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BIOGAS PRODUCTION FROM ANAEROBIC CO-DIGESTION OF CASSAVA EFFLUENT AND HUMAN URINE

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ABSTRACT

This study investigated anaerobic co-digestion of cassava liquid waste (Highly acidic with low nitrogen) and human urine (basic and rich in nitrogen). This method greatly contributes to the production of biogas. The digester operating in batch and continuous mode using cassava effluent + human urine + cow dung. The operation of the batch digester showed good purification with removal of the COD, nitrogen retention and fuel gas production of 192 m^3 with average of 80.75% methane. The operation of the digester Continuous revealed a biogas production of 166.45 m^3 with 61.23% methane. Biogas production remains remarkable whatever the mode of operation and the biogas used to cook attiéké, will reduce the use of firewood for cooking attiéké.

Key words: Anaerobic co-digestion, Cassava liquid waste, Human urine, Biogas.

INTRODUCTION

In Côte d'Ivoire, the main food form of tuberous roots of cassava is attiéké (semolina of manioc steamed) (Kakou, 2000). The production of this popular food with the majority of the Ivorian population generates significant waste due to 0.74 m^3 of water per tonne of processed cassava. According to Aboua *et al.,* (1990), 40 000 to 50 000 tonnes of fresh cassava tubers can produce 28 000 to 34 000 tonnes of attiéké. However, these effluent have firstly high organic matter content with fillers in BOD and COD respectively from 6 to 50 g/L and 1.5 to 35 g/L (Mahan, 2004; Kpata, 2005; Ubalua, 2007; Kpata-Konan *et al.*, 2011; Kpata-Konan *et al.*, 2013) and share with other toxic cyanide contents up to 500 ppm (Asiedu, 1991; Ihedioha, 2002; Goualo *et al.*, 2007). For the specific case of 93 Ebrié villages engulfed by the Autonomous District of Abidjan (Ivory Coast, West Africa) where many women are principally engaged in the manufacture of attiéké whereas, untreated wastewater from this activity are discharged into the natural environment including the Ebrié lagoon. These effluents degrade the quality of life, generate odors, promote the spread of pathogens and cause risks to human and animal health (Marache, 2001).

To remedy the pollution of the receiving environment, anaerobic digestion, a natural process of organic matter transformation into gas under microorganisms action (Yen and Brown, 2007; Kalloum *et al.*, 2011), appears to be a credible alternative for the treatment of these effluents. This method is widely used for the treatment of organic food waste highly loaded (Ubalua, 2007; Bouallagui *et al.*, 2009; Malekkhahi *et al.*, 2012). Anaerobic digestion allows energy recovery and recycling of agricultural waste cassava. In fact, it allows the production of biogas rich in methane (Neves *et al.*, 2006; Kalloum *et al.*, 2007) and the digestat from the process is rich in nitrogen (Gomez-Lahoz *et al.*, 2006; Kalloum *et al.*, 2011). Like other agro-food waste, effluent from cassava is rich in organic matter and acidic, but deficient in nitrogen (0.6 - 0.8 g/L), with pH values below 3 (Mahan, 2004; Kpata, 2005; Kpata-Konan *et al.*, 2011; Kpata-Konan *et al.*, 2013). These properties make it a bio-recalcitrance.

To sweeten the cassava effluent from the perspective of methane production can be done resorts to human urine? To this question we are trying to answer in the affirmative. Indeed, the human urine is rich in nitrogen (3 - 8 g/L) and becomes basic (pH > 8) through the processes of ammonification of organic nitrogen in the hygienization by storage (Kpata, 2005; Gnagne *et al.*, 2006; Kpata-Konan *et al.,* 2011; Kpata-Konan *et al.*, 2013). To respond accurately and factual, try this anaerobic digestion on a pilot digester was conducted by the attiéké factory of Azito village located in Yopougon (Abidjan Autonomous District). This work aims to evaluate methane production by co-digestion of waste cassava with human urine.

MATERIALS AND METHODS

Experimental device: Anaerobic digestion was carried out in a 6 m^3 capacity bioreactor, closed hermetically (Figure 1). This digester has three parts: upper part which constitutes the gas holder, a central part which forms the middle reaction and a lower portion reserved for emptying. With a volume of 2 m^3, the gas holder is equipped with a check valve, a safety relief valve and a manometer.

The reaction mixture has a volume of 4 m^3. It contains the effluent mixture of cassava, urine and cow dung. This part of the driver comprises a digester mixer powered by a gear motor FIMET, pipe supply, a discharge pipe on which is fixed a valve flap. The kneader reactor serves to homogenize the medium so as to prevent settling. The feed pipe is used for supplying the digester from a motor pump SDMO ST 2.36 H. As to the discharge pipe, situated at the bottom of the digester, it serves to drain the reactor.

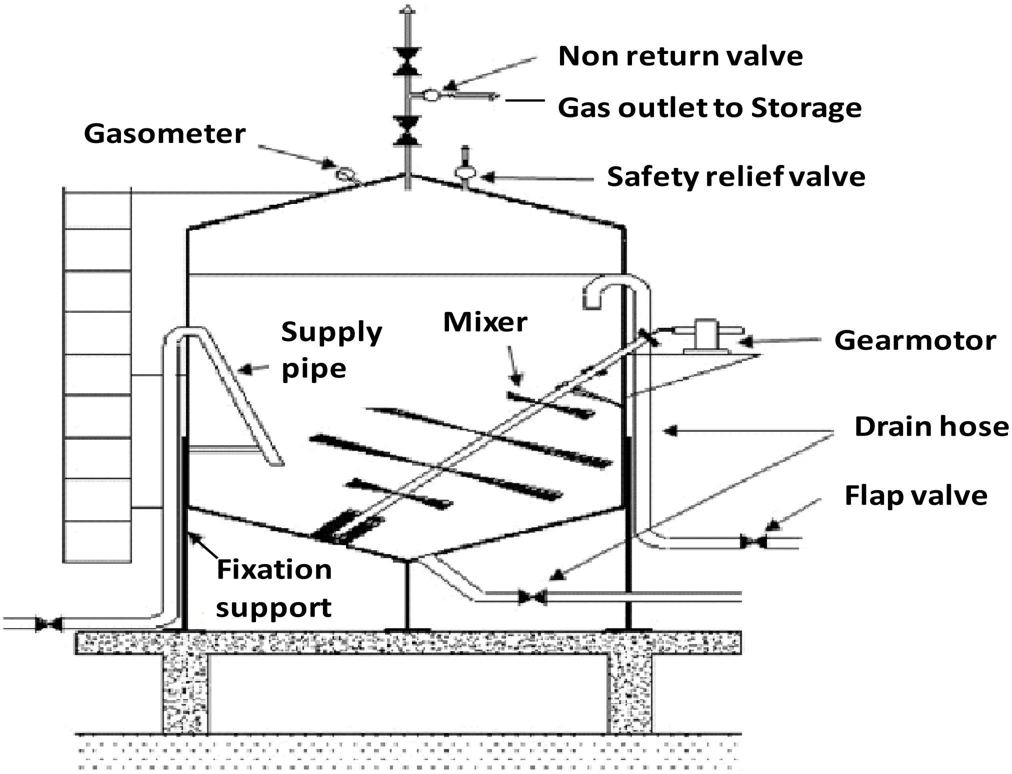

Figure-1: Schema describing the experimental device

Substrate: The pilot digester is fed with a mixture of 2.3 m^3 of cassava effluent, 1.7 m^3 of human urine and 323 kg of cow dung. Feeding this digester is made from a pump positioned between the storage tank and cassava effluent supply line of the digester. This digester operated discontinuously and continuously. The continuous mode operation allowed on other days supply evacuates an equivalent volume of effluent discharge line. During feeding sessions, an amount of 200 L of mixture of effluents cassava buffered to pH = 7 with human urine have been introduced into the digester. This reactor operating as a piston design is mechanically stirred by rotating once a day during 30 minutes.

Technical analysis: Volume (V) of biogas produced was measured daily using this formula: $V = (P_i / P_{atm}) \times \exp(1/(\gamma \times V_1))$; with P_i = initial pressure (bar) ; P_{atm} = Atmospheric pressure (bar) ; γ = 1.42 (Gama for natural gas) ; V_1 = Volume of gas holder (m^3).

The composition of the produced biogas was determined by gas chromatography. The energy value was obtained using the formula described by Ricard et al., (2010): PCI = 9.65 x M; PCI:

calorific value, expressed in kWh/m^3; M:methane proportion, percentage, in the biogas produced. Temperature, pH and Chemical Oxygen Demand (COD) were determined according to the standard methods. Total nitrogen was estimated by the Kjeldahl method. Temperature, pH, COD and TKN were determined twice per week. Carbon is the principal component of the organic substances found in wastewater. By biodegradation process under anaerobic conditions, microorganisms use carbon compounds to generate energy. In this study, carbon and nitrogen compounds were respectively determined as COD and TKN.

RESULTS

Purifying capacity biodigester: Removal of COD from 27.46 to 5.01 g/L with a purification rate of 81.75% is observed (Table I). The nitrogen values range from 3.87 to 2.08 g/L with a purification rate of 46.18%. The digester was operated on average 29.0 °C with a mean pH value of 7.87. The ratio COD/TKN observed during operation of the pilot batch digester ranged between 0.86 and 0.50.

Table-I: Physico-chemical parameters values in the output of the batch digester

Parameters	Digester characteristics
COD (g/L)	27.46 to 5.01
Treatment efficiency %	81.75
TKN (g/L)	3.87 to 2.08
Treatment efficiency %	46.18
COD/TKN	0.86 to 0.50
T (°C) average	29.0
pH average	7.87

Biodigester functioning in batch mode: The total volume of biogas produced during the period of operation of the pilot digester experimental batch is valued at 192.73 m^3. Gas production was almost nil during the first 50 days (Figure 2). The amounts of methane in the biogas produced fluctuated between 75.16 and 84.10% (Figure 3). Over the entire follow-up period of the pilot digester batch, the average content of methane in the biogas produced is estimated at 80.75%. As for carbon dioxide, the recorded amounts fluctuated between 12.98 and 19.11% (Figure 3). The average carbon dioxide on this observation period is 5.91%. At dinitrogen, the recorded values vary between 0.65 and 7.21% (Figure 3) for an average value estimated at 2.59% at the end of the 129 days of observation. Quantities of oxygen produced ranged respectively between 0.3 and 2.63% (Figure 3). The average value of oxygen during the 129 days was 0.88%.

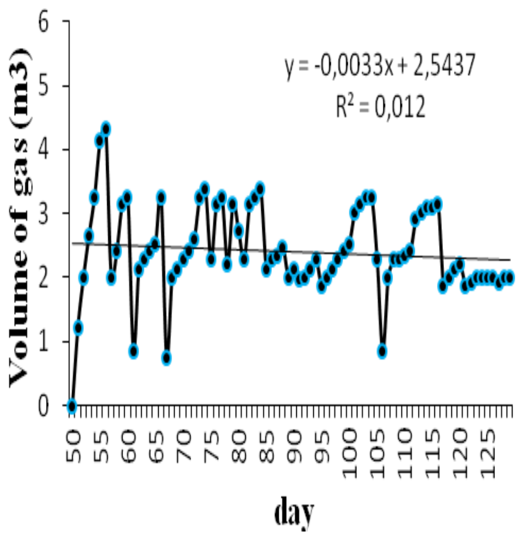

Figure-3: Evolution amounts of CH4, CO2, O2 and in the biogas produced during the operation of the batch digester pilot

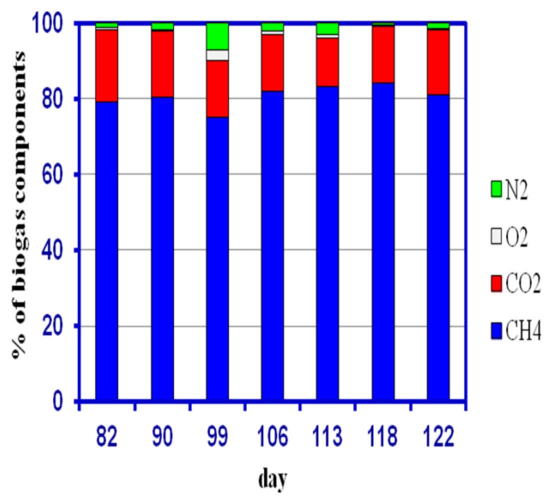

Figure-2: Gas evolution during operation of the digester mode driver discontinuous.

During the period of the batch, the total volume of biogas registered is estimated at 192.73 m^3. The average content of methane is estimated 80.75% (Table II). The lower heating value (LHV) of biogas produced during the period of operation in batch mode of 129 days is 1501.90 kwh. Reduced daily and monthly LHV corresponding are respectively estimated at 11.64 and 349.28 kwh.

Table-II: Summary data of the energy potential of biogas for the operation of the pilot batch

Average CH_4 (%)	LHV (kwh/m^3)	LHV (kwh pour 192,73 m^3)	Daily production (kwh)	Monthl production (kwh)
80.75	7.79	1 501. 90	11.64	349.28

LHV= lower heating value.

Biodigester functioning in continuous mode: The total volume of biogas produced during the entire period of operation of the continuous-mode driver digester is estimated at 166.45 m^3. The daily quantities of biogas produced ranged from 2.00 m^3 to 5.30 m^3 (Figure 4). Peak production (5.30 m^3) was recorded on the 164th day. Product biogas flammability test was positive throughout this period. The measured amounts of methane in the biogas produced fluctuated between 45.81 and 72.79% (Figure 5). The period of operation of the pilot digester in continuous mode, average proportion of methane in the biogas is estimated at 61.23%.

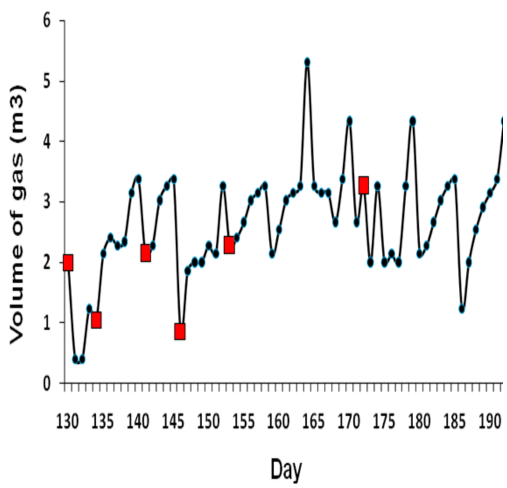

Figure-4: Evolution of biogas in the pilot digester operating in continuous mode. Red squares indicate day feed digester.

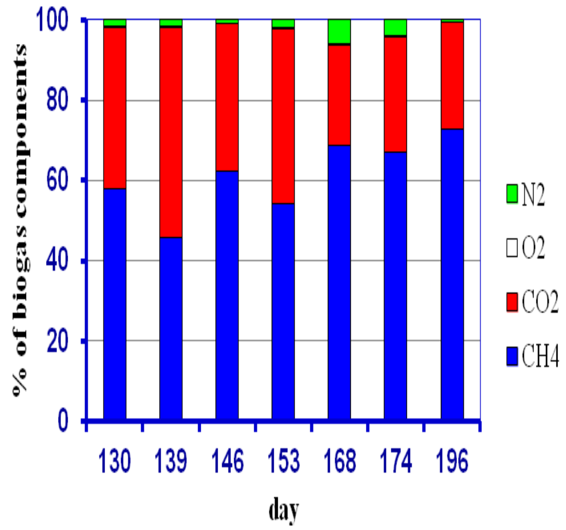

Figure-5: Evolution amounts of CH4, CO2, O2 and N2 in the biogas produced during the operation of the pilot digester in continuous mode.

For carbon dioxide, the identified quantities ranged between 24.77 and 52.38% (Figure 5) with an average value of 36.16%. At dinitrogen, the observed values were between 0.63 and 5.96% (Figure 5) with a mean value of 2.35% during 63 days of observation. For oxygen, the quantities recorded over the entire reactor operating in a continuous mode period varied between 0.04 and 0.48% (Figure 5). The average value of dioxygen during these 63 days was 0.29%.

During the period of continuous operation, the total volume of registered biogas is estimated at 166.45 m^3 with an average grade of 61.23% methane (Table III). The lower heating value (LHV) of biogas produced during this period is estimated at 983.50 kwh. Reduced daily and monthly LHV corresponding are respectively estimated at 15.61 and 468.33 kwh.

Table-III: Summary data of the energy potential of biogas recorded during continuous operation.

Average CH_4 (%)	LHV (kwh/m^3)	LHV (kwh for 166,45 m^3)	Daily production (kwh)	Monthly production (kwh)
61,23	5,91	983,50	468,33	15,61

LHV= lower heating value.

DISCUSSION

The analysis results show that the volume and composition of biogas are important for controlling and monitoring the process of anaerobic digestion. A good biogas production, ie rich in CH_4, reflects the proper operation of the digester. The production of biogas in digester pilot operated in batch mode was recorded after 50 days of operation. This startup delay of anaerobic digestion could be justified by the cow dung insufficient introduced into the reactor. This failure has not promoted the rapid growth of microorganisms. Indeed, the work of Kalloum *et al.* (2007) on the anaerobic digestion of household waste and Igoud *et al.* (2002) on the anaerobic digestion of cattle manure produced biogas respectively after 25 days and 10 days of operation. It should be noted that the drop in gas production observed in batch mode is related to the decrease in the methanogenic bacterial community. Furthermore, gas production was continuous without interruption despite the different phases of loopbacks. This is linked to the maintenance of the methanogenic bacterial community in the digester.

Regarding the composition of the biogas, methane batch averages 80.75%. In the continuous digester in the average volume of methane is 61.21%. This difference could be explained by the contribution of organic matter introduced each recharge continuously.

Although disrupted the operation of the pilot digester, repeated recharge pilot digester after at least two months of operation has not destabilized the biochemical and microbiological equilibrium. This stability of the reaction medium despite the different phases of refeeding can be explained by the fact that the cassava effluent is respectively buffered (pH = 7) with human urine before its introduction into the digester. This power before pH adjustment allowed to control the pH of the reaction medium to stabilize around 8. What was involved in maintaining sustainable methanogenic bacteria responsible for the production of biogas in the reaction medium. According Steyer *et al.* (2002) and Liu *et al.* (2003) the resistance of methanogenic bacteria is closely related to the environment of the reaction medium which is optimal for pH ranges around neutrality.

Generally the biogas collected in the digester is essentially composed of CH_4, CO_2, N_2 and O_2. The methane in the biogas produced fluctuated between 45.81 and 84.10% with an average of 70.99%. Indeed, a methane content of 50% is acceptable for anaerobic digestion of waste (Stroot *et al.*, 2001; Bolzonella *et al.*, 2006). At the energy aspect of the registered biogas in this study, it was measured using the net calorific value (Ricard *et al.*, 2010; Acqualys, 2012). The lower heating value of methane is 9.65 kWh/m^3 (Ricard *et al.*, 2010), the potential for energy production in the transformation of effluents from the production of biogas attiéké is valued at 1501.90 kwh after 129 days in a batch mode and 983.50 kwh after 63 days of operation in continuous mode the digester.

This study shows that the production and biogas composition remains remarkable whatever the mode of operation. They deviate economically obvious that the production of biogas from effluents from factories attiéké be an important source of income for producing attiéké. Which could reduce the use of firewood for cooking attiéké?

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