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RESEARCH ARTICLE

OPTIMIZATION OF CASSAVA EFFLUENT BIOMETHANIZATION WITH ASH AS COSUBSTRATE

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Abstract

The main objective of this study is to determine the optimal conditions for anaerobic biodigestion of cassava effluents with the ash of cassava peels as co-substrate. To do this, three (03) digesters were used in which were put effluent + ash for digester 1, effluent + ash + cow dung for digester 2 and effluent + ash + urine for digester 3. The physico-chemical parameters (temperature, pH), biochemical parameters (COD and TKN) and the volume of biogas produced were quantified. In each of the reaction media a decrease in values was observed in pH (digester 1: 7.15 to 6.92; digester 2: 7.20 to 5.38; digester 3: 7.00 to 5.28), COD (digester 1: 1.66g/l to 1.16g/l; digester 2: 1.81g/l to 1.44g/l; digester 3: 1.46g/l to 0.99g/l) and NTK (digester 1: 0.27 g/l to 0.24 g/l; digester 2: 0.29 g/l to 0.22 g/l; digester 3: 0.25 g/l to 0.16 g/l). For the temperature of the media, the recorded values are in the range of mesophilic fermentation (digester 1: 26.66°C, digester 2: 27.97°C and digester 3: 27°C). Regarding gas production, the digesters produced gas from day 1 with 37.463 m³, 37.463 m³ and 69.272 m³ respectively. A significant improvement in the biogas production rate was observed in all digesters. Thus, the ash could be used as a replacement for human urine for pH adjustment of cassava effluents.

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Introduction:-

Cassava (*Manihot esculenta* Crantz) is a tropical root crop, native to the Amazon basin (FAO, 2013). It has become an important source of food energy that provides staple food for approximately 800 million people worldwide (FAO, 2013). Cassava is the third most important food product in the tropics after rice and maize (Koko et al. 2014). Annual production in Côte d'Ivoire estimated at 2,450,000 tons, ranks second among food crops after yam (FAO, 2013). It constitutes a main source of income for households, especially for women and the very poor through its production, processing and marketing (Emmanuel, 2010). According to Akoroda (2007) the ease and mastery of cassava processing technologies have made it possible to obtain various derivative products. These include: toh from Guinea; tapioca from Benin; cassava foutou, "placali" and "attiéké" from Côte d'Ivoire. Very popular in Côte d'Ivoire where it has become a national dish, attiéké is the main form of food use of cassava. However, the process of making attiéké generates waste represented by peels, snares and pressing juice (Krabi et al., 2015). The latter also called effluent is toxic due to its high cyanide content that can reach 500 ppm (Goualo et al., 2007).

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These effluents are also loaded with organic matter with COD values that can vary from 6 to 50 g/L and BOD varying from 1.5 to 35 g/L (Kpata-Konan, 2013). Discharged into the environment and represent a source of pollution for the population. Indeed, according to (Marache (2001), these effluents generate olfactory nuisances, promote the spread of pathogens and cause risks to human and animal health. Thus, previous anaerobic codigestion studies (Kpata, 2005; Kpata-konan et al.; 2013) on cassava effluents were initiated in Azito village. These studies, which aimed to optimize the biodigestion process of these effluents, consisted of fertilization and pH adjustment with human urine before starting the treatment of cassava effluents from the attiéké production chain. The effluents are stored in confined enclosures (digesters) in which the fermentation reactions are optimized and controlled. This biological process produces combustible biogas, a renewable energy, from organic matter by bacteria under anaerobic conditions (Le Hyaric et al., 2010; Kalloum et al., 2011; Zhu et al., 2011). According to Gomez-Lahoz et al. (2007) and Poh and Chong (2009), this anaerobic digestion can reduce the organic pollutant load by half. But the proportion of urine used (40%) for a better biogas productivity seems high. Moreover, it is increasingly out of reach. In order to reduce the amount of urine and also cassava waste (peel), the ash from the cassava peelings after drying has been used as a co-substrate in the biodigestion process which has the same characteristics as urine and more available.

Material and Methods:-

Material:-

The reactors each consist of two parts (**Figure 1**). The first part consists of a large metal drum with a capacity of 28 L and contains the reaction medium. The second part is made up of a small metal drum with a capacity of 18 litres, the open side of which is immersed in the larger drum until it touches the bottom of the latter. The small barrel serves as a gasometer where the biogas produced is stored. A mixer and valve are mounted on this drum. The mixer is used to homogenise the reaction medium to prevent settling. The valve is used to burn the biogas produced.

The raw material for this study is cassava effluent with a pH of between 3.00 and 4.20, a mixture of washing water from peeled cassava and the juice collected after pressing the cassava paste from the Lobiaattieke factory (Daloa). Cow dung, ash and human urine with a pH between 8.00 and 10.00 were used respectively for inoculation and neutralisation of the reactor medium. The cow dung came from the slaughterhouse in the town of Daloa. The ash obtained after the combustion of cassava peels was used to enrich the cassava effluents in nitrogen and to correct the pH of these effluents. Urine was collected in the TSDU (urine-diverting dry toilets) installed at the Université Jean Lorougnon GUEDE.

The temperature and pH of the reaction medium were measured using a WTW type pH meter (pH 3210 SET 2). A commercial type CAP.20 kg/GRAD.50 g was used to weigh the cow dung.



Figure1:- Schema describing the experimental device.

Methods:-

The three digesters were fed as follows:

- digester 1: effluent (E)+ ash (As)
- - digester 2: effluent (E) + ash (As)+ cow dung (C)
- digester 3: effluent (E) + ash (As) + urine (U)

To make the ash, we collected 300 kg of cassava peelings, which were put into 50 kg bags for transport. The manioc peelings were laid out in the sun for 7 days to dry, and then burnt on the 7th day until a white ash was obtained.

Technical analysis

Temperature, pH and Chemical Oxygen Demand (COD) were determined according to the standard methods AFNOR(1994). Total nitrogen was estimated by the Kjeldahl method. Temperature and pH were monitored daily in the reactors, while 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.

Volume (V) of biogas produced was measured daily using this formula: $V = \pi \times R^2 \times H$; with H = height of rising of the gasometer (small barrel); R = Radius of the gasometer (small barrel).

Statistical analysis

In order to determine whether the observed differences between reactors performances were significantly different. ANOVA was carried out to highlight differences between digesters depending on the variables considered. The statistical analyses were carried out using Paleontological Statistic (PAST) version4.02 (Hammer et al., 2001).

Results:-

pH

The pH levels in all the reactors changed in a similar way throughout the study period (**Figure 2**). The values of the pH in the digester drop slightly from 7.15 to 6.92 for the digester 1 (E + As), 7.20 to 5.38 for the reactor 2 (E + As+ C), 7.00 to 4.47 and for the digester 3 (E + As+ U).Overall, the pH in digester 1 is significantly ($p < 0.05$) higher than that in digesters 2 and 3 (Table 1).However, there was no significant difference between digester 2 and 3 ($0.9231 \geq 0.05$). (**Table I**)

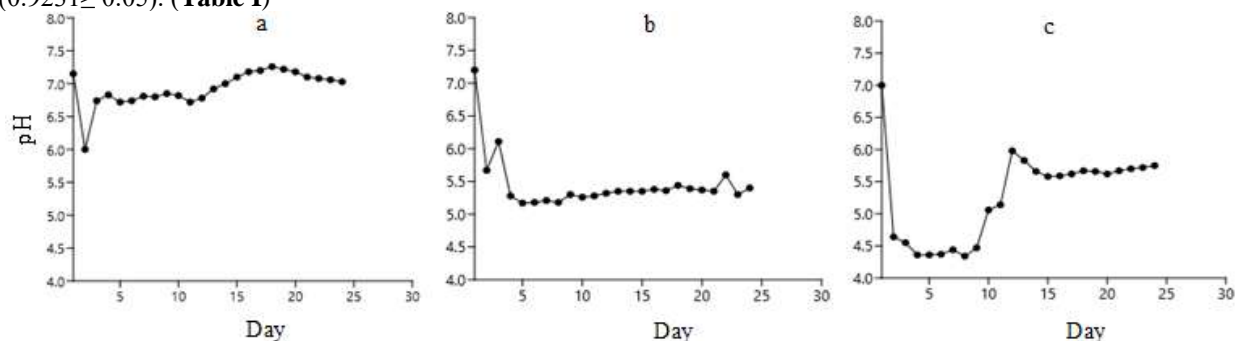


Figure 2:- Daily variation in pH in the different reactors.a: reactor 1 (E +As = cassava effluent + Ash), b: reactor 2 (E + As + C = cassava effluent + Ash + cow dung), c: reactor 3 (E+ As+ U = cassava effluent + Ash + urine).

Table 1:- Results of the PASTE 4.02 parametric test carried out to compare pH,

pH	E +As	E+ As+ C	E+ As+ U
E +As		$1,6.10^{-08}$	$2,9.10^{-08}$
E+ As+ C	$1,6.10^{-08}$		0,9231
E+ As+ U	$2,9.10^{-08}$	0,9231	

E +As = effluent (E)+ Ash (As), E+ As+ C = cassava effluent + Ash+ cow dung, E+ As+ U = cassava effluent + Ash + urine.

Temperature

The temperature measured in digester 1 varied between 29.5 and 24°C, with an average of 26.66°C (**Figure 3a**). In digester 2, the temperature recorded fluctuated between 34.5 and 24.5°C (**Figure 3b**), with an average of 27.97°C.

In digester 3, the temperature fluctuated between 30.5 and 24°C (**Figure 3c**), with an average of 27°C. Overall, the digesters operated in a mesophilic manner. Statistical analysis ($p \geq 0.05$) showed that there was no difference between the digesters (**Table 2**).

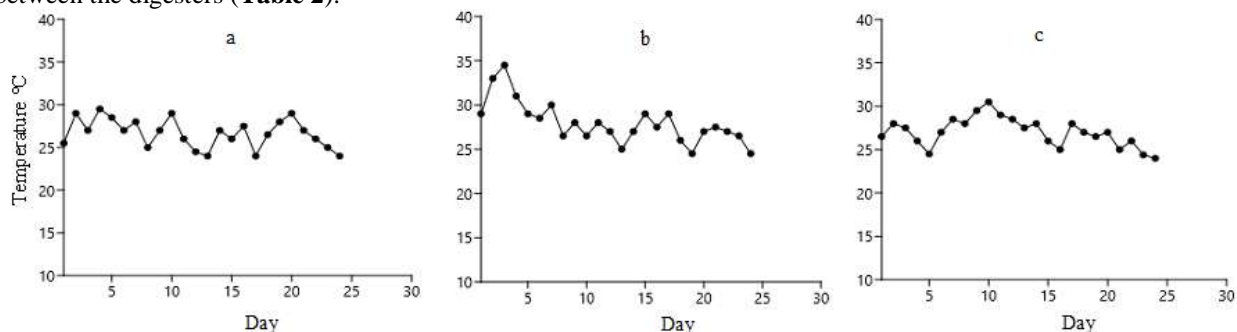


Figure 3:- Daily variation in temperature in the different reactors.a: reactor 1(E +As = cassava effluent + Ash), b: reactor 2 (E+ As+ C = cassava effluent + Ash+ cow dung), c: reactor 3 (E+ As+ U = cassava effluent + Ash + urine).

Table 2:- Results of the PASTE 4.02 parametric test carried out to compare the temperature in the different digesters.

Temperature	E +As	E+ As+ C	E+ As+ U
E +As		0,9917	0,9917
E+ As+ C	0,9917		0,9917
E+ As+ U	0,9917	0,9917	

E +As = effluent (E)+ Ash (As), E+ As+ C = cassava effluent + Ash+ cow dung, E+ As+ U = cassava effluent + Ash + urine.

Kjeldahl nitrogen (KTN)

The amount of nitrogen observed in the digesters fell slightly throughout the experiment. The nitrogen concentrations observed varied from 0.27 to 0.24 g/L for digester 1 (E + C), from 0.29 to 0.224 g/L for digester 2 (E + As + C) and from 0.252 to 0.16 g/L for reactor 3 (E + As + U) (**Figure 4**). Statistical analysis showed that KTN concentrations did not vary significantly ($p \geq 0.05$) in the digester (**Table 3**).

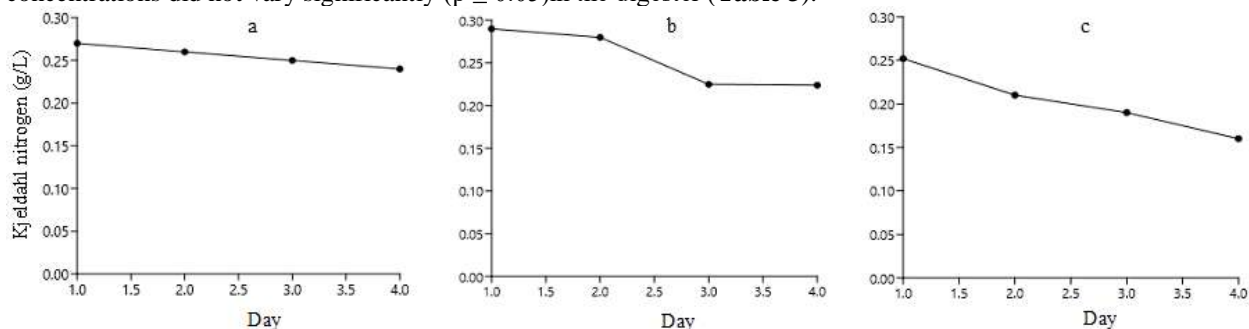


Figure 4:- Daily variation in Kjeldahl nitrogen in the different reactors.a: reactor 1(E +As = cassava effluent + Ash), b: reactor 2 (E+ As+ C = cassava effluent + Ash+ cow dung), c: reactor 3 (E+ As+ U = cassava effluent + Ash + urine).

Table 3: - Results of the PASTE 4.02 parametric test carried out to compare the KNT in the different digesters

KTN	E +As	E+ As+ C	E+ As+ U
E +As		0,9825	0,08067
E+ As+ C	0,2534		0,0611
E+ As+ U	3,513	3,767	

E +As = cassava effluent + Ash, E+ As+ C = cassava effluent + Ash+ cow dung, E+ As+ U = cassava effluent + Ash + urine,

Chemical oxygen demand (COD)

During the experiment, COD decreased in all the digesters (**Figure 5**). The initial quantity of organic matter is 1.668 g/l for digester 1, 1.812 g/l for digester 2 and 1.460 g/l for digester 3. In digester 1, a gradual reduction in the

pollutant load from 1.668 g/l to 1.169 g/l was observed from day 1 to the last day. In digester 2, the pollutant load recorded varied between 1.812 g/l and 1.449 g/l. For digester 3, the pollutant load fell from 1.460 g/l to 0.998 g/l (Figure 4). Overall, there were no significant ($p \geq 0.05$) differences between the digesters (Table 4).

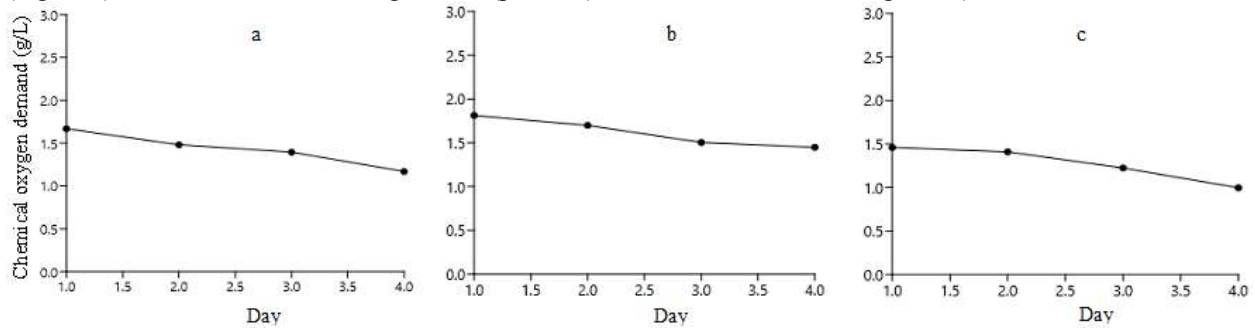


Figure 5:- Daily variation in Chemical oxygen demand in the different reactors. a: reactor 1 (E +As = cassava effluent + Ash), b: reactor 2 (E + As + C = cassava effluent + Ash + cow dung), c: reactor 3 (E+ As+ U = cassava effluent + Ash + urine).

Table 4:- Results of the PASTE 4.02 parametric test carried out to compare the COD in the different digesters.

DCO	E + As	E + As + C	E + As + U
E + As		0,4029	0,5275
E + As + C	1,915		0,08218
E + As + U	1,581	3,496	

Volume of biogas produced

Figure 6 shows biogas production in the various digesters over the study period. Biogas production in all digesters began on day 1 of the experiment, with volumes of 7.775 m³ for digester 1 (E + As), 12.930 m³ for digester 2 (E + As+ C) and 9.189 m³ for digester 3 (E + As + U).

Digester 1 (E + As) reached a peak of 9.189 m³ on day 3 and then gradually decreased until day 9. The total volume of gas produced was 37.463 m³. The flammability test for the gas produced was positive from day 3 to day 5.

As for digester 2 (E + As + C), the peak of the gas produced was observed on the 3rd day of the experiment with a volume of 13.546 m³ before decreasing on the 10th day. The total volume of gas produced in this digester was 57.880 m³, with a positive flammability test on days 2 to 4.

For digester 3 (E + As + U), two peaks were recorded. The first peak of 9.189 m³ occurred on day 3 and then fell until day 9. The second peak occurred on day 10 following a sudden increase in gas volume of 12.016 m³, and then gradually decreased until day 16. The total volume of gas produced by this digester was 69.272 m³. The flammability test was positive from day 10 to day 13 (Figure 5). Overall, gas production showed no significant difference ($p < 0.05$) in the digesters.

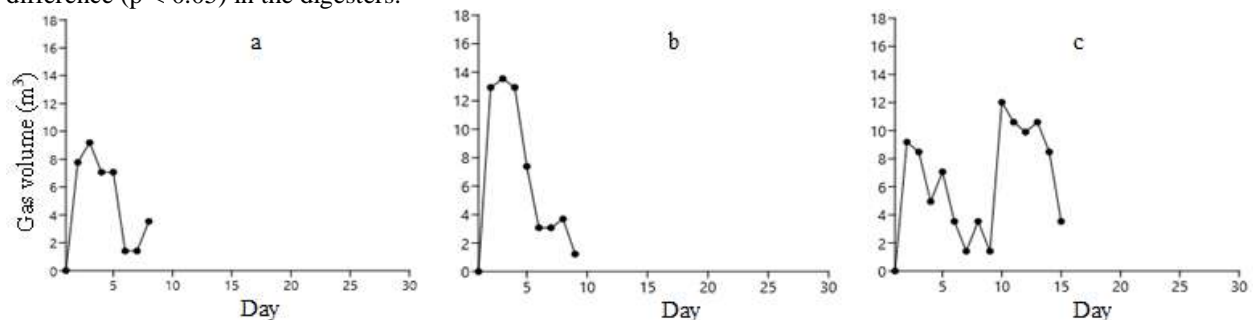


Figure 6:- Daily variation in gas volume in the various digesters. a: reactor 1 (E +As = cassava effluent + Ash), b: reactor 2 (E + As + C = cassava effluent + Ash + cow dung), c: reactor 3 (E+ As+ U = cassava effluent + Ash + urine).

Table 5:- Results of the PASTE 4.02 parametric test carried out to compare the gas volume in the different digesters.

V gaz	E +As	E+ As+ C	E+ As+ U
E +As		0,4137	0,3632
E+ As+ C	0,4137		0,9962
E+ As+ U	0,3632	0,9962	

E +As = cassava effluent + Ash, E+ As+ C = cassava effluent + Ash+ cow dung, E+ As+ U = cassava effluent + Ash + urine,

Discussion:-

The change in pH in the digesters as a whole is believed to be due to the addition of ash, which has a basic character, to the acidic cassava effluent (Mahan, 2004). According to Parawira et al (2006), the optimal pH for anaerobic digestion is between 6.4 and 7.2 in the biomethanisation process. The slight decrease in pH values observed in the first days of the experiment could be explained by the formation of organic acids during the degradation of organic matter. These first days of experimentation correspond to the hydrolysis and acidogenic phases in the biomethanisation process, as confirmed by Maiga et al., (2008). These pH drops in the ash-enriched digesters did not, however, have an inhibiting effect on the methanisation process because they were of short duration and low amplitude. The stabilisation of the pH in the optimal range would be due to the presence of acetogenic bacteria that dissociate the organic acids produced (lactic acid, acetic acid, propionic acid, etc.) as also observed by Colin et al. (2007) and Ahou (2019). The temperature in all the digesters operated in the mesophilic fermentation range (24 and 35 °C). This temperature range is favoured by the country's tropical climate characterised by high sunshine and average annual temperatures of over 26 °C (Kouamé et al., 2010). According to De La Farge (1995), mesophilic systems are the most common and best controlled. These systems are more resistant to temperature variations and are sufficiently suitable for small and medium-sized systems used in the agri-food sector. With regard to nitrogen concentration, it is generally accepted that concentrations of around 0.2 g/L are beneficial for anaerobic digestion processes (Liu et al, 2008). However, a higher concentration constitutes a real toxicity for metabolic processes. This low nitrogen reduction could be explained by the low volatilisation of ammoniacal nitrogen observed in anaerobic digestion (Maiga et al., 2008). The residues of this digestion can therefore be used as fertiliser in agriculture. The high concentrations of nitrogen observed in these digesters would be due to the addition of ash and human urine. The gradual decrease in COD indicates that the digesters are functioning well overall. According to Maglwa (2019), these reductions in pollutant load could be explained by the potential consumption of organic matter by the purifying microflora during its natural evolution in these digesters.

The high production and flammability in a very short time of the biogas produced in the digesters were favoured by the adjustment of the pH (almost neutral) of the reaction medium at the start of the experiment. According to Guiraud (2003) and Kalloumet al. (2007), pH values close to neutrality are much more favourable to the development of the methanogenic bacteria responsible for biogas production. Furthermore, the flammability test of the biogas produced by the reactors was positive from day 3 for the E+C digester, day 2 for the E+C+B digester and day 10 for the E+C+U digester. In addition, the gas produced burns with a blue flame. These results indicate the presence of methane in the biogas of these three co-digestion systems. The observed results could be due to a positive synergy of the bacteria within the bioreactors, especially in those containing the substrates cassava effluent + ash and effluent + ash + cow dung. These digesters would be best suited for anaerobic digestion of cassava manure.

Conclusion:-

The results indicate a significant improvement in the biogas production rate in all digesters. A positive flammability test in a very short time especially for digester1 (E+C) from the 3rd day of feeding and digester2 (E+C+B) from the 2nd day of feeding. Fertilisation and pH adjustment prior to the start of the treatment of cassava effluent from the attike production chain by anaerobic digestion is crucial for the optimisation of the biomethanisation process. The results of the study show that ash could be used as a replacement for human urine for the adjustment of the pH of the cassava effluent which has a very high acidity. In addition, it is recommended to seed the reaction medium with cow dung to boost biogas production.

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