3].

Table 1. Forest surface of Cantabria

Use	Hectares (Ha)	%
Forest with trees	209,611	39.4
Forest without trees	145,201	27.3
Total forest	359,458	67.5
Eucalyptus	29,513	5.5
Total Cantabria	532,139	100

One of the fundamental parameters that influences the election of the type of energy crop is the yield, as much in amount (tn/Ha), like in power quality (kJ/kg) [4, 5]. The necessity of this work is based on the short scientific literature dealing with the

power characterization of the different varieties of *Eucalyptus* in its youthful stage.

Thus, in the present work the youthful stages of two varieties of *Eucalyptus* are characterized. These are the ones that better adapt to the climatologic characteristics of Cantabria [6].

Table 2. Physical characterization of the parcel

Type of soil	Orientation	Annual Fertilization	Slope (%)	Age (years)	Mediterranean Index	Annual average precipitation (mm)
Argillaceous	South	250 gr 8-24-16 complex granulated	1	2.7	1.80	1,340

The work was made in the four seasons of the year, which has allowed studying the influence of the seasonality in the calorific value of the species. The method used for the power characterization was the one proposed by Hubard [7].

In addition, the influence that the implantation of these species would have on the CO_2 emissions and in the greenhouse effect has been evaluated.

2. Calorific value

The parameter most important to characterize a substance as combustible is the calorific value. This is defined as the amount of heat that gives when it is burned, with excess of oxygen, to a given pressure and temperature.
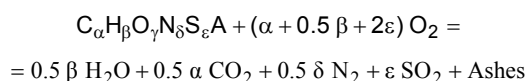
It is assumed that the final products of the combustion are O_2, CO_2, SO_2 and N_2 in gaseous phase, and H_2O in liquid phase.

The water formed in the combustion comes from moisture contained in samples, the air moisture, and the moisture formed by reaction of hydrogen contained in the dry sample.

Two calorific values are defined:

- Gross Calorific Value (GCV), assuming that the water generated in the combustion is in liquid state

- Net Calorific Value (NCV), if the water generated in the combustion is in steam state

The method used gives as result the GCV, the difference between both is the vaporization energy of the water in the products of the combustion. It is assumed that the chemical reaction of the combustion of dry biomass is the following equation:

$$C_\alpha H_\beta O_\gamma N_\delta S_\varepsilon A + (\alpha + 0.5\,\beta + 2\varepsilon)\,O_2 =$$

$$= 0.5\,\beta\,H_2O + 0.5\,\alpha\,CO_2 + 0.5\,\delta\,N_2 + \varepsilon\,SO_2 + Ashes$$

It is deduced form the equation that each mol of hydrogen generates nine of water. The atmospheric air contains humidity, and since in a real combustion oxygen is extracted of it, and the combustible also contains humidity, all this water must be considered in the determination of the NCV. The relation between the GCV and the NCV will be the GCV except the heat necessary to vaporize the water formed in the reaction. Considering that the vaporization heat of water is 2,442 kJ/kg [8], the relation between both values can be expressed as:

$$NCV = GCV - 2,442 \cdot 0.01\,(H_b + H_a) - 2,442 \cdot 0.01 \cdot 9\,H_d$$

where H_d is % of hydrogen in the dry sample, H_b is % of moisture of the waste and H_a is % of air humidity in the combustion.

The tests were performed in an atmosphere of pure O_2, and this is the reason why the term H_a is null.

3. Material and methods

3.1. Samples collection
The work presented here began with the selection of the trees of the two species, in the field property of the forest company Forests 2000 SL (Group Sniace S.A.), located in the town of Ganzo (Torrelavega).

The physical characterization of the parcel is shown in Table 2. All these variables modify the volume and the quality of the plantations and consequently their components [9, 10].

The study tries to avoid the influence of geographical factors (orientation, altitude microclimate...) and geological factors (depth of the mother rock, structure of the ground, fertilization...) in the final results, so only a parcel was considered. The aim was to observe if each species offers different calorific values, due to itself and not to external factors.

The trees of which the set of the samples were extracted had an age between 2 and 3 years, therefore they were in the youthful stage.

For both species, the sampling consisted of the collection of representative samples of the three different fractions in which the tree was divided, namely leaves, branch and bark. This way, the study takes a set of six samples that is combination of the 3 fractions of each one of the two species.

The trials were repeated for each one of the four seasons of the year, which allowed to observe the effects of the seasonality. Once the samples are collected and classified, were transported to the Energy Laboratory of the University of Cantabria.

3.2. Laboratory devices
For the characterization of the samples in the laboratory the devices used were a moisture meter, a calorimeter and a precision balance.

The moisture meter is an electronic analyzer, model MA145 Sartorius, that allows to measure the moisture of the different fractions that compose the wastes, with a sensitivity of 0.01%.

The combustion experiments have been made in a calorimeter, model C 5000 IKA, that gives as result the GCV. This calorimeter is able to analyze combustible liquids or solids, making the combustion in an atmosphere of O_2. The calorimeter allows to operate in two ways, in agreement with the norms DIN and ASTM.

The samples analyzed in the calorimeter were weighed with a balance with sensitivity 0.1 mg, model BP 121S Sartorius.

3.3. Tests procedure
After the collection, several portions of the 21 samples (approximately a gram each one) were extracted in the Laboratory. From 5 portions of each simple the moisture was analyzed, and from other 5 its GCV. This process was repeated 4 times during the year, once every season.

4. Results

Firstly, the bioclimatic diagram of the area was performed, Fig 1. This represents the physical and climatic characteristics of a zone which influences the amount and quality of forest products. The variables used in the elaboration of these diagrams are: 1) the average temperature in ºC, T, (2) the minimum temperature to keep vegetal activity, (3)

the potential evotranspiration in mm, ETP, (4) the residual evotranspiration in mm, and, (5) the hydric availability in mm, HA, and (6) real bioclimatic intensity in bcu, IBR. All of them have great influence in the vegetal activity and as a result in the generation of biomass [11].
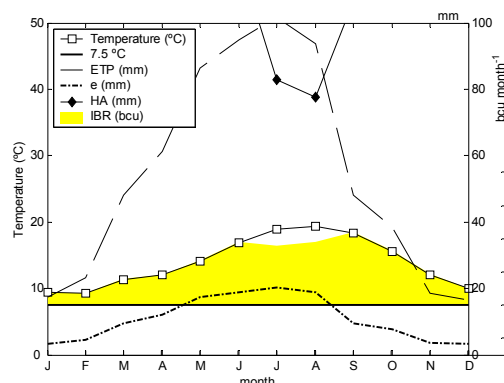

Fig 1. Bioclimatic diagram of the field

The analysis of the diagram demonstrates that the average temperatures in the winter months are superior to minimum temperature for the vegetal activity, and this is the reason why the trees do not stop their growth during winter.

It can be also observed that in the months of summer the real bioclimatic intensity is inferior to the potential one, and coincides with the curve of average temperatures. This smaller hydric availability implies that in this period the growth stops.

However, the diagram reflects the great capacity of this region to develop forest species, and as a result for the generation of biomass, and its potential use as energy crop.

Another aspect that influences the variation of the GCV for the different seasons, is the annual variability in the concentration of essential oils and volatile components. These elements have a GCV around 40,000 kJ/kg [12].

In Figure 2, the annual average of the NCV for each fraction is shown. Considering the percentage, in weight, of each part in the final biomass, Figure 3, an average NCV for *Eucalyptus Globulus* and *Eucalyptus Nitens* of 9,890 and 9,707 kJ/kg, respectively, is obtained.

The average amount of biomass per hectare produced in a plantation of *E. Globulus*, with an age from 2 to 3 years, is 23 tons of biomass [13].

Thus, an annual average of NCV of 9,000 kJ/kg would imply an energy of 210 MJ/Ha.

The forest plantations play a fundamental role in the reduction of CO_2 concentration in the atmosphere, since Carbon compounds are the basis of all living matter, namely leaves, branches, bark and roots.

Table 5. Gross calorific value in kJ/kg of different parts of the two species of *Eucalyptus*
(Age: 2-3 years, Moisture: 55 - 35 %)

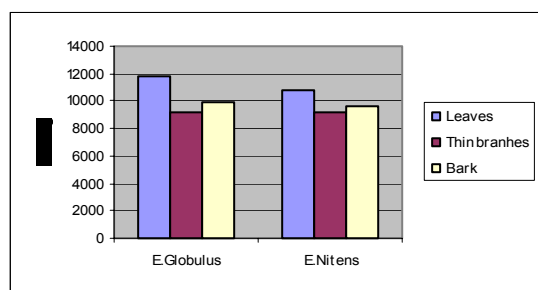|		Spring	Summer	Autumn	Winter
Globulus	Leaves	11,780	11,984	12,120	11,560
	Bark	9,164	9,322	9,502	9,132
	Branches	9,117	9,324	9,401	9,022
Nitens	Leaves	10,482	10,500	10,619	10,327
	Bark	9,388	9,494	9,601	9,194
	Branches	8,919			

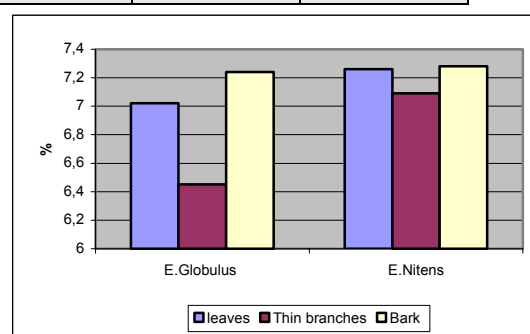Fig 2. Calorific value, annual average, in kJ/kg for each fraction of the tree (2-3 years).

Fig 3. Weight percentage of N_2 for each fraction of the tree.

In this work the analysis of the influence that would have in Cantabria the operation of parcels with *Eucalyptus* as energy crops, related with the amount of CO_2 fixed by them, is presented.

According to [14] and [13] a standard plantation of *Eucalyptus* with an age of 2.5 years has generated 23 tn/Ha of biomass. The average amount of carbon contained in that biomass is 46.7% [13], which means that the plantation stores 39.38 tn/ha of CO_2.

Considering that the forest surface non planted in the region is 145,201 Has, the use of this area for *Eucalyptus* plantations would produce the annual store of 2.29 million of tons of CO_2.

In 2001, the emissions of greenhouse gases in Spain were 307.6 millions of tons of CO_2, and considering that the emissions of Cantabria represent the 1.33% of Spain, 4.09 millions of tons of CO_2 correspond to this region [15].

According to this, if *Eucalyptus* were introduced in the non planted forest surface of Cantabria, they would absorb 56% of CO_2 emitted by the human activity in the region.

5. Conclusions

The bioclimático diagram made, that is representative of great part of Cantabria, shows a great potential for plantation of forest species, which does that the use of these as power resource has a great interest.

In intensive exploitation systems of forest surfaces, destined to the energy crops, the contribution of nutrients through programs of artificial fertilization is necessary. One method could be returning and scattering the ashes produced by the biomass burned in the origin places.

The plantations of *Eucalyptus* store greater amount of energy than other species of fast growth, (*Poplar, Willow ...*). This is based in its greater capacity of biomass generation by hectare, and its great GCV. The high GCV is caused by the presence of substances, fundamentally in the leaves, with a great GCV.

Analyzing these results, it is evident that the amount of CO_2 fixed annually depends directly on the growth of the tree, and this is the reason why

the *Eucalyptus*, being a fast growth species, would play a key role in the purification of the atmosphere.

Thus, if in Cantabria you would introduce species of *Eucalyptus* in the non planted forest surface, cutting the trees every 2 or 3 years, 56% of annual CO_2 assigned to the Cantabrian industries would be approximately fixed.

Acknowledgments

References:

[1] Faaij, A., Energy from biomass ans wastes. Dissertation Utrech University, Departament of science, Technology and Society, Utrech University, Utrech, 1997.

[2] Williams, R.H., and Larson E.D., Biomass and bioenergy. Vol.10,pp 149-166

[3] 3er Inventario Forestal Nacional. Dirección General de Montes y Conservación de la Naturaleza del Gobierno de Cantabria.

[4] Mitchell C., Ford-Robertson J., Hinckley, T., Senerby-Forse, L., Ecophysiology of short rotation forest crops.Amsterdam:Elsevier 1992

[5] Biewinga E., Van der Bijl G., Sustainability of energy crops in Europe: a methodology developed and applied.No.CLM 234-1996.Utrech,1996.

[6] Bosques 2000 S.L. Departamento de investigación. Grupo SNIACE S.A.

[7] Hubard et al, Experimental Thermochemistry, Interscience, New York, 1956.

[8] Consejería de Medio Ambiente y ordenación del Territorio. Gobierno de Cantabria.

[9] Battaglia, M., Sands, P. J., Candy S. G., Hybrid growth model to predict height and volume growth in Eucalyptus Globulus plantation. Forest Ecology and management. 120 (1999) 193-201.

[10] Mistra, R. K., Turnbull, C. R. A., Cromer, R. N., Gibbons, A. K., LaSala A.V., Bellow-and above ground growth of eucalyptus nitens in a young plantation I. Biomass. Forest Ecology and

[11] Montero J. L., Gonzalez J. L., Diagramas Bioclimáticos, ICONA, Ministerio de Agricultura, Pesca y Alimentación.

[12] Martín, E., Lara, F., Inflamabilidad y energía de las especies del sotobosque, Ed Instituto Nacional de Investigaciones Agrarias, Ministerio de agricultura, Pesca y Alimentación, 1989.

[13] Brañas, J., González- Río, E., Merino, A., Contenido y distribución de nutrientes en plantaciones de Eucalyptus Globulus en el noroeste de la península ibérica. Investigaciones agrarias, Vol. (2) 2000, 317-355.

[14] Tejedor, C., Personal comunication. Bosques 2000 S.L. Grupo Sniace S.A.

[15] Ministerio de Medio Ambiente de España, WWW.mma.es