Journal of Sustainable Bioenergy Systems, 2020, 10, 113-130
https://www.scirp.org/journal/jsbs
ISSN Online: 2165-4018
ISSN Print: 2165-400X

Valorization of Agricultural Waste: Theoretical Estimation and Experimental Biomethane Yield from Cashew Nut Hulls

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How to cite this paper: Nikiema, M., Somda, M.K., Sawadogo, J.B., Dianou, D., Traoré, A.S. and Ouattara, A.S. (2020) Valorization of Agricultural Waste: Theoretical Estimation and Experimental Biomethane Yield from Cashew Nut Hulls. *Journal of Sustainable Bioenergy Systems*, **10**, 113-130.
https://doi.org/10.4236/jsbs.2020.104009

Received: September 23, 2020
Accepted: December 14, 2020
Published: December 17, 2020

Abstract

Biomethane potential production from cashew nut hulls, an agricultural waste, was carried out using old and fresh hulls as substrates. Samples were taken from old hulls (around 8 years old) and fresh hulls produced in cashew scale transformation units at Bobo Dioulasso/Burkina Faso. Physicochemical parameters showed that cashew hulls can be a good candidate for anaerobic digestion. But high acidity, total phenols and lignin tenor could be a constraint for anaerobic bacteria. Theoretical biochemical methane potential showed high value of 666.937 CH_4 L. (Kg VS)$^{-1}$ and 526.206 CH_4 L. (Kg VS)$^{-1}$ for crushed fresh and powdered old hulls, respectively. Experimental biochemical methane potential showed significantly low potential of 1.982 CH_4 L. (Kg VM)$^{-1}$ and 46.840 CH_4 L. (Kg VM)$^{-1}$ for fresh and hold hulls, respectively. Pretreatment for optimization, chemical composition and co-digestion system must be expected for a better anaerobic digestion performance.

Keywords

Agricultural Waste, Cashew Shells, Anaerobic Digestion, Bio-Energy, Burkina Faso

1. Introduction

Cashew trees are grown in tropical regions of the world. The cashew tree occupies an important position among tropical fructiferous trees on account of growing

commercialization of its main products: nut, cashew nut shell liquid (CNSL), and cashew "apple". Cashew almond is the main commercial product of this tree which can produce around 200 to 300 fruits per year. Cashew production is more concentrated in tropical areas such as Northeast Brazil, West Africa, East Africa, Southeast Asia and islands in southern Indonesia (**Figure 1**) [1] [2].

The processing of cashew nuts is carried out on large industrial scales in countries such as India, Vietnam and Brazil [2]. However, in many African countries such as Kenya, Mozambique, Tanzania, Burkina Faso, Nigeria, Benin, Côte d'Ivoire and Guinea-Bissau, the cashew nut transformation takes place either on small industrial or semi-industrial scales. In most West African producing countries, there are artisanal transformation units. In Burkina Faso, cashew sector is experiencing an increasingly significant development. The main production provinces are those of Kénédougou and Houet (region), Léraba and Comoé (Cascades region), Poni and Noumbiel (South-West region) and Sissili (Center-West region) with an estimated production of 81,000 tons in 2017 [3].

Processing units, whether large or small, semi-industrial or artisanal, generate 21% almonds and 79% consists of 73% hulls and 6% dandruff [4]. Thousands of tons of hulls and dandruff are rejected and constitute a source of environmental pollution. Indeed, transformation units store cashew hulls face difficulties accessing energy and managing waste. Hulls and dandruff are burnt to provide energy necessary for weakening of nuts, steaming and drying almonds. This combustion generates significant damage to the environment and human health [5]. In the small scale transformation units of Burkina Faso, this kind of waste can be advantageously used to provide energy necessary for steps of weakening of nuts and drying almonds, particularly energy-consuming processes which generally use unsustainable energy sources such as wood and

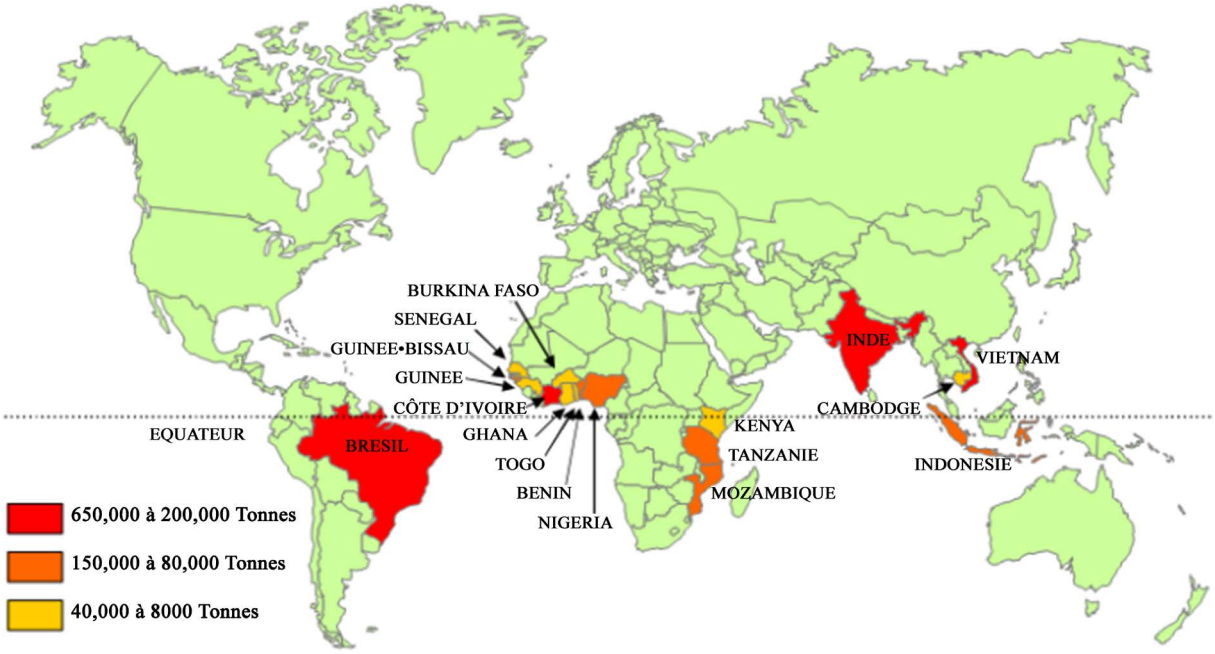

Figure 1. World geographic representation of cashew nut producer (reported by [2]).

butane gas [6].

Cashew nut consists of a hard woody hull containing cashew nut shell liquid (CNSL). CNSL is composed of 70% - 90% anacardic acid, 10% - 18% cardol and around 5% cardanol [7] [8]. Most of the cashew nuts valorization work are oriented towards CNSL extraction processes, some only speaking of thermochemical treatment, in particular pyrolysis and gasification [7] [9] [10]. Wastes (hulls and dandruff) are lignocellulosic compounds, studies showed the possibility to use them in bioenergy (biogas) production. Lignocellulosic substrates include woody substrates such as hardwood and softwood, agricultural residues, dedicated energy crops, weeds and municipal solid waste. Structure and components of weed cell walls are significantly different from that of most plant species, which can influence digestibility during bioconversion process [11] [12]. The possibility to use agro-wastes like coconut oil cake, cashew apple waste, and grass from lawn cuttings in anaerobic digestion was demonstrated [13]. The anaerobic digestion of cashew bagasse was experimented, but no conclusive result was found due to the complexity of this substrate [14]. No study has currently been carried out on use of cashew hulls in anaerobic digestion given complexity of this new substrat. The presence of certain substances including anacardic acids, cardol and cardanol could constitute a limit to the bioconversion of cashew shells into biogas. The objective of this study is to determine physicochemical composition of cashew hulls in order to estimate biomethane potential and to consider various treatments suitable for an application.

2. Materials and Methods

2.1. Sampling and Preparation of Cashew Hulls

Sampling was carried out on the site of ANATRANS, a high scale transformation unit of cashew, located to Bobo-Dioulasso, in Burkina Faso, West Africa. Two types of waste sample were used: eight-year-old hulls (OH) and fresh hulls (FH) freshly produced. Old hulls samples were ground to particles with a diameter of 1.0 mm while fresh hulls were justly crushed, as shown in **Figure 2**.

2.2. Chemical Analysis

2.2.1. pH and Acidity

The pH was determined according to method described by [15]. Five gram (5 g) of powdered old hulls and crushed fresh hulls was homogenized in 45 mL of distilled water. pH meter (WTW pH340) previously calibrated with buffer solutions at 25˚C was used for measurement. Ten gram (10 g) of sample were diluted into 90 mL distilled water. Solution was used for titration of lactic acidity (in triplicate) with 0.1 N sodium hydroxide until a stable pH of 8.50 is obtained. Acidity was calculated according to [15] and confirmed by direct titration of NaOH 0.1 N with phenolphthalein indicator as follows Equation (1).

$$\text{Acidity}(\%) = \frac{N \times V\text{NaOH} \times M}{\text{Pe} \times 10} \quad (1)$$

Figure 2. Photograph showing condition of two types of sample of cashew hulls: (a) Old hulls; (b) Powdered old hulls; (c) Fresh hulls; (d) Crushed fresh hulls.

where: *N*: Normality of NaOH (0.1 N), *V*NaOH: Volume of NaOH to have turn (mL), *M*: Anacardic acid molecular weight (342.4718 g/mol), Pe: Test sample in grams (5 g), 10: g of acid per 1000 g of sample.

2.2.2. Determination of Total and Volatile Solids

Total and volatile solids contents were determined according to [16], implemented in analysis of soils reported by [17]. Total solid content (TS) was determined by drying 5 g sample in an oven at 105˚C until a constant weight is obtained. Volatile solid (VS) content was obtained by weight difference between dried waste and waste burned at 550˚C for 4 hours.

2.2.3. Determination of Total Phenols

Adapted method described by [18] using 1:5 ratio (w/v) was used. One gram (1 g) of defatted hulls samples was macerated in a closed 50 ml bottle containing 10 ml mixture of methanol (80%) and water (20%) on a magnetic stirrer at room temperature. After 24 h, the mixture was centrifuged at 1000 g and supernatant was used for phenols assay. Total phenols were estimated by [19] method reported by [20]. Fifty microliters (50 µl) of Folin-Ciocalteu reagent (FCR) (0.2 N in distilled water) was mixed with 10 µl of shells extract (0.1 mg/mL) in a 96-well plate. Five minutes (5 min) incubation, 40 µl of Na_2CO_3 (75 g/L) is added to the previous mixture. The mixtures were kept at room temperature in the dark for 2 h. Absorbances were then read at 760 nm using a BioteckEpoch spectrophotometer UV (CECIL CE 2041, Cambridge, England). Phenols contents extracts were determined from regression equation ($Y = 0.014X + 0.145$; $R^2 = 0.997$) obtained from a dilution range of gallic acid in water. Three tests were carried out, and the result was expressed in milligrams of gallic acid equivalent per 1 g of extract (mg GAE·g^{-1}).

2.2.4. Determination of Macromolecules

Lipid content was determined according to Soxhlet extraction method using hexane as solvent [21]. The balloons were washed and dried. Empty weight of balloons was determined. Five grams (5 g) of waste powder were introduced into extraction cartridges which were closed with cotton and placed in Soxhlet. The balloons were filled with approximately 300 mL hexane and then connected to Soxhlet. The whole was connected to a refrigeration system and was connected to a cryostat to condense solvent vapors intended to entrain the lipids. The extractions lasted 4 h. Hexane was separated from lipids by evaporation on rotary evaporator and flasks were dried at 105˚C. After 1 h, flasks were cooled in desiccators and then weighed.

Total protein content was determined by Kjedahl method as described by [22] reported by [23]. One and half gram (1.5 g) of sample was placed in a flask and 12 mL sulfuric acid (95%) and catalyst tablet (Kjeltabs) were added. After hydrolysis step at 400˚C for 2 h, distillation was performed using Kjeltec apparatus. Ammonia formed will be titrated with sulfuric acid 1 N. Total protein was determined indirectly by a nitrogen-to-protein factor (6.25), 16% in proteins [24].

Lignin content of biomass samples was determined in accordance with [25] by [26]. Extracted dried biomass after lipid analysis was used. Dried extracted raw biomass (0.3 g) was weighed in glass test tubes and 3 mL H_2SO_4 (72%) was added. Sample was kept at room temperature for 2 h with carefully shaking at 30 min intervals to hydrolyze and solubilize the carbohydrates. The sample was then diluted with water (560 mL to reduce sulphuric acid concentration to 3% and further boiled for 4 h. Next, lignin is allowed to settle before being filtered. The second step of hydrolysis was made to occur in autoclave at 121˚C for 1 h. Slurry was then cooled at room temperature. Hydrolyzates were filtered through vaccum using filtering crucible. Acid insoluble lignin was determined by drying the residues at 105˚C and accounting for ash by incinerating the hydrolyzed samples at 575˚C in a muffle furnace. Acid soluble lignin fraction was determined by measuring absorbance of acid hydrolyzed samples at 320 nm. Lignin content was calculated as the summation of acid insoluble lignin and acid soluble lignin. Lignin content was calculated as summation of acid insoluble lignin and acid soluble lignin [25] using Equation (2).

$$\text{Soluble lignin}(\%) = \frac{A}{110} \times \frac{\text{Dilution}}{m(\text{g})} \times 100\% \quad (2)$$

where: A = Absorbance, m = Original sample weight (g).

Combined hemicelluloses and celluloses (H & C) content of crude cake representing carbohydrates was estimated by difference according to [27] following Equation (3):

$$\text{H \& C}(\%) = 100\% - (\%\text{Protein} + \%\text{Lipid} + \%\text{Lignin} + \%\text{Ash}) \quad (3)$$

2.2.5. Mineral Composition

Mineral composition was determined by atomic absorption spectrophotometer

AAS VARIAN 240 FS according to [28]. Waste sample (0.5 g) was used for digestion with wet ashing procedure. Sixteen milliliters (60 mL) of different acids, HNO_3 - HCl (3:1) were used for a 0.5 g sample. Each mixture was heated up to 130˚C for 4 h on the hot plate. Then, acid mixtures were added again. After cooling, 5 mL of distilled water were added to the sample and mixed. The residue was filtered through blue band filter paper. Then sample was diluted to 10 mL with distilled water. Blank digestions were also carried out in the same way.

2.3. Theoric Biomethane Potential (TBMP) and Biodegradability

2.3.1. Estimation of Theoric Biomethane Potential (TBMP)

TBMP was determined via the Equation (4) used by [29] [30] study reported by [31]:

$$\text{TBMP} = \left(\text{Lipid} \times 1014 + \text{Protein} \times 496 + \text{Carbohydrate} \times 415 + \text{Lignin} \times 727\right) \times 0.001 \quad (4)$$

where: TBMP unit as CH_4 L (kg VS)$^{-1}$, and lipid, protein, carbohydrate and lignin as g (kg·VS)$^{-1}$.

2.3.2. Experimental Biodegradability

Biochemical methane potential (BMP) of cashew hulls was determined using methods reported by [32] and [13]. The basic medium was prepared by mixing K_2HPO_4 (2 g) and NH_4Cl (2 g) in 1000 mL of distilled water. The media were prepared in 300 ml glass bottles filled to 1/3 (v/v) according to technique. Four grams (4 g) of waste were introduced into bottles for a load of 4% (w/v). After 3 days pre-fermentation at 37˚C, pH was adjusted to 7.0 using $NaHCO_3$ (10%, w/v). Then 6 mL Balch mineral solution was added [33]. The amount of inoculum placed represented 10% (v/v) in a final volume of 40 mL. The inoculum was an activated sludge, prepared by mixing wastewater and old reactor sludge according to technique described by [34].

After inoculation, bottle was hermetically sealed with screw caps fitted with a septum to guarantee perfect gas tightness. Anaerobiosis was then carried out in medium by degassing under a flow of nitrogen. Then, bottles were covered with aluminum foil and incubated at 37˚C for 30 days. A control without substrate was also performed to account for endogenous biogas production from the inoculums. The experiments were carried out in triplicates. A gas chromatograph (Girdel Serie) equipped with a Porapak Q 100/120 column and a thermal conductivity detector was used to determine methane production in the headspace of septum bottles. The temperature of oven and detector in the GC were 60˚C and 100˚C, respectively. Nitrogen (N50) was used as the carrier gas in GC.

2.4. Statistical Analyses

The XLSAT software 2016.02.27444 was used for data statistical analysis. Analysis of variance (ANOVA) was carried out to compare the results obtained from old hulls and fresh hulls using Fisher's tests at probability threshold p = 5%.

3. Results and Discussion

3.1. Physicochemical Parameter

Table 1 presents the physicochemical characteristics of two types of hulls (fresh and old hulls). The pH of fresh and fold hulls samples was respectively around 4.20 and 6.41. These results agree with those of [35] and [36] on "margines", acid effluents with pH values between 4.5 and 6, due to the presence of organic acids (phenolic acids, fatty acids). The pH is negatively strongly correlated with titratable acidity ($r = -0.99$) expressed as a function of anacardic acid. The acidity values were 4.25% total solids for fresh hulls and 0.38% total solids for old hulls. Fresh hulls have a significantly higher acidity than those of old hulls ($P = 0.0001$). The high acidity of fresh hulls could be explained by the presence of organic acids (phenolic acids, fatty acids). According to [7] [8] reported by [4], CNSL (Cashew Nut Shell Liquid) is an oily substance naturally composed of 70 to 90% anacardic acid, 10% to 18% cardol and about 5% of cardanol, a rate which increases with the extraction temperature, the anacardic acid decarboxylating into cardanol. Self-oxidation and polymerization reactions phenomena in vegetable transform phenolic alcohols into phenolic acids [35] [37]. In view of these characteristics, it is necessary to find an appropriate pretreatment of hulls before biomethanization and control pH during process.

Volatile Solids content in fresh hulls (89.21% VS) was significantly higher ($P = 0.0001$) than old hulls one's (85.08% VS). The proportion of volatile solids in mashed fresh hulls was very close to those obtained by [38] and [39]. Indeed,

Table 1. Physical and biochemical characteristics of cashew nut shells sample.

Parameter	Averages			
	Units	Fresh hulls	Old hulls	*P value*
pH	-	4.20	6.41	<0.0001
Acidity	% anacardic acid	4.25	0.38	<0.0001
Total Solid	% TS	90.66	90.91	0.067
Volatile Solid	% TS	89.21	85.08	<0.0001
Ash	% TS	2.18	6.07	<0.0001
Lipids	% TS	45.91	7.91	0.002
H&C	% TS	26.95	20.83	0.182
Protein	% TS	3.17	8.08	<0.0001
Insoluble Lignin	% TS	21.50	56.41	<0.0001
soluble Lignin	% TS	0.29	0.70	0.227
Total phenols	mg EAG·g^{-1} TS	46.95	2.79	<0.0001
Nitrogen	% TS	0.51	1.29	<0.0001
TC	% TS	51	48.63	<0.0001
C/N	-	100	37.69	<0.0001

H & C: Hemicelluloses and Cellulose; TC: Total carbon, C/N: Ratio Carbone-Nitrogen.

92.4% of dry matter and 85.1% VS on grasses (turf); 94.9% TS and 94.8% VS on wheat straw were found by [38]. Studies on grasses (fodder) showed 88.2% VS and 95.8% VS [40]. Work on *Calotropis procera* leaves, energetically valued for anaerobic biofermentation found 81.43% VS [39]. High volatile solids values indicate a preferred substrate for anaerobic digestion microorganisms [39] [41]. Biomethane production was directly linked to volatile solid reported by [42]. The concentration and nature of organic matter are decisive for biomethanogenic potential of substrates [41].

Crushed fresh hulls had 26.95% TS carbohydrate (Hemicellulose and Cellulose), 45.91% TS lipid and 3.17% TS protein contents. As for old hulls, contents were 20.83% TS, 7.91% TS, 8.08% TS for carbohydrate (Hemicellulose and Cellulose), lipid and protein, respectively. Protein content from fresh hull in our study was near to that found by [43] (2.32% TS) and [27] (3.125% TS). This difference in shells constituents could be due to natural biodegradation of cashew shells in environment through biological processes, physical phenomena, and chemical reactions [44]. Carbohydrate (Hemicellulose and Cellulose) and lignin are elements of major content in agricultural waste. H & C were 26.95% and 20.83% TS for crushed fresh and old hulls, respectively. Results showed a significative different ($p = 0.001$) with lignin insoluble content in crushed fresh hulls (21.50%) and powdered old hulls (56.41%). Value found in our study was lower than [27] one's which was 27%. Study reported by [45] and [46] found values between 30% - 40% for lignin, 25 - 30 for hemicellulose and 25 - 30 for cellulose in nut shells. Generally, lignocellulosic biomass consists of 35% - 50% cellulose, 20% - 35% hemicellulose, and 10% - 25% lignin reported by [47]. Lignin could also be a toxic component for the microorganisms of anaerobic digestion. According to [48], lignin monomers inhibit methanogenic bacteria by 50% from 2200 $mg \cdot L^{-1}$. Studies have shown the need for proper pretreatment of substrates containing high proportions of lignin [49] [50] [51]. The ability of basidiomycete fungi to mineralize lignin and faster than other groups of microorganisms was reported by [36].

The C/N ratios of the samples were 100 and 39.69 for fresh and old hulls, respectively. C/N ratio represents the relationship between the amount of nitrogen and carbon in a feedstock and makes it possible to generally predict the state of equilibrium influencing the digestibility of a substrate [39]. According to [52], [53]; and [54] optimum range of C/N ratio for anaerobic digestion is 20-35:1. A low ratio results in increased content of free ammonia that causes high pH leading to methanogenic inhibition [55]. A high ratio causes rapid depletion of nitrogen causing lower gas production. The values of C/N ratio of our samples, in particular old hulls, are suitable for biomethanization, because it is very close to the optimum values according to [54]. The C/N ration of crushed fresh hulls samples is high compared to substrates such as nutshell 43.92:1, rice husks 47:1, leaves 71.43:1 [56] [57] [58]. Its high values imply the need to carry out codigestion with nitrogen-rich substrates such as livestock effluents. The high lipid

contents 41.74% DM contained in the fresh shells could have harmful effects on flora producing biogas. Indeed, studies have shown that long chain fatty acids (LFAs) strongly inhibit bacteria and their toxicity threshold is variable depending on the type of bacteria [59]. The phenomenon of AGLC synergism being very strong according to the same authors, mixtures of AGLC greatly decrease inhibition threshold. Control pH monitoring was required during anaerobic digestion.

Total phenols had significantly higher contents in fresh hulls (42.68 mg EAG·g^{-1}) compared to old hulls (2.44 mg EAG·g^{-1}). This decrease in quantity over time would be explained by degradation. Indeed, biodegradation, tannins and anthocyanins polymerization was reported by [60]. The presence of these molecules would be a source of toxicity for anaerobic digestion microorganisms. The antimicrobial margines properties were due to phenol compounds as denoted by [61] [62]. Indeed, the degree of aromatic compounds toxicity depends on their nature and their degree of polymerization. Monomers inhibit methanogenic bacteria by 50% from 1000 mg·L^{-1} [63] [35]. These types of substrates are needed for biological pretreatment of upstream from anaerobic digestion. Indeed, several studies have shown the possibility of microorganisms to degrade total phenols [64] [65]. The studies reported by [36] noted a large number of microorganisms have the ability to degrade phenols at low concentrations. These are bacteria such as *Rhodopseudomonas satustrisand*, *Pseudomonas putida* [66] [67] [68], fungi *Aspergillus niger*, *Phanerochaete chrysosporium*, *Aspergillus terreus* [64] [65] [69] and yeasts *Candida tropicalis* [70] [71].

3.2. Mineral Component of Cashew Hulls

Table 2 gives ionic composition of hull samples. The results show a significant difference irons contents between powdered old hulls and crushed fresh hulls samples ($P < 0.05$). This could be explained by possible contaminants that settle on shell over time. Macro-elements such as Na^{2+}, Ca^{2+} and Mg^{2+} contained in hulls are sufficient to stimulate microorganisms' growth [72]. Concentrations of

Table 2. Mineral composition of cashew nut hulls.

Mineral	Average [g·(Kg TS)$^{-1}$]		*P* value
	Fresh hulls	Old hulls	
Fe	0.115	0.662	0.004
Na	0.141	0.237	0.235
Ca	1.117	3.157	0.063
Mg	1.228	3.389	0.007
K	6.885	15.357	0.075
Zn	0.023	0.039	0.281
Cd	0.0001	0.0002	0.423
Pb	0.014	0.016	0.423

micronutrients Fe^{2+} can allow development of anaerobic digestion with optimums located respectively between 0.28 - 50.40 $mg{\cdot}L^{-1}$ [73] [74] and [75] reported that Mg^{2+}, Ca^{2+} and Na^{+} ions begin to be inhibitors at concentrations of 1000, 2500 and 3500 $mg{\cdot}L^{-1}$ respectively. Concentrations of 20 $mg{\cdot}L^{-1}$ zinc caused inhibition 50% of methane production [76]. Total inhibition of methanogenesis has been observed for concentrations above 100 $mg{\cdot}L^{-1}$ Zinc [77] and 0.1 $mg{\cdot}L^{-1}$ of cadmium [78]. These values depend of course on operating conditions inherent in systems studied and vary according to inocula. Mineral concentrations of sample are not limiting and can theoretically stimulate anaerobic digestion. [79] indicated that heavy metals should not cause problems during anaerobic digestion, because the concentration of ions is kept low due to precipitation with sulfites and carbonates.

3.3. Estimation of Cashew Nut Hulls Biomethane Potential

Figure 3 shows evolution of biogas production with crushed fresh hulls, powdered old hulls and control (inoculum only). Biogas production increased until the 25th day, and stabilized after 25th day. The average of biogas production was found to be 293.33 mL and 228.50 mL for Old and Fresh Hulls, respectively (**Figure 3**). Control and crushed fresh hulls presented a similar biomethane production (**Figure 4**). **Figure 5** shows the same result with biomethane significantly high

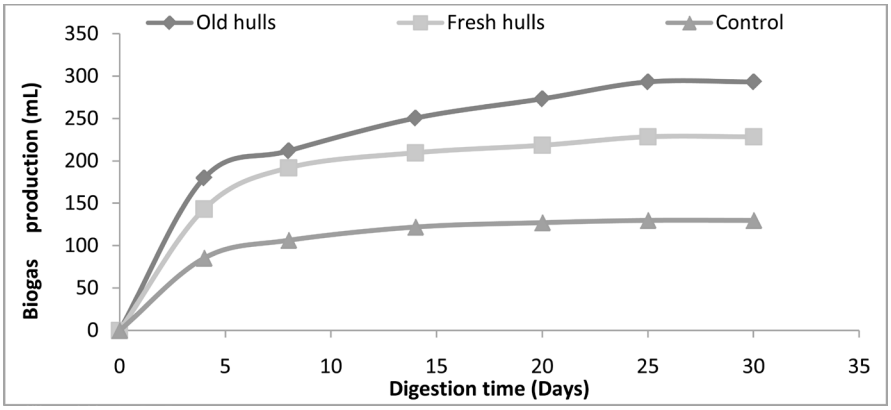

Figure 3. Evolution of biogas production from old and fresh hulls samples.

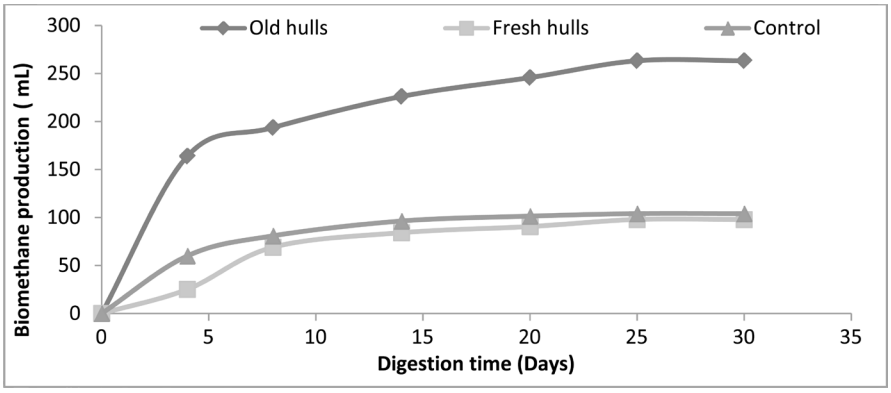

Figure 4. Evolution of biomethane production from old and fresh hulls samples.

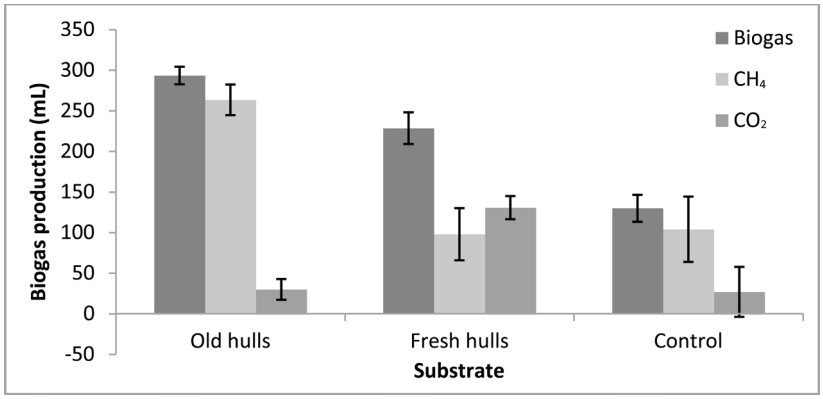

Figure 5. Cumulative biogas, methane (CH_4) and carbon dioxide (CO_2) productions for 30 days incubation period.

Table 3. Values of theoretical and experimental potential biochemical methane.

Sample	Average (CH_4 L. (KgVS)$^{-1}$)		*p* value
	Old hulls	Fresh hulls	
EPBM	77.400	28.760	0.002
TBMP	526.206	666.937	0.004

TBMP: Theoretical biochemical methane potential; EBMP: Experimental potential biochemical methane.

production with powdered old hulls comparatively to crushed fresh hulls. This result could be explained by inhibition of methanogenic bacteria activity by higher content of CNSL composed of phenolic compounds such as anacardic acid, cardanol, cardol and 2-methylcardol into crushed fresh hulls [80] [81]. The need to develop co-digestion systems seems to be the best option for proper anaerobic digestion of these types of substrates.

Table 3 shows a significant difference between theoretical and experimental values of the biomethane potential of two types of shells used. Biomethane potential was 77.400 CH_4 L. (KgVS)$^{-1}$ and 28.760 CH_4 L. (KgVS)$^{-1}$ for powdered old shell and crushed fresh shell, respectively. The theoretical values were 526.206 CH_4 L. (KgVS)$^{-1}$ for old shell and 666.937 CH_4 L. (KgVS)$^{-1}$ for crushed fresh hulls. The differences between theoretical and experimental values could be explained by the constraints during anaerobic digestion due to physicochemical composition of substrate. Anacardic acid has an effect on anaerobic digestion bacteria, including a significant reduction in the production of biomethane [81]. Values of 30 L/KgTS of biogas were obtained by [14] using cashew apple bagasse as a substrate. [13] found around 140 L/KgVS of biogas produced in cashew apple waste anaerobic digestion and methane content was 46% corresponding to 60.7 L/KgVS for 25 days. Cashew nut hulls being more complex than bagasse, this would explain the differences in terms of values.

4. Conclusion

Potentialities of cashew nut shells residues as substrates for anaerobic digestion

have been investigated. Physicochemical parameters of different cashew hulls samples showed substrates that can be used in anaerobic digestion. However, the presence of high-level inhibiting substances such as lignin and total phenols would present risks for methanogenic bacteria. This is observed in the performance of experimental tests which showed a drop in productivity in case of crushed fresh hulls. Optimization of chemical composition of cashew hulls with pretreatment and co-digestion system could be interesting and expected for a better anaerobic digestion performance.

Acknowledgments

This work was financially supported by a research grant from the International Foundation for Science (IFS_ I-3-E-6204-1). Therefore, the authors are grateful to this funding and support of this research.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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