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ENERGY CANE AS A SOURCE OF VEGETABLE FIBER AND THE GENERATION OF RENEWABLE ENERGY FOR BIOMASS BOILERS.

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Abstract: Energy cane varieties are obtained by hybridization of commercial sugarcane varieties with wild species of the Saccharum genus, whose fiber content is equal to or greater than 19%. In the present work, the results of the sowing and characterization of four varieties of energy cane, two from the University of Florida/Canal Point and two from INICA of Cuba, are shown. The chemical and morphological characterization of the varieties and determination of yield per hectare were carried out. They were also converted to pellets and their chemical and mechanical characterization and caloric power were also carried out. The varieties, under rainfed conditions, have shown dry biomass yields in the order of 80-100 t/ha/year after 12 months, more than 2 times those of the best sugarcane varieties and four to five times those reported for forest species. The production cost of energy cane is lower than forestry species, transportation is simpler and it uses the same technology as the sugar industry. Another advantage of energy cane is its ability to grow on land that is not suitable for agriculture, so it does not compete with food production.
Keywords: Biofuels, plant biomass, energy forests, biomass boilers, sugar cane.

INTRODUCTION

Sugarcane is one of the plants with the greatest capacity to convert solar energy into biomass, due to its characteristics of being a plant of the so-called C4 cycle (Obregón Luna, 1999). Energy sugarcane varieties are those F1 non-transgenic varieties obtained by hybridization of commercial hybrid sugarcane varieties with wild species, all of the *Saccharum* genus, whose fiber content on a dry basis is equal to or greater than 19%. One limitation for the introduction of these varieties has been the farmers' tradition of viewing sugarcane only as a sugar producer.

The Dominican Republic is highly dependent on fossil fuels for electricity generation. According to Law number 57-07 of the National Energy Commission (CNE, 2020), on Incentives for the Development of Renewable Energy Sources and its regulations, "institutes a fund from the tax differential on fossil fuels, which will be maintained at 5% of said differential as of the year 2005 for incentive programs for the development of renewable energy sources and energy savings". The country has abundant primary sources of renewable energy, among which are eminently agricultural, which can contribute to reduce dependence on imported fossil fuels, if their exploitation is developed, since they have a high strategic value for the country's supply and/or export.

According to the CNE, (2020), "the main sources of biomass for energy generation in the country are *Acacia Mangium, Eucalyptus and Leucaena* and other agricultural residues such as sugar cane bagasse, forest thinnings, sawdust and other residues, constituting *Acacia Mangium* as the one with the highest consumption at present".

Although its use and advantages have been publicized for several years (Irvine and Benda, 1979; Alexander, 1985), it has not yet been widely exploited in the world as fuel for biomass boilers, being used in some cases as a substitute for firewood in the start-up of sugar mills. It is also being used in the production of cellulosic ethanol, as CO_2 sink forests and as tutors in tomato plantations and other protected crops (April, 2022). One of the advantages of energy cane is that its planting does not compete with food crops and forested areas, since it can grow on land that is not suitable for agriculture. In addition, these varieties are not invasive, they grow in rainfed areas and their harvesting uses the same technology used for the sugar industry, which is an established culture in the country.

The present work shows the results obtained from the planting and characterization of four varieties of energy cane in an experimental farm, two varieties from the University of Florida/Canal Point and two varieties from the Cuban Institute of Sugar Cane Research (INICA). The chemical and morphological characterization of the varieties, determination of yield per hectare at 12 months were carried out. Also, their conversion to pellets at pilot scale and characterization of the pellets obtained were carried out, taking into account their mechanical properties, chemical composition, chlorine and sulfur contents and caloric power. A comparison was made with other forest biomass species such as *Acacia Mangium, Eucalyptus and Leucaena.*

LITERATURE REVIEW

Vegetable biomass has its antecedents in the use of firewood and charcoal as fuel for cooking. Starting in 1890, the sugar mills began burning bagasse in boilers to generate electricity during the harvest. Currently, the installed capacity is 16 MW in the sugar mills and 4.2 MW in other facilities. There are also several facilities that have replaced conventional boilers with biomass boilers, such as two textile companies in Zona Franca, Gildan Dominicana and Dos Ríos Enterprises (Gómez, 2016) (Gómez, 2016).

In a study conducted by the National Energy Commission (CNE,2018), the baseline of the biomass market in the Dominican Republic was established. It was determined that the daily biomass consumption in 2018 was 2,219 metric tons. Of the biomass types studied, *Acacia mangium* was the dominant species among producers and intermediaries. The average total cost of shredded acacia is $43 dollars per metric ton, with a selling price of $48 dollars per metric ton. In addition, chemical characterization of nine samples of Dominican forest, herbaceous and residual biomass was carried out. The energy content (PCS) on a dry basis ranged from 14.8 to 18.2 MJ/kg, with rice husks having the lowest calorific value and *Acacia mangium* from Monte Plata having the highest calorific value.

Regarding the geographic information system of areas and biomass production potential for industrial heat and electric power generation, the country's biomass potential for the production of forage species and fast-growing trees was determined through a nationwide georeferencing and soil capacity analysis. It was established that there is a potential of 476,071 hectares for the production of grasses and 449,248 hectares suitable for the promotion of high-value forest species for energy production (CNE, 2018).

Dominican Republic has companies that supply a reliable alternative source of clean energy, this is the case of Dominican Energy Crops, a company that owns an energy farm that manages 5,000 hectares of Acacia plantations for biomass production and, additionally, concentrates its efforts in developing and managing third party energy farms, with the purpose of supplying quality biomass in a constant, reliable and sustainable manner (El Dinero, 2018). Dominican Energy Crops has its main production center in Los Llanos, San Pedro de Macorís.

Ochs, in his publication entitled "Aprovechamiento de los Recursos de Energía Sostenible de la República Dominicana" (2015) "expresses that the country produces around 1.5 million tons of sugarcane bagasse per year and only 30% is used to generate electricity, although the main sugar mills use bagasse for cogeneration".

In the United States, three companies are operating bioethanol plants from crop residues and energy cane (Hirasawa and Kajita, 2014). A study conducted at Louisiana State University, determined a cost between 70 and 110 dollars per dry ton of energy cane for use as feedstock for obtaining cellulosic ethanol (Salassi and Falconer, 2015; Kumar el al., 2021).

It is reported (Biofuel Digest, 2011) that, in Texas, BP has started planting 120 ha of energy cane for the production of second generation ethanol, which will be expanded to 20,000 ha. Other cellulosic ethanol plants in Florida are also using energy cane as feedstock (Hoffstadt et al. 2020). The University of Florida in cooperation with centers in Louisiana and the U.S. Department of Agriculture (Canal Point) Station are developing high yielding, disease resistant and low temperature resistant varieties of energy cane.

Other countries working on sugarcane energy applications include Brazil, Cuba and the French center CIRAD (Center for International Cooperation in Agronomic Research for Development), which has stations on several Caribbean islands.

Sugarcane is one of the plants with the greatest capacity to convert solar energy into biomass, due to its characteristics of being a plant of the so-called C4 cycle (Triana and Leonard, 1990; Diniz et al., 2019). Energy cane varieties are those F1 non-transgenic varieties obtained by hybridization of commercial sugarcane hybrid varieties with wild species, all of the genus *Saccharum* , whose dry base fiber content is equal to or greater than 19% (Keenliside,1986) They have also been called "Very high fiber content sugarcane varieties" (Jorge & Vera, 2005).

Tew and Cobil (2008) classified energy cane into two categories: Type I and Type II. Type I is closer to traditional sugarcane, but with lower sucrose content and higher fiber. Type II, only has very low sugar content and very high fiber and is suitable only for biomass generation (Santchurn and Ramdoyal, 2014).

The U.S. variety development program maintains interest in biomass energy. As a result, the Louisiana program successfully released three cultivars (Tew & Cobil, 2007)). In Florida, several energy cane varieties have been developed (Mislevy & Martin, 1995) found the first generation hybrid (F1) to be the most suitable as energy cane. Korndorfer, (2011) found that energy cane was more suitable than giant reed (Arundo donax L.) as a biomass source in the sandy soils of south Florida. Additionally, (Alvarez and Helsel, 2011) concluded that energy cane had great potential as a biomass source in Florida. Mark (2010), presented a joint work with specialists from 8 states in the southeastern United States with the advantages of using energy cane in latitudes up to 33° N (Viator & White, 2010). The work identified more than 1,500,000 hectares with potential for the development of energy cane.

In Barbados, energy cane cultivars with more than 25% fiber have been planted for electricity generation (Rao and Davis, 2007). In Mauritius, a similar program was developed (Ramdoyal and Badaloo, 2002).

In Texas, the biomass program of A&M University has tried to obtain hybrids between Miscanthus and sugarcane, the "Miscane," (Jessup, 2009); with the characteristic of being resistant to freezing, to achieve its cultivation in high latitudes (Viator & White, 2010). Other countries reporting the development of energetic sugarcane varieties are Japan, (Sugimoto and Terajima, 2012), and Thailand (Rao & Weerathaworn, 2009). In Brazil, the pioneer in the development of energy cane was Canavialis, a private company obtaining yields 138% higher than traditional cane (Matsuoka and Bressiani, 2012).

In Spain, the company Biothek Ecology Fuel has reported the development of energy cane and Arundo K12 varieties for use as renewable fuel (Traxco, 2015). The potential of energy cane as a fibrous source in the pulp and paper industry has also been studied (Triana & Abril, 2008) .

Studies carried out by the Cuban Sugarcane Research Institute (INICA) (Ponce, 1993), show the results of the selection and evaluation of individuals from the sugarcane germplasm bank, in relation to the agricultural indexes that determine biomass production. Fiber content was analyzed as a fundamental element that characterizes a variety for energy use. The selected individuals included F1, BC1 of *Saccharum Officinarum* by *Saccharum Spontaneum* and varieties of *Saccharum Robustum, Saccharum Barberi and Saccharum Sinense.* The most promising ones underwent intensive studies to observe their agricultural performance in different soils and climatic zones of the country and to evaluate their reaction to rust and charcoal.

The selected varieties were analyzed for fiber, dry matter and moisture content at various harvest ages and different times after cutting. Those with the best overall performance (agricultural, phytopathological and energetic) had the heat of combustion of their dry matter determined (Milanés, 1994), in addition to the production of stems and biomass by the estimation method.

The best performing individuals were F1. The selected material showed high resistance to diseases such as rust and charcoal, both in natural conditions and in tests under artificial infection. The highest stem biomass production corresponded to the F1 varieties, yielding between 100 and 180 tons per hectare per year, depending on soil type and prevailing rainfall conditions.

In relation to harvest time, energy cane varieties are more versatile than sugar cane varieties. They can be harvested at 10 to 12 months of age. The increase in age and the effects of flowering help the drying of the stalks, which favors the energetic use (Obregón Luna, 1999).

The use of sugarcane as fuel should be done with less than 25% humidity, which is reached 30 to 45 days after the canes are cut. Two months after harvesting, they reach equilibrium humidity between 12 and 15%. The fuel value of energy cane is equivalent to 15 t of oil/ha per year, for a yield of 100 t/ha. It is reported in a study of the energy balance of 12-month varieties and yields of 100 t/ha/year (Jorge and Vera, 2005), that each hectare planted with these varieties represents 15 t of oil equivalent. Regarding soil characteristics, the same author emphasizes that these varieties grow in very poor soils that are not suitable for other crops, so another advantage of this type of sugarcane is that it does not compete with areas for food production.

Another advantage of energy cane is the high number of canes produced per seedling, not only in the plant cane, but also in the shoots (Matsuoka and Stolf, 2012), which influences the high yields obtained by generating three to five times more stems than traditional varieties (Matsuoka, 2013).

It is reported that the length of the fibers is double that of traditional varieties (2 mm) and the properties of the paper samples obtained are similar to those produced with hardwoods (Triana and Abril, 2008).

One of the difficulties for the introduction of energy cane has been the lack of a reference value for these varieties, not in relation to sugar content, which is the traditional method, but in reference to the fossil fuels it replaces. A work by Abril and collaborators (2019) makes a proposal to value energy cane varieties in reference to the oil or coal substituted, which may represent a stimulus for producers of these varieties.

In general, an energy crop must have the following characteristics to be viable.

- Be easy to process into a feasible way to feed a boiler.
- High energy density.
- High dry matter yield/area/year

- Available all year round.
- Favorable production cost.
- Renewable.
- Not to compete with food production.

MATERIALS AND METHODS

PLANTING OF ENERGETIC SUGARCANE VARIETIES.

Four varieties of energy cane were planted, two from the University of Florida, United States of America, UFCP 821655 and UFCP 781013 and two varieties from the Cuban Institute of Sugar Cane Research (INICA), Cuba, C90-176 and C90-178. The varieties were acquired in the form of cuttings, certified free of pests and diseases, with the corresponding permits from the Plant Health Directorate of the Ministry of Agriculture of the Dominican Republic. Planting was carried out in September.

Table 1 shows the parameters established for planting the four varieties.

Parameter	Value
Sowing method	manual
Distance between grooves	0.80 m
Groove height	0.20 m
Planting depth of cuttings	0.15 m
Distance between cuttings	0.20 m
Number of buds on cuttings	2
Fertilizer used	NPK 25-05-18
Fertilizer added	20 g/sheaf
Irrigation at planting	20 liters/m ^{2}
Subsequent irrigation	No irrigation

Table 1. Parameters established for planting cuttings of the four energy cane varieties.

Approximately 0.1 ha of each variety were planted in an experimental farm located in the municipality of Guerra, dedicated to planting varieties of sugarcane and yerba elefante. The soil characteristics are classified as type III and correspond to black vertisols without irrigation.

SAMPLING OF ENERGY CANE FOR PHYSICAL-CHEMICAL ANALYSIS

The DIECA method (Badilla, 2002) was selected, where 5 linear meters were taken in two furrows. In both, 6 canes were randomly selected per sampling point, for a total of 20 canes per sample. The canes were cut in an integral way, including bud, stems and leaves. They were transported to the laboratory for processing within 4 hours of cutting.

MORPHOLOGICAL CHARACTERIZATION OF ENERGY CANE VARIETIES

Fiber length determinations were performed using a MOTIC SMZ-161 Series stereo Zoom Microscope coupled to image analysis software using the modified TAPPI T 9 wd-75 (Holocellulose in wood) method.

PHYSICOCHEMICAL CHARACTERIZATION OF ENERGY CANE SAMPLES

Ash determination.

It was carried out by combustion in a muffle at 550° C, according to the ASTM D1102-56 weighing method.

DETERMINATION OF STRUCTURAL CARBOHYDRATES (CELLULOSE, HEMICELLULOSES AND LIGNIN)

Cellulose, hemicellulose and lignin were determined according to NREL TP-510-42618, using UV-visible spectroscopy and HPLC.

DETERMINATION OF THE YIELD OF ENERGY CANE VARIETIES ONE YEAR AFTER PLANTING

The following procedure was carried out for each variety:

- An area of $1m^2$ is marked from the center of a seedling and repeated in 2 other areas.
- The number of canes in the selected area is counted and averaged.
- Twenty canes of the variety are cut randomly throughout the field.
- The canes are cut into suitable portions of approximately 40 cm and weighed.
- Calculate the yield in t/ha by multiplying the weight of a cane by the number of canes per square meter per 10000 m^2 /ha.

DETERMINATION OF SUGARCANE MOISTURE

Moisture in sugarcane was determined by kiln drying, using the ICUMSA GS7-5 method (1994).

PREPARATION OF ENERGY CANE PELLETS FOR THEIR EVALUATION AS FUEL

Reception

Approximately 250 kg of cane of each of the 4 varieties aged 12 months were cut manually in the experimental field, in an integrated manner (stalks, straw and bud), and were cut into pieces of approximately 40 cm.

Drying of the cane

The cane pieces were dried in a solar dryer with a polycarbonate cover for 6 hours at a temperature of 60^0 C and external humidity of 50%, reaching a humidity between 20% and 25%.

Ground

The dry sugarcane was ground with a hammer mill (Buskirk, USA, Model HM1000) equipped with a 20HP motor and 3 mm perforated outlet screen.

Pelletization

The hammer mill is connected to the pelletizer by a conveyor in order to achieve a continuous grinding-pelletizing process. The pellets obtained were allowed to stand until they reached room temperature and were packaged in sealed 20 kg PE bags. The pellets were evaluated according to the standards of the Pellet Fuels Institute. (2018).

DETERMINATION OF CHEMICAL COMPOSITION AND CALORIFIC VALUE OF ENERGY CANE PELLETS

The determinations were carried out through the Company X Solutions de Chile in the laboratories of the Universidad Católica del Maule, Chile, according to the standards ISO Standard 17225-2 (2014) "Solid biofuels - Fuel specifications and classes.

Approximately 2 kg of each sample was processed into pellets.

Samples were prepared in accordance with the UNE-CEN/TS 14780 EX standard applicable to solid biofuels.

MATHEMATICAL TREATMENT OF EXPERIMENTAL RESULTS

In general, the coefficient of variation was determined for the experimental results, according to the expression $CV \pm t.s/n^{1/2}$, where CV is the coefficient of variation, t is the Student's t-statistic for 95% confidence and n-1 degrees of freedom, n is the number of determinations.

RESULTS

PLANTING OF ENERGETIC SUGARCANE VARIETIES

Survival at 30 days

Table 2 shows the survival results of the cuttings 30 days after planting.

Variety	Sown cuttings (±20)	Survival (%)	Canes per plant (average)	Average stem height (cm)
C90-176	800	82	8	25
C90-178	800	88	7	22
UFCP 821655	800	83	9	23
UFCP 781013	800	81	7	24

Table 2. Seeding results of the four varieties at 30 days.

As highlighted in the table, the survival percentages of both varieties were very high, due to the good quality of the seeds and the speed of shipment and planting. It was observed that the cuttings had a large number of active buds, which is due to the fact that they came from 9 to 10 months old canes.

CHEMICAL CHARACTERIZATION OF ENERGETIC SUGARCANE VARIETIES (12 MONTHS)

Table 3 shows the results of the chemical characterization of the four varieties of energy cane, using NREL methods.

No	Determi-nation	Value (%)			
1	Variety	**C90-176**	**C90-178**	**UFCP 821655**	**UFCP 781013**
2	Cellulose	46±2	45±2	47±2	48±2
3	Hemi-celluloses	29±3	29±3	28±4	28±3
4	Lignin	23±3	23±3	20±3	20±3
5	Ashes	1.7±0.1	1.8±0.1	2.0±0.2	2.0±0.2

Table 3. Chemical Characterization of the energy cane varieties (12 months)

Comparing the chemical compositions among the four varieties, it is observed that there are very small variations in them, which is to be expected considering that in all cases they come from F1 non-transgenic varieties obtained by hybridization of commercial hybrid sugar varieties with wild species, all of the *Saccharum* genus (Jorge & Vera, 2005). It is worth noting the low ash content, which favors its use as fuel in boilers.

MORPHOLOGICAL CHARACTERIZATION OF ENERGY CANE VARIETIES

The results of the morphological characterization of the four varieties of energy cane are shown in Table 4. They are compared with sugarcane, pine and Eucalyptus varieties. It should be noted that the fiber length of the energy varieties is approximately double that of the sugar varieties and greater than that of the Eucalyptus, which gives them a very favorable characteristic for their use in applications as vegetable fiber in the paper, board, molded products and handicraft industries.

YIELD OF ENERGY CANE VARIETIES ONE YEAR AFTER PLANTING

Table 5 shows the characterization values and yields per hectare of the four varieties studied, 12 months after planting.

The C90-176 and C90-178 varieties differ from the UFCP varieties in that the former have a larger stem diameter. However, the UFCP varieties have a greater number of canes per square meter, which in a certain way standardizes the yields obtained per hectare. Yields in all cases are in the order of 200 t/ha, values much higher than any energy crop.

These yields were obtained in an experimental field, so that, under practical conditions in a normal field, yields will be lower, possibly in the order of 120-150 t/ha.yr.

Variety	Fiber length (mm) (L)	Fiber diameter (µm) (D)	Thinness (L/D)
Energy reed: C90-176	2.2±0.2	24±0.3	92
Energy reed: C90-178	2.1±0.2	24±0.3	88
Energy rod: UFCP 1	2.1±0.2	23±0.3	87
Energy rod: UFCP 2	2.0±0.2	23±0.3	87
Ja 60-5 (Sugar Cane) ** Ja 60-5 (Sugar Cane) ** Ja 60-5 (Sugar Cane) ** Ja 60-5 (Sugar Cane)	1.1	23	49
Ba. 43-26 (Sugar Cane) ** (Sugarcane) ** (Sugarcane)	1.3	22	57
Pine (Pinus sylvestris) ** Pine (Pinus sylvestris) ** Pine (Pinus sylvestris)	2.9	28	104
Eucalyptus globulus, (7-year) **	1.0	13	77

Table 4. Morphological characterization of energy cane varieties
** The Sugar Cane Derivatives Industry. In Chapter. IV. p. 115.
of Sugarcane Derivatives. ICIDCA (2004) ISBN 959-7165-14-7.

VARIETY	C90-176	C90-178	UFCP 821655	UFCP 781013
Average number of canes per m2	X=46	X= 45	X=53	X= 52
Stem length cm (x_m), n=20	232	228	205	234
Diameter of stems (cm)	4.8	4.6	3.8	3.6
Distance between buds cm (x_m) n=8	18	17	16	17
Straw weight kg (20 reeds)	0.70	0.73	0.95	0.90
Weight of head kg (20 canes)	1.85	1.75	1.60	1.65
Weight of stems kg (20 canes)	8.69	8.70	7.00	7.05
Total weight kg (20 rods)	11.24	11.18	9.59	9.60
Yield (t/ha)	259	252	254	250
Yield Stems (t/ha)	200	196	186	183

Table 5. Yield per hectare of the varieties at 12 months.

MOISTURE CONTENT OF ENERGY CANE VARIETIES

Table 6 shows the moisture contents of the components of the four varieties. These values are important for their use as direct fuel in biomass boilers. The moisture content of the stems of varieties C90-176 and C90-178 are lower than those of the University of Florida varieties, which gives them an advantage for their use as fuel. In all cases, 30 days after cutting, all air-dried varieties acquired a moisture content between 15% and 20%, which corresponds to that reported by Jorge (2005).

VARIETY	C90-176	C90-178	UFCP 821655	UFCP 781013
Straw	27.5	30.2	28.5	32.2
Bud	54.0	55.3	56.0	55.5
Stems	50.2	51.3	57.2	56.3

Table 6. Moisture content of the varieties (%)

PREPARATION OF PELLETS FROM ENERGY CANE VARIETIES FOR THEIR EVALUATION AS FUEL

Mechanical properties of pellets produced at pilot scale

The mechanical properties of the pellets obtained from the four energy cane varieties are shown in Table 7. Pellet Fuel Institute (2018) standards were used.

The results show that there are no differences in the physical characteristics of the pellets obtained, which is to be expected considering that the chemical compositions of the different varieties (cellulose, hemicelluloses, lignin and ash) do not differ. The values are within the recommended ranges for the use of pellets as fuel in biomass boilers, especially a mechanical durability greater than 90%, higher than the value of 85% recommended by the standard.

No	Analysis	C90-176	C90-178	UFCP 821655	UFCP 781013
1	Mechanical Durability (%)	96±4	95±6	93±4	95±4
2	Bulk Density (kg/m)^3	660.5±0.4	663.0±0.5	662.5±0.4	661.5±0.3
3	Fine (%<3.15 mm)	1.6±0.4	1.7±0.3	1.8±0.5	1.8±0.6
4	Diameter (mm)	6.1±0.2	6.0±0.3	6.2±0.3	6.1±0.2
5	Length (mm)	30.0±0.6	32.0±0.7	31.0±0.8	33.0±0.6

Table 7. Mechanical properties of pellets.

No	Analysis	C90-176	C90-178	UFCP 821655	UFCP 781013
1	Humidity (%)	8.3±0.2	8.1±0.3	8.5±0.2	8.5±0.3
2	Ash (%)	1.5±0.1	1.6±0.2	1.7±0.2	1.6±0.1
3	Higher Calorific Value (MJ/kg)	18.5±0.3	18.0±0.4	18.1±0.4	18.5±0.5
4	Lower Calorific Value (MJ/kg)	15.6±0.3	15.1±0.4	15.0±0.3	15.4±0.5
5	Carbon (%)	48.3±0.3	47.6±0.5	48.0±0.4	47.9±0.5
6	Hydrogen (%)	5.5±0.2	5.8±0.3	6.0±0.2	5.7±0.3
7	Nitrogen (%)	1.1±0.2	0.9±0.3	1.0±0.3	1.0±0.3
8	Sulfur (mg/kg)	0.023±0.005	0.025±0.003	0.028±0.004	0.024±0.005
9	Chlorine (mg/kg)	0.016±0.002	0.015±0.003	0.017±0.002	0.016±0.003

Table 8. Chemical composition and calorific value of energy cane pellets.

Property/Species	Energy cane	Acacia Mangium (1)	Eucalyptus (2)	Leucaena (3)
Yield (t/ha.year) (50% humidity)	80-100	12-19	16-25	15-20
Calorific value (MJ/kg) (dry)	18.3	18.1	19.7	17.1
Cost per t (USD)	26	43	48	nd
Invasive species	no	no	no	yes
Type of technology	Sugar	Forestry	Forestry	forestry

Table 9. Comparison of energy cane with main forest biomass species.

CNE, 2018 (2) Brown, 2000 (3) Aldana & Casanova, 2010

DETERMINATION OF CHEMICAL COMPOSITION AND CALORIFIC VALUE OF ENERGY CANE PELLETS

Table 8 shows the results of the determination of the chemical composition and the upper and lower calorific value of the four varieties of energy cane.

It is noteworthy the low ash content presented by the 4 varieties and the high value of the calorific value, which favors its use as fuel in boilers. The calorific value is slightly lower than that reported for timber species and forest residues (CNE, 2018). Chlorine and sulfur contents are very low, which is another advantage for its use as biomass boiler fuel.

COMPARISON OF ENERGY CANE WITH OTHER PLANT BIOMASS SOURCES FOR POWER GENERATION

Table 9 shows a comparison between the main sources of plant biomass used in the Dominican Republic for power generation in boilers.

The table shows that the caloric power values are similar, with a slightly higher value for eucalyptus. The yields of energy cane are 4 to 5 times higher than those of forest species, being possibly one of the plant species with the highest yields known. The production cost of energy cane is lower than that of forest species, mainly because it does not require the chipping process, transportation is simpler and it also uses the same technology used in the sugar industry, of which there is a great tradition in the country. Another advantage of energy cane is its capacity to grow on land that is not suitable for agriculture, so it does not compete with food production.

CONCLUSIONS

Four new varieties of energy cane were introduced in the Dominican Republic, which had an excellent adaptation to the climatic conditions of the country. The varieties, under rainfed conditions, have shown vigorous growth and tillering. At 12 months, the four varieties show biomass yields of around 200 t/ha/year, which represents for dry sugarcane, in the order of 80-100 t/ha/year, more than 2 times those of the best sugarcane varieties and four to five times those reported for forest species. It was also possible to establish a full-cycle procedure for cutting, drying, milling and palletizing energy cane, without the need for milling in a sugar mill. The production cost of energy cane is lower than that of forest species, transportation is simpler and it also uses the same technology used in the sugar industry, of which there is a great tradition in the country. Another advantage of energy cane is its capacity to grow on land that is not suitable for agriculture, so it does not compete with food production, and also represents a way for its use as a CO_2 sink forest, due to its great capacity to fix this greenhouse gas, as an important contribution to the environment. One perspective for the use of these varieties is their conversion into pellets for export, for which there is a growing market at very favorable prices in Europe and the United States of America.

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