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Assessment of biofuel potential of dead neem leaves (*Azadirachta indica*) biomass in Maroua town, Cameroon

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Dead leaves of neem trees in the Sahelian urban zone are among the wastes that are underutilized, since it is either buried or burnt, and thus, contribute to increased environmental pollution. Unfortunately, the lack of information on the biomass and energy potentials of these wastes empedes any initiative for its industrial biomethanization. This study was investigated with the aim of evaluating the biofuel potentials of dead neem leaves in Maroua town. The number of neem trees, as well as biomass produced by their dead leaves in the town was estimated. Different possible forms of energy which could be generated from biomass were determined. Results revealed the presence of 45500 neem trees in the whole town. In addition, averagely 1.2 kg of dead neem leaves was daily produced per tree. All the neem trees were able to generate 53.7 tons biomass/day, which can supply 756.538 m^3 of biogas in 7 months of defoliation. This biogas volume was assimilated to 5.674 MWh/day of electrical energy, sufficient enough to support the need of 7565 householders. The biogas produced could be used as cooking energy source, or substitute the firewood demand of 3926 householders for 7 months, leading to the preservation of 567.45 ha land /year from destruction as the result of uncontrolled firewood collection in the sahelian zone.

Key words: Biomethanization, biogas, biofuel, dead neem leaves, energy, Maroua town.

INTRODUCTION

In response to environmental and energy problems around the world, the use of renewable energies appears as the best solution to these crisis (De Jong et al., 2016). Indeed, fossil fuels have been recognized as the main sources of greenhouse gas effect emitted into the atmosphere and destabilizing the climate (Mudhoo, 2012). Several countries recognizing this situation have gradually implemented policies to use renewable energy

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Figure 1. Mini-bioreactors producing biogas from dead neem leaves.

(De Jong et al., 2013; Sánchez et al., 2015). Bioenergy has thus proven the ability to effectively find alternatives to substitute the fossil energy (Kumar et al., 2009; He et al., 2014). In addition, adoption of biogas limits the deforestation caused by the collection of firewood that represents the only source of energy for more than 81% of inhabitants in the sub-Saharan Africa (Uyigue and Archibong, 2010; Folefack and Abou, 2009). For example, less than 05% of inhabitants of the Far North of Cameroon use cooking gas as the source of energy when preparing their meals. The rest depend essentially on the firewood collected from a semi desert environment (MINFOF, 2014). According to MINFOF (2014), the existing potential firewood in the environment of the Far North can satisfy just 75% of the needs of the population and the deficit will be 45% in 2022. However, for the production of the bioenergy to be more sustainable, it appears fundamental to use resources which are locally available and not competing with agricultural commodities (Zagorskis et al., 2012). Thus, this study was aimed at the use of dead neem leaves biomass which flood several cities in the Sahel and are commonly swept and burnt (Lacour, 2012; Faye, 2010; Mussoline, 2013). Moreover, their biomethanization can significantly contribute to solve in its way the energy crisis (cooking energy supply), and reduce the ecological destruction found in Sahelian areas (Folefack and Abou, 2009). However, the lack of information on the biomass and energy potentials of these dead leaves has hindered any initiative in industrial biomethanization over the years. The case study of the biofuel potentials of this biomass within Maroua town is discussed.

MATERIALS AND METHODS

Assessment of the biomass potential

The average daily amount (m) of the biomass collected from 60 neem trees from two different sites was daily quantified. This sampling was conducted from October 2014 to May 2015. The total number of neem trees (NT) in Maroua town was determined.

The total annual biomass of dead neem leaves (M_T) was estimated using Equation 1.

$$\boldsymbol{M_T = 220 \times m \times NT} \qquad 1$$

Energy potential of the dead neem leaves biomass

It was considered that all the dead neem leaves biomass undergo anaerobic digestion with the aim of producing biogas. The annually amount of biogas Q_g provided is expressed by Equation 2 (Tizé et al., 2011; Lacour, 2012).

$$\mathbf{Q_g} = \boldsymbol{q_u} \times \mathbf{M}_{\boldsymbol{T}} \qquad \mathbf{2}$$

To determine the quantity of biogas/Kg of biomass ($\boldsymbol{q_u}$), the test of co-digestion of dead neem leaves was conducted in the mini-bioreactors (Figure 1). Dead leaves of neem collected were biologically pretreated to improve their productivity (Mussoline, 2013; Montgomery and Bochmann, 2014). A quantity of 2.8 kg of leaves was mixed with 1.4 kg of fresh cow dung and moistened with 4.2 L of water. After 5 days, 10 days, 15 days, 20 days and 30 days of pretreatment, samples of 135 g (D45) and 105 g (D35) of dead leaves of neem (dry matter) are used and associated respectively with 50 g and 55g (dry matter) of cow dung to feed mini bioreactors of 1.5 L. A total of 10 treatments (FN2BP) with four replications were made up. Two treatments of no pretreated dead neem leaves (FNB) and two treatments containing essentially 50 g and 55 g of dung (dry matter) were also made. Productions of biogas during anaerobic co-digestion of these treatments have been evaluated.

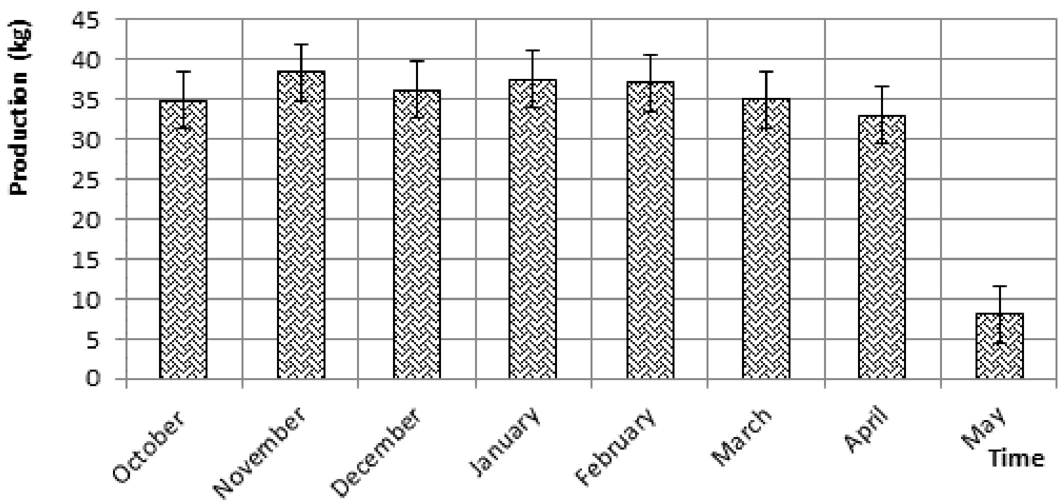

Figure 2. Average amount of dead neem leaves biomass produced per tree and month.

The potential electricity value E which could be supplied from the produced biogas was estimated using the proposed conversion by Sama and Thiombiano (2012) (Equation 3).

$$E = 6Q_g \quad (3)$$

The final electricity production of dead neem leave biomass taking in account the yield of 33% of the biogas generator according to Mussoline (2013) is calculated (Equation 4).

$$NE = 2Q_g \quad (4)$$

Elsewhere, Tize et al. (2011) have established an equation which permits the determination of corresponding volume of liquefied butane gas from the biogas production. By using this equation, the number of bottles (Nb) of 12.5 L of butane which is the most distributed in Cameroon was estimated (Equation 5).

$$\mathbf{N_b = 0.032Q_g} \quad \mathbf{(5)}$$

Statistical analysis

The recorded biogas productions were subject to an analysis of variance at the level of 5% of significance. As the dead neem leaves are concerned, the collected data were analysed in order to determine the average production of dead neem leaves and its distribution in the town. In addition, the various benefits derived from the use of the quantified biomass of dead neem leaves were statistically appreciated.

RESULTS AND DISCUSSION

Potential of dead neem leaves biomass

The amount of dead leaves produced by a tree during the defoliation period is shown in Figure 2. Result indicated that the largest drop of dead neem leaves in the city of Maroua was recorded in November. During this month, an average of 1.28 kg per day was produced. This production experienced a steady decline over the time.

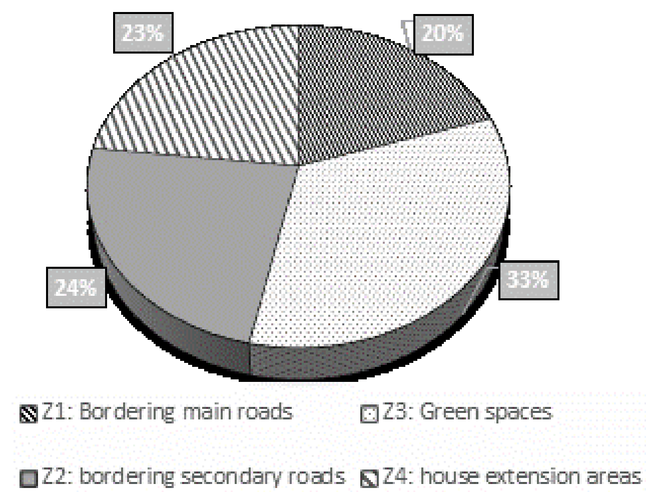

Figure 3. Distribution of neem trees in Maroua town.

The lowest production of neem leaves biomass was observed in May. Beyond this month, the leaves biomass that failed was almost zero. In a similar study conducted by Tizé (2012), it was observed that the production was 1.27 kg per day and per tree in November and December. It therefore appears that the amount of dead leaves gradually declined from November to May. Furthermore, it was estimated that the biomass production was proportional to the diameter of the neem tree taken at breast height. The overall average of dead neem leaves was 1.2 kg·tree-1·day-1. As far as the neem tree population is concerned, 45500 trees were enumerated in Maroua, not uniformly distributed on approximately 3294.78 ha area. About 20% of these trees are bordering the main streets, while 23.5% secondary roads of the city (Figure 3).

Taken into consideration the population of neem trees,

Table 1. Biogas productivities (q_u) of pretreated dead neem leaves.

Treatments	Proportion D45		Proportion D35	
	Production	q_u (L/kg)	Production	q_u (L/kg)
FN2BP5	8694±778^{eB}	64.4	7657±631^{eA}	73
FN2BP10	6776±735^{dB}	50.2	4815±991^{cA}	45.8
FN2BP15	5612±710^{cA}	41.6	6017±353^{dA}	57.3
FN2BP20	4846±436^{cA}	35.9	4591±297^{cA}	43.7
FN2BP30	3088±491^{bA}	22.9	3090±401^{bA}	29.4
TB	1716±77^{aA}	34.3	1777±566^{aA}	32.3
FNB	0		0	

Table 2. Different forms of energy production from dead neem leave biomass in Maroua town during the defoliation period.

Production	Oct	Nov	Dec	Jan	Feb	March	April	May	Annual total	Daily mean
Biomass (ton)	1583	1747	1643	1706	1684	1593	1502	364	1182.9	53.7
Biogas ($10^3 m^3$)	101.4	111.8	105.1	109.2	107.7	101.9	96.1	23.3	756.5	3.448
Potential Electricity (MWh)	506.7	559.1	525.6	546	538.7	509.6	480.5	115.5	3782.7	17.2
Net Electricity (MWh)	167.2	184.5	173.5	180.2	177.8	168.2	158.6	38.4	1248.3	5.6
Firewood (ton)	507	559	526	546	539	510	480	116	3783	17.2

the daily estimate of the total biomass production in Maroua was 53.7 tons. This biomass was estimated to 11.820 tons/year. The final destination of this biomass is usually the landfill, where it is simply buried and undergoes degradation process to release CO_2, CH_4 and other substances that are known as the main greenhouse gas effect. A similar phenomenon was observed with rice biomass that yielded about 15% of anthropogenic methane in the atmosphere (Mussoline, 2013). Biomethanization of dead neem leaves can generate substantial energetic which can be beneficial to the population and environment.

Energy potential of dead neem leaves biomass in Maroua

The various biogas productivities obtained from the anaerobic digestion of dead neem leaves are illustrated in Table 1.

It appears from this table that the dead neem leaves pretreated for 5 days have been the most productive. A proportion of D45 of FN2BP5 producing 64.4 L/Kg of biogas is 28 and 181% higher than those of FN2BP10 and FN2BP30 respectively. It appears that the greatest productivity (73 L/kg) was obtained from FN2BP5 at a proportion of D35. In similar studies, the productivity of dead neem leaves at D25 was 46.9 L/kg (Tizé et al., 2015). Therefore, the productions are inversely proportional to pretreatment duration. According to Montgomery and Bochmann (2014), when the duration of the biological pretreatment increases, the products released are less productive in term of biogas as part of them are consumed by aerobic microorganisms. Moreover, FN2BP5 treatment at the proportion of D45 has generated 5 times more biogas than TB treatment containing only cow dung (50 g) while non-pretreated dead neem leaves (FNB) have not produced biogas. This demonstrates the interest to use biological pretreatment of lignocellulosic substrates which increases the formation of sugars through the activity of the hydrolytic microorganisms (Godin et al., 2010).

The valorization of the total dead neem leave biomass into different forms of energy is shown–as indicated in Table 2 taken into consideration the productivity of 73 L of biogas/kg of dead neem leaves.

The biomethanization of all biomass of dead neem leaves estimated in Maroua town could generate annually 756**.**538 m^3 of biogas. During all the defoliation period which is about 220 days, the daily production was 3438.8 m^3. This daily production is equivalent to the one supplied by the cow dungs which was 8**.**597 m^3 (IEPF, 2012).

In terms of the potential in electricity, the above quantity of biogas generated 17.194 MWh per day. In one year, the electricity supply will be about 3.783 GWh. Due to the low yield estimated to 33% (Mussoline, 2013) when converting biogas into the electricity, the net electricity production is 1,25 GWh/year or 5.674MWh/day. This could reduce the energy deficit in Cameroon that was estimated at 50 GWh in 2011 (SIE-Cameroon, 2011). According to ENEO (2015), the average electricity consumption in Cameroon is estimated at 165 kWh per capita, per year. Therefore, the dead neem leaves biomass in Maroua can meet the electricity needs of 7565 people covering 1260 families according to their average size (Madi et al., 2003).

Table 3. Surface area (ha) preserved from the destruction caused by firewood collection when valorizing dead neem leaves.

Surface areas preserved	Oct	Nov	Dec	Jan	Feb	March	April	May	Annual total	Daily mean
Yearly	76.0	83.9	78.8	81.9	80.8	76.4	72.1	17.5	567.4	2.6
in 10 years	760.0	838.7	788.4	819.0	808.1	764.4	720.7	174.7	5674.0	2.6

In terms of firewood, the daily production of biogas could substitute 17.2 tons, which corresponds to 3,783 tons of firewood per year. Knowing that the annual consumption of 266.4 kg/person in the city (MINFOF, 2014), 23558 people or 3926 households who were supposed to use firewood could be supplied in seven months. The valorisation of the dead neem leaves into biogas could therefore contribute to 7.15% reduction of fire wood consumption estimated at 52.884 tons/year in 2007 in Maroua town (Folefack and Abou, 2009). When converting the biogas produced into domestic gas (butane) available in 12.5 L bottles in Maroua, it corresponded to 24.209 bottles. At a price of 6500 FCFA a bottle authorized on the market, this stock could generate an income of 157.359 millions CFA.

Ecological interest

According to Ntsama et al. (2007), the consumption of a ton of wood is equivalent to the destruction of 0.15 ha of the forest in the Sahel region. Therefore, the surface area which could be preserved through the year and in 10 years is illustrated in Table 3.

From Table 3, the valorisation of the biogas as cooking energy from dead neem biomass quantified in Maroua town could allow the preservation of 567.45 ha/year of the forest, usually destroyed by the population when fetching firewood. This surface is daily estimated at 2.6 ha and in 10 years, will be 5674 ha. This contributes to the reduction of the surface destroyed from the use of firewood estimated at 194,490 ha in 2008, against 875.57 ha in 1990 in Cameroon (SIE-Cameroun, 2011). Just from the ecological role played by the biomethanization of dead neem leaves which are accessible, it could be more efficient than many strategies (planting trees) taken by governments in order to fight against deforestation in northern Cameroon (SIE-Cameroun, 2011). The interest of effluents of digestion that can serve as biological amendment in agriculture is not negligible. This new fertilizer could contribute to the setting-up of organic farming in the city from which healthy and biological food could quantitatively and qualitatively be available.

Conclusion

In Maroua town, dead neem leaves biomass produced daily about 53.7 tons. This biomass can yield 3438.8 m^3 of biogas energy daily which is equivalent to 3.783 tons/year in term of firewood. This mass of wood can feed in term of energy 23558 people for seven months. Therefore, this is assimilated to an annual wood preservation of 567.45 ha from the destruction as the result of firewood collection. The valuation of this gas into electricity could effectively generate 1.25 GWh/year. This could meet the demand for electricity of 7565 people. It therefore appears that the recovery of dead neem leaves could provide solutions to energy problems in Maroua city and in the Sahel region where neem trees are the main planted trees. For further studies, it is suggested the optimization of the management of dead neem leaves through physical, chemical and biological pretreatments.

Conflict of interests

The authors have not declared any conflict of interest.

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