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Utilization of Cassava Wastes for Value Added Products: An Overview

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Abstract— *Different categories of wastes and residues generated during cassava processing must be properly managed so as not to constitute environmental hazard. The huge cost of treatment and disposal create avenue for alternative uses to be explored. This study reviewed the various value added products which can be produced from cassava wastes substrate as feed-stock for bio-energy. Theoretically, it was estimated that one kilogram of cassava peelings will yield 118 g of bio-methane and 226 g of bio-ethanol, one liter of cassava wastewater will yield 16 g and 9 g of bio-ethanol and bio-methane, respectively. Whereas 20 g and 10 g of bio-ethanol and bio-methane, respectively will be obtained from one liter of bagasse. These was also compared with the estimated values obtained based on Chemical Oxygen Demand (COD): 23.9 g of CH4/g COD in one liter of cassava wastewater, Volatile Solids (VS): 23.1 g of CH4/g VS in one liter of cassava wastewater and Total Solids (TS):22.9g of CH4/g TS in one liter of cassava wastewater and 0.414 g using Buswell's equation. This is study can be utilized when making decision on the potentials of cassava wastes for value added products*.

Keywords— *Cassava, Wastes, Bio-energy, Bio-methane, and Bio-ethanol.*

I. INTRODUCTION

Waste generation is a key environmental issue in all food processing industries, including cassava processing industries. The continuous growth and thriving of cassava processing businesses in most developing countries have resulted in the generation of large amounts of cassava processing wastes and residues. There are basically four categories of wastes and residues during cassava processing: (i) peels from initial processing (ii) fibrous by-products from crushing and sieving (iii) settling starch residues and cassava processing bagasse and (iv) wastewater effluents (Ubalua, 2007; Zhang *et al.*, 2016). The cost of treatment and disposal of these wastes and residues constitute a huge financial burden to the cassava processing industries in rural regions of developing countries. As a result of this challenge, rural cassava processors resort to indiscriminate disposal of cassava processing wastes into the environment and water bodies without any form of treatment, leading to the alteration of the receiving water bodies and ecological systems (Coker *et al.*, 2014). These wastes are known to have high levels of Chemical Oxygen Demand (COD), Biochemical Oxygen Demand (BOD) and are often laden with suspended solids that are toxic (Plevin and Donnelly, 2004; Barros *et al*., 2012).

From the foregoing, there is a need for a better management and utilization of these wastes and residues. Due to their rich organic nature, cassava wastes can serve as substrate for microbial processes in the production of different products (Siddhartha *et al.*, 2012). Attention has been given by some researchers (Budiyon and Kusworo, 2011; Zhan *et al.*, 2016; Ozoegwu *et al.*, 2017) to producing products such as organic acid, flavor and aroma compounds, methane and hydrogen gas, enzymes, ethanol, lactic acid, bio-surfactant, polyhydroxyalkanoate, essential oils, xathan gum and fertilizer from cassava bagasse, peels and wastewater (Siddhartha *et al.*, 2012). The use of cassava wastes as feedstock for methane (biogas) production could be a viable alternative to firewood (Coker *et al.*, 2014). The aim of this study, therefore, is to review the various value added products which can be produced from cassava wastes and residues (peels, bagasse, stillage and waste waters) as feed-stock for bio-energy.

II. CASSAVA ROOTS PRODUCTION IN AFRICA

World annual production of cassava roots is estimated at approximately 270 million Metric Tonnes (MT), out of which 54% (147million MT) are produced in Africa as shown in figure 1 (FAOSTAT, 2016). Of the total African cassava production (Fig. 2), West African countries produce the majority 76 million MT (52%), of cassava roots; followed by Eastern African countries with a production of approximately 37 million MT (or 25% of Africa's total).

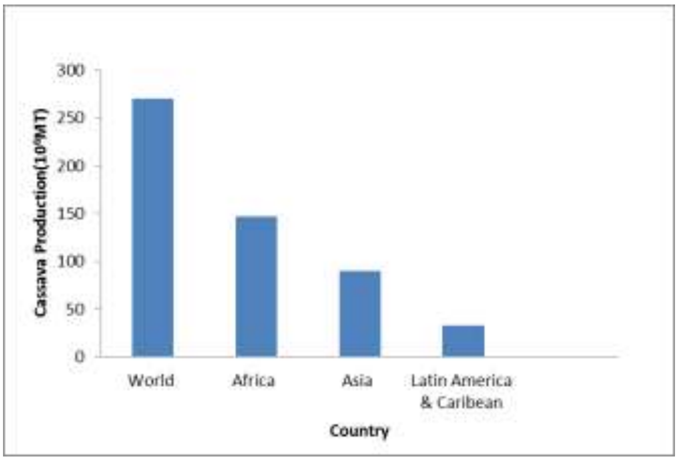

Fig. 1. Cassava production in the world.
Source: FAOSTAT (2016).

Nigeria has a yearly production of approximately 55 million MT; equal to 37% of the total cassava produced in Africa (Fig. 3). Nigeria is the African largest producer (FAOSTAT, 2016).

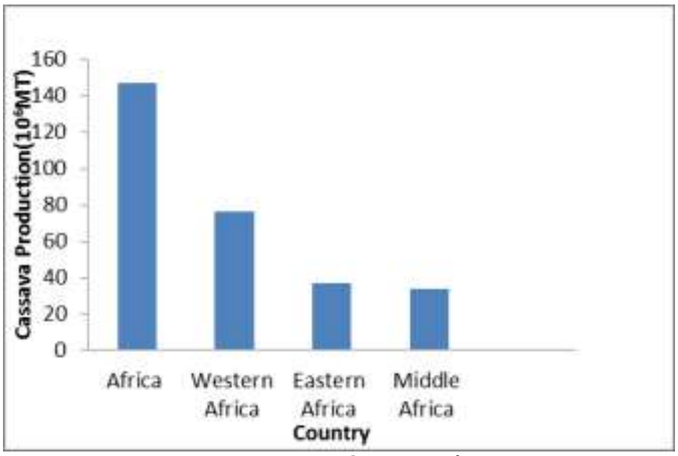

Fig. 2. Cassava production in Africa.
Source: FAOSTAT (2016).

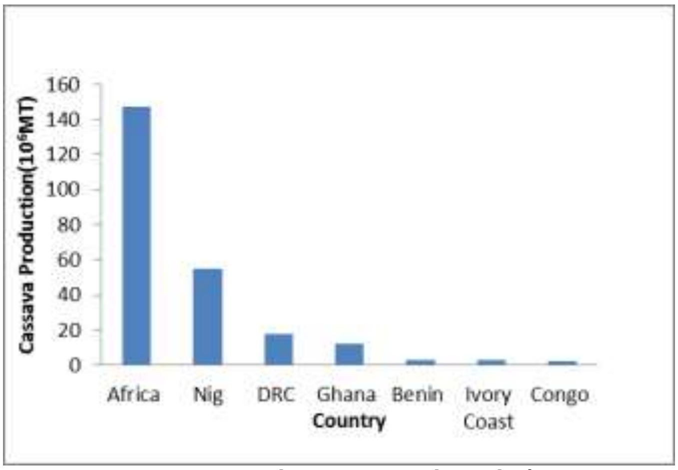

Fig. 3. Cassava production in west and central Africa.
Source: FAOSTAT (2016).

III. Cassava Processing Wastes

It is estimated that the processing of fresh cassava roots gives rise to between 8.85 and 10.62 MT of liquid waste per MT of fresh cassava processed, containing approximately 1% total solids(TS) (Zhang *et al.*, 2016). In addition between 0.93 and 1.12 MT of wet cassava bagasse and peels are produced per metric ton of dry cassava processed (Zhang *et al.*, 2016).

Figure 4, describes the production of High Quality Cassava Flour (HQCF) from fresh cassava roots. It can seen that between 150-200 Kg HQCF can be produced from 1 MT of fresh cassava roots with a corresponding wastes generated of between 550-700 Kg consisting of peels, fibrous waste, sifting juice and waste water. Also 1 MT of fresh cassava roots can yield between 180-200 Kg starch with about 680 Kg wastes produced (Fig. 5). More so, between 200-240 Kg of Garri/Attieke is produced from 1 MT of fresh cassava roots with between 500-600 Kg of wastes generated (Fig. 6). Whereas 1 MT of fresh cassava roots will produce between 280-300 Kg ,Fufu with result with resultant wastes generation of between 80-130 Kg.

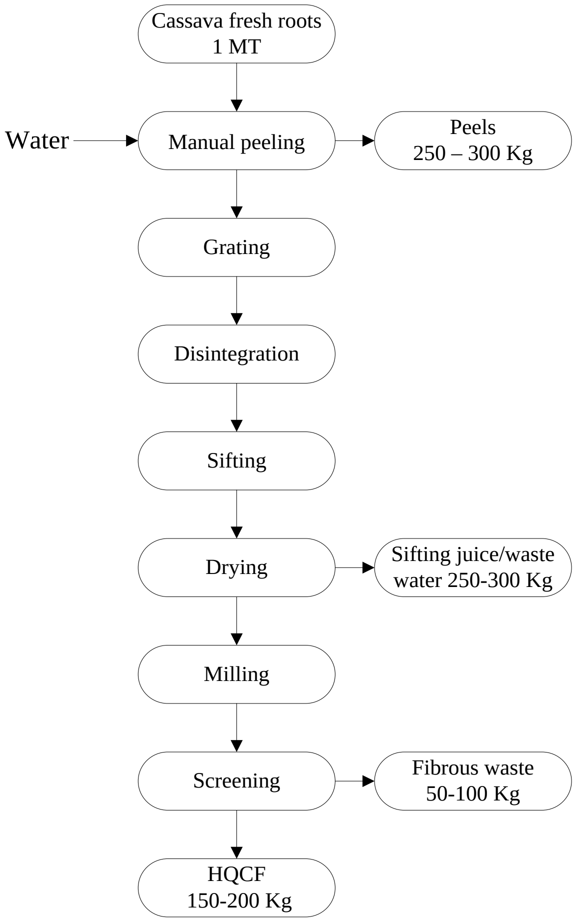

Fig. 4. Flow chart of high quality cassava flour production process.
Source: FAO (2001).

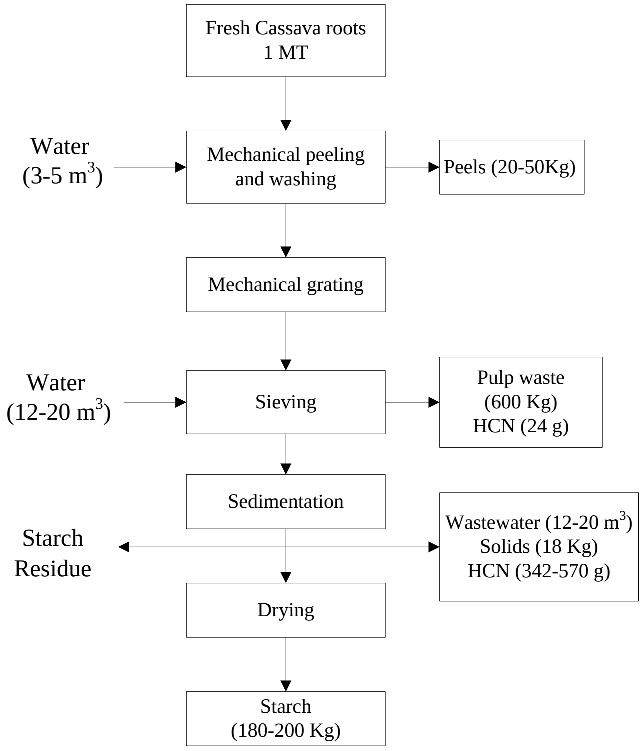

Fig. 5. Flow chart of cassava based starch production process.
Source: FAO (2001)

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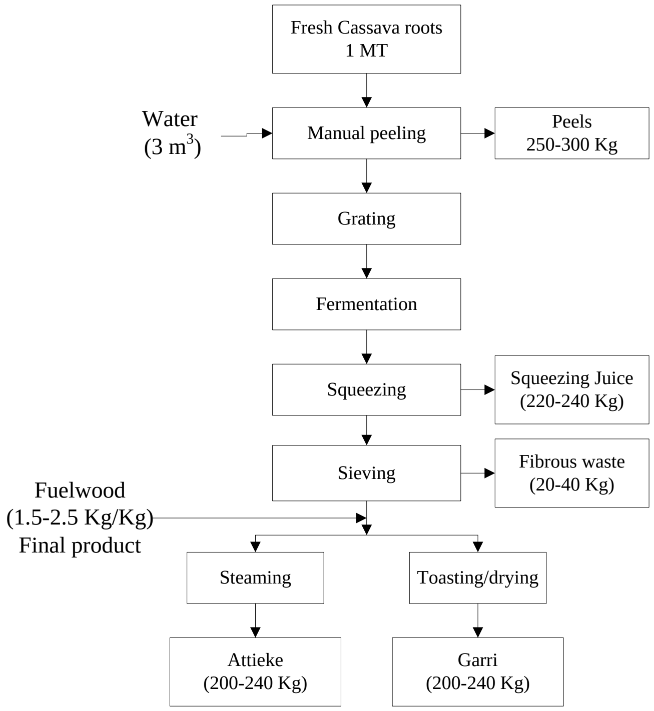

Fig. 6. Flow chart of Garri and/ Attieke production process.
Source: FAO (2001)

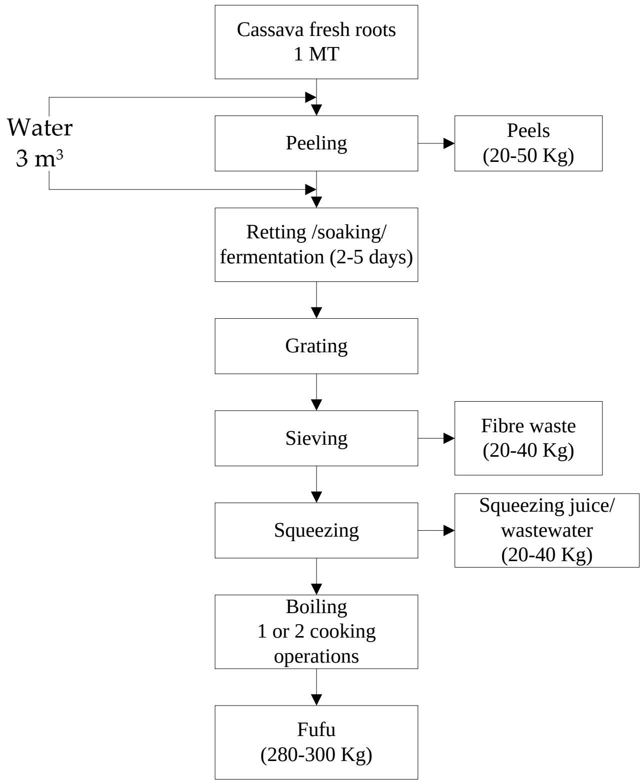

Fig. 7. Flow chart of Fufu production process.
Source: FAO (2001)

IV. Physico-Chemical Characteristics of Cassava Wastes

Cassava starch wastes (wastewater and solid waste) contains between 9.6-37.5 (g/L) total carbohydrates and 2.3 total proteins (Zhang *et al.,* 2016). Cassava starch wastewater is weakly acidic liquid and nutrient (N and P contents) can be as high as 1300 and 780 mg/L respectively. Also cassava bagasse, a typical solid residue of cassava processing contains between 40.1% and 75.1% starch (dry weight) and between 14.9% and 50.6% fibre (Zhang *et al.,* 2016).

Tables 1 and 2 give the summary of physicochemical characteristics of cassava starch wastes and bagasse respectively.

TABLE 1. The physiochemical characteristics of cassava (*Manihot esculenta* spp) starch wastes (wastewater and solid wastes) composition

	(g/L)@pH=36-6.2
Total Solid (TS)	4.5 - 38.2
Volatile Solid (VS)	3.4 - 33.0
Total Chemical Oxygen Demand (TCOD)	8.0 - 66.2
Soluble Chemical Oxygen Demand (SCOD)	14.2-345
Biochemical Oxygen Demand (BOD)	-
Total carbohydrate	9.6 - 37.5
Solid carbohydrate	-
Oil and grease	0.6
Total protein	2.3
Total nitrogen	0.1 - 1.3
Total phosphorous	0.07- 0.78

Source: Zhang *et al.* (2016)

TABLE 2. Cassava (*Manihot esculenta* spp) bagasse composition

	% by dry weight
Starch	40.1-75.1
Crude fibre	14.9-50.6
Cellulose	4.1-11.4
Hemicellulose	4.2-8.3
Lignin	1.2
Crude fat (lipids)	0.5-1.1
Crude protein	0.3-1.6
Total ash	0.7-11.9
Total solid	-
Volatile solid	-
Total nitrogen	-

Source: Zhang *et al.* (2016)

V. Cassava Wastes Conversion Processes

Cassava wastes to bio-energy processes are categorized into two major groups namely: (a) Thermo-chemical processes comprising combustion, pyrolysis and gasification, (b) Biochemical processes comprising anaerobic digestion and bio-ethanol fermentation (Gumisiriza *et al.,* 2017).

The application of this transformation concept, particularly the green processing options would contribute to the development of innovative technologies for cassava wastes management. The physicochemical nature of the waste dictates the choice of the technology appropriate for treating such wastes.

Generally, thermal processes convert the wastes directly into heat energy while thermo-chemical and biochemical processes first convert the wastes into secondary energy such as syngas, torrefied pellets, biogas, bio-ethanol and bio-oil, which can subsequently be burnt(in furnaces, steam turbine, gas turbine or gas engine) to produce energy in the form of heat and electricity (Fig. 8). The conversion of solid wastes into secondary energy carriers allows for a clear and more efficient energy harnessing process (Gumisiriza *et al.,* 2017).

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A. Thermo-chemical Conversion Processes

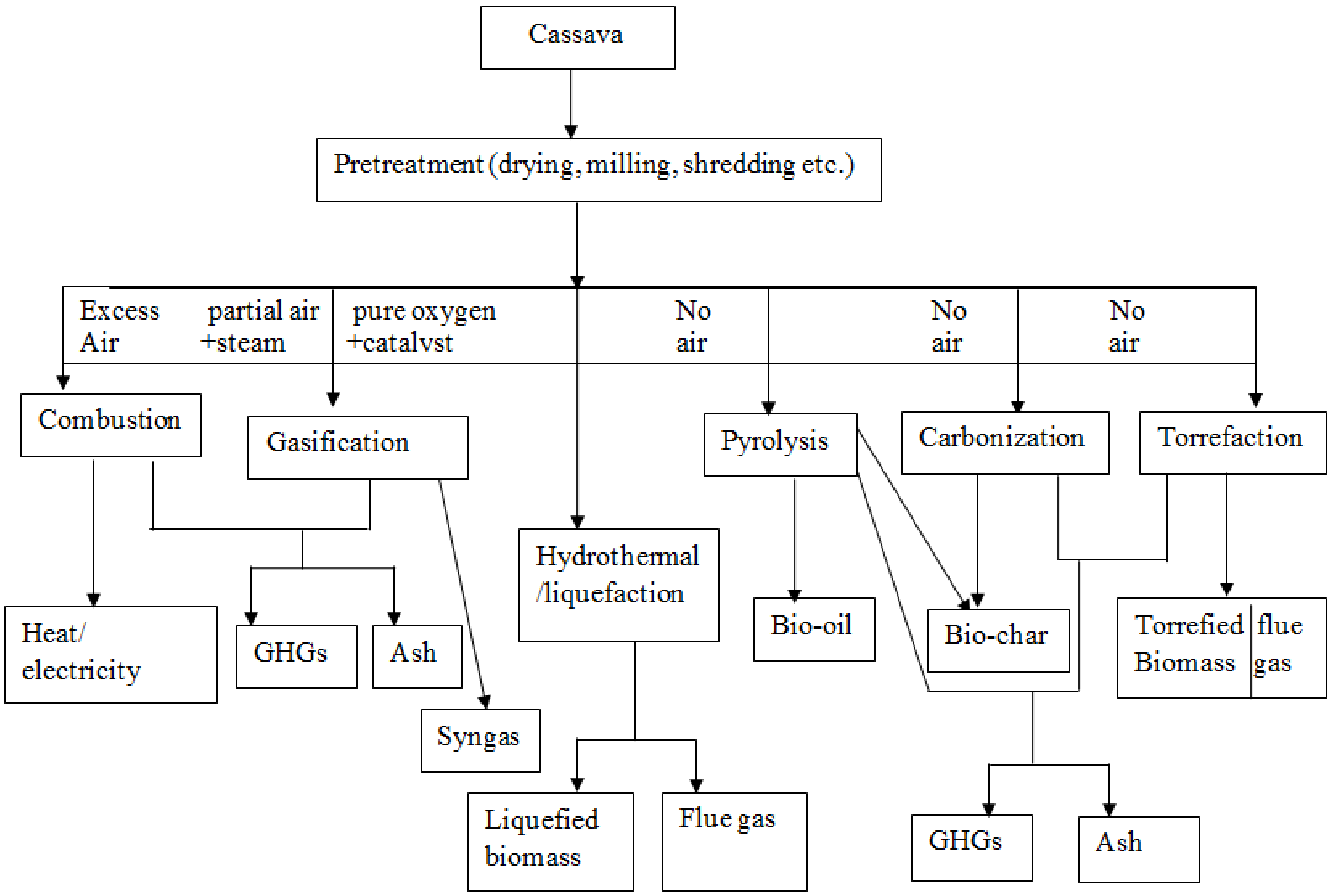
The thermo-chemical conversion processes employ a series of chemical reactions occurring at different temperatures and may require partial oxidation as in gasification or proceed in the absence of oxygen as in pyrolysis (Fig. 8).

These conversion processes are temperature dependent and require strict control of process conditions in specially designed reactors. In addition, thermo-chemical transformation is virtually independent of environmental conditions for production purposes (Verma *et al.*, 2012). The principles underlying the application of some of the thermo-chemical conversion processes in harnessing bio-fuel from wastes biomass are described as:

a. *Pyrolysis*: This is thermal degradation of organic material in the absence of oxygen. It occurs at relatively low temperatures (400-900°C) (Bosmans *et al.*, 2013). In pyrolysis, biomass waste is subjected to an optimal temperature of 700°C in the absence of oxygen resulting in the production of pyrolysis oil (bio-oil), char and synthesis gas (syngas) (Fig. 8). Syngas is a mixture of majorly CO, CO_2, H_2, H_2O, CH_4, trace amounts of higher hydrocarbons such as small char particles. These can be used as secondary fuel to generate electricity (Gumisiriza *et al.*, 2017). Some other major products of pyrolysis are:

i. *Bio-oil*: This is the liquid fuel product of biomass pyrolysis. The color varies from light brownish yellow to dark brown for various fractions during condensation phase with pungent smoky odor and acidic pH. It is an emulsion of a variety of soluble and insoluble compounds in water (Verma *et al.*, 2012).

ii. *Bio-char*: This is a pyrolysis byproduct along with bio-oil and flue gases. In recent times, bio-char is less preferred over bio-oil as fuel source due to handling, incompatibility with transportation sector(automobile engines) storage and secondary pollutants issues(higher ash content) (Mullen *et al.*,2010;Uzun *et al.*, 2007).



(Due to bio-char combustion)

Fig. 8. Cassava wastes thermo-chemical conversion pathway.

Source: Adapted from (Verma et al., 2012)

b. Gasification: This is a partial oxidation of organic substances at elevated temperature (500-1800°C) to produce syngas. Biomass wastes gasification occurs as the char reacts with carbon dioxide and water vapor (steam) to produce carbon monoxide and hydrogen, syngas can be used as a feedstock(through some reforming processing),or as a fuel (Helsen and Bosmans,2010).

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c. Torrefaction: This is the thermal upgrading of biomass into a more homogeneous product that is densified through pelletisation to generate a more energy dense product called torrefied pellets (TOPs) or briquettes with similar properties to coal (Batidzirai *et al.,* 2013). The energy derived from biomass through thermal upgrading (heating) is concentrated into an energy-dense and homogeneous product (TOPs) useful for further thermo-chemical conversion (Yan *et al.,* 2010). Torrefaction process is also referred to as mild pyrolysis and is a thermo-chemical process conducted in the temperature range between 200-300°C under an inert atmosphere and low heating rate (Medic *et al.*, 2012).The process involves biomass chipping to allow efficient drying, screening for impurities before sizing and drying to 20% moisture content (Schorr *et al.*,2012).

However, Cassava wastes being a highly wet biomass apart from peels and fibrous residues are not regarded as a promising feedstock for direct utilization or application of the conventional thermo-chemical processes due to its high moisture content (Tock *et al.,* 2010).

B. Biochemical Conversion of Cassava Wastes

One of the conversions of cassava wastes biomass to bio-energy is through biochemical conversion which yields bio-ethanol, biogas and bio-fertilizer. Biochemical conversion processes of wastes to bio-energy are much more eco-friendly as compared to the thermo-chemical processes, which is preferred for our study (Fig. 9).

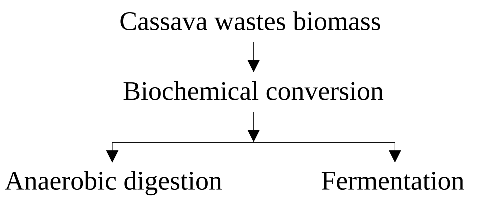

Fig. 9. Flow chart of cassava wastes biomass conversion process.

Figure 10, shows the cassava wastes and residues generated from some major products of cassava. Ethanol production constitutes the major contributor of the cassava wastes.

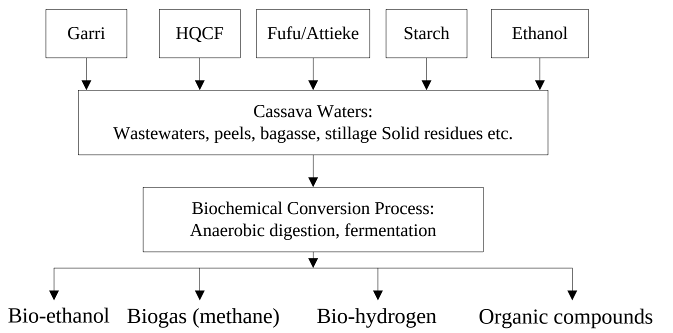

Fig. 10. Biochemical conversion of cassava based wastes into useful products. Source: Ekop (2009).

Cassava has been used for bio-ethanol production. The cassava-to-ethanol conversion process has been well established in China, Thailand and West Africa. Figure 11, describes the bio-ethanol production from cassava chips; the wastes generated at various stages (unit operations) are well detailed. After liquefaction, saccharification and fermentation processes, the ethanol is separated through distillation, leaving large quantities of cassava stillage (i.e. cassava ethanol wastewater, distillery slopes etc.) as waste product (Zhang et al., 2016).

One ton cassava waste water can yield 28m^3 of biomethane. Jansson *et al*. (2009) reported that 6.6tons of fresh cassava roots is required to produce 1 ton of ethanol while Li and Chan-Halbrendt (2009) stated that 1 ton of ethanol requires 3tons of dry cassava roots or 7.2 tons of fresh cassava roots.

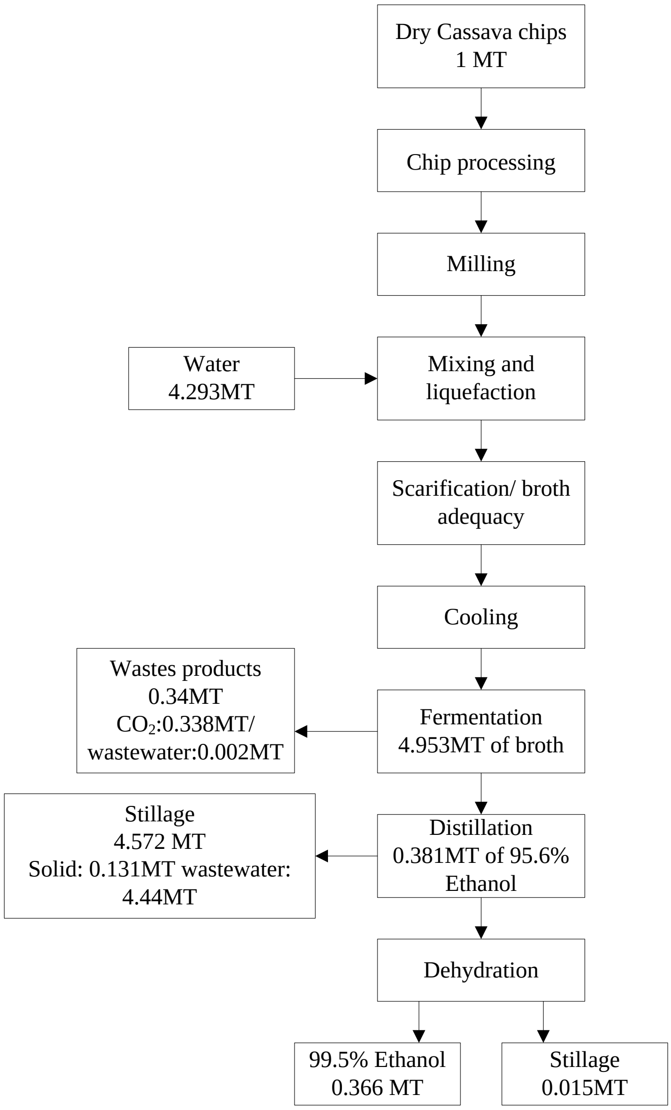

Fig. 11. Flow chart of cassava-based ethanol production process. Source: Zhang et al. (2016)

a. Anaerobic Digestion: This involves microbial decomposition and breakdown of biomass in the absence of oxygen, anaerobic reactors are generally used for the production of methane rich biogas from cassava wastes and residues. Biogas is a product of a microbial process known as

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anaerobic digestion. The residue left after anaerobic digestion adds value to the process as they can be used for agricultural purposes as fertilizer (Okudoh *et al.,* 2014). Anaerobic digestion is the standard solution for treating biomass wastewaters. Biogas production is a complex process, which can be divided into four phases: hydrolysis, acidogenesis, acetogenesis/dehydrogenation and methanation as shown in figure 12. Hydrolyzing and fermenting microorganisms are responsible for the initial degradation of cassava wastes to produce mainly acetate and hydrogen. A complex consortium of microorganisms is involved in the hydrolysis and fermentation processes.

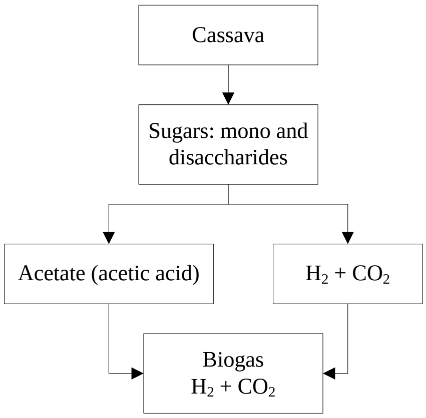

Fig. 12. The stages of biogas production process.
Source: Modified from Weiland (2010) and Okudoh *et al.,* (2014).

Bagi *et al.,* (2007) suggested that hydrogen may be a limiting substrate for methanogens. At the end of the degradation chain, two groups of methanogenic bacteria produce biogas (i.e. methane and CO_2) from acetate and hydrogen (Weiland, 2010; Okudoh *et al.*, 2014).

Acetotrophic methanogenesis:

$$CH_3COOH \longrightarrow CH_4 + CO_2 \quad (1)$$

Hydrogenotrophic methanogenesis:

$$CO_2 + 4H_2 \longrightarrow CH_4 + H_2O \quad (2)$$

b. Co-digestion of substrate (mixed substrates): According to Okudoh *et al.,* (2014) cassava biogas production used either raw material from cassava roots, tapioca effluent; peels etc. or such material in co-digestion with cow dung, chicken manure and food-processing waste and distillery wastewaters to improve the carbon nitrogen (C/N) ratio. These experiments are aimed to optimize biogas yields by increasing the methane production. The results of some of these studies are shown in Table 3.

c. Fermentation: This process is responsible for 91% of global ethanol production. Approximately 9% of the ethanol is produced synthetically. Bio-ethanol fermentation like anaerobic digestion is also biochemical process in which sugars in cassava wastes and residues are degraded and converted to bio-ethanol by some specific microorganisms. Cassava wastes are feed-stocks for both the 1st generation and 2nd generation processes (Ozoegwu *et al.,* 2017). Cassava wastes performed well in all stages of fermentation for bioethanol production (Okudoh *et al.*, 2014). Zhang *et al.,* (2016) asserted that cassava industrial wastes have a high proportion of structural carbohydrate and lignin and the hydrolysis of these components is the first step for either fermentation to bio-ethanol or anaerobic digestion to biogas. It is believed that pretreatment is a key determinant of bio-ethanol fermentation yield. According to Thang *et al.,* (2010) cassava wastes can yield 91% of bio-ethanol in direct fermentation with clostridium saccharoperbutylacetonicum. Cassava based ethanol has a lower net energy, better carbon dioxide emission and lower external cost of carbon dioxide. A study by Wang (2002), compared the yield of bioethanol from different energy crops such as maize, sugarcane and sweet sorghum (Table 4).

TABLE 3. Biogas studies involving cassava and its products.

Substrate	Method	Biogas yield (m^3kg^{-1}VS)	Highest methane content
Dried cassava tubers, cow dung (seed culture) and mud	Continuous two-phase digesters:6 L acid tank 21 L methane tank mesophilic	13.2L per kgVS	64
Cassava roots (100g/L) and chicken manure	Single-stage batch digester mesophilic urea (0.4g/L):scaled up to 50L digester	1.95 per 5L cassava slurry: 564 per 50L digester	68%
Cassava peels and livestock (cow, pig, poultry) waste	Batch digester: mesophilic; substrate ratio=1:1	35	-
Cassava peels, cow dung and cow pea	Batch digester: mesophilic	Cow pea (87.5) Cow dung (124.3) Cassava peels (87.1)	Cow pea (97%) Cow dung (68%) Cassava peels (51%)
Cassava stillage (liquid waste) and excess sludge	Batch: two-phase digesters thermophilic	Biogas yields not determined, hydrogen yield of 74mL/g of volatile solids	62%
Cassava residue and distillery wastewater	Batch bioreactor: thermophilic	-	259.46mL/g-VS

Source: Okudoh *et al.,* (2014)

TABLE 4. Comparison of bio-ethanol production from different energy crop.

Crops	Yields (Ton/ hectare/year)	Conversion rate to ethanol(litres/ton)	Bioethanol yield (litres/hectare/year)
Sugar	70	70	4900
Sweet sorghum	35	80	2800
Rice	5	450	2250
Maize	5	410	2050
Wheat	4	390	1560
Cassava	40	150	6000

Source: Okudoh *et al.,* (2014)

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Fresh cassava tubers contain 20-30% carbohydrate; 100g of fresh tubers contains 20.41g starch, cassava peels contain a mean value of 21.83% dry matter with 5.22% starch (Fakir *et al*., 2012). A study by Nywamanya *et al.* (2012) using non-edible parts of cassava for bioethanol production revealed that cassava peels and stems contains greater than 28% dry matter. The study showed that 10 g cassava biomass yielded greater than 8.5 g sugar, which in turn produced greater than 60% bioethanol based on the amount of ethanol produced from each 500mL batch of the fermentation solution (beer). A summary of some previous studies carried out on cassava for bioethanol production is shown in Table 5.

Further reports substantiate yield of bioethanol from cassava wastes are found by Oyeleke *et al.* (2012) and Nywamanya *et al.* (2012).

d. Bio-hydrogen is another useful product that can be obtained from cassava wastes through fermentation. According to Zhang *et al.* (2016) the performance of a biohydrogen production system is likely related to favorable C: N and C: P ratios and to the presence of other intrinsic nutrients. Bio-hydrogen production from cassava wastes have been reported details by Luo *et al.* (2010), Wang *et al.* (2013). Leano and Babel (2012), Cappelleti *et al.* (2011), and O-Thang *et al.* (2011).

TABLE 5. Some previous bio-ethanol studies on cassava and its product.

Feedstock	Method	Bioethanol yields	Ref
Cassava peels, Stems, leaves and roots	Sugar fermentation; Distillation; saccharomyces cerevisiae	>60% per 8.5g of sugar	Nywamanga et al. (2012)
Cassava starch and chips	Batch(1L); mesophilic; clostridium Saccharoperbutylacetonium N1-4	21g/L of sample 63%(w/v)higher than maize	Rathanachonsis et al (2009)
Cassava pulp	Enzyme saccharification with aspergillus niger BCC 17849. Fermentation with candida tripicalis	14.3g/L per 4%(W/V)pulp	FIIRO(2006); Zhang *et al. (*2016)
Cassava slurry	Ultrasonic pretreatment	43.05g/L sample 95.72% fermentation efficiency;three times higher yield than control	Nitayavardhana *et al.* (2010)
Cassava waste	Enzyme; acid hydrolysis 10Lfermenter saccharomyles cerevisiae TISTR 5596	3.62g/L; 91% (w/v) theoretical yield	Thang *et al.*(2010)

Source: Okudoh *et al.* (2014)

e. Organic compounds: Cassava wastes can also be potential substrates for the production of organic acids such as citric acid, lactic acid, succinic acid, volatile fatty acid and acetic acid. These products are very useful particularly in the pharmaceutical, chemical and food industries. Zhang *et al*. (2016) provides various organic compounds produced from cassava industrial wastes.

C. *Prediction of Theoretical Bio-fuel Potential*

There are several methods of estimating the theoretical yield of biofuel especially Bio-methane Potential (BMP) .We will adopt some of these methods for this study.

(i) Traditional bio-fuel can be estimated when atomic or the organic compositions (lipids,proteins,carbohydrates) are known for example methane yield can be determine using equation 3:

CH_4=415·%Carbohydrates+496·%Proteins+1014·%Lipids (3)

Otherwise based on chemical formula determine by experimental analysis (Raposo *et al*., 2011).

(ii) BMP estimated from the Chemical Oxygen Demand (COD) level of the cassava wastes substrate. Under anaerobic degradation, 1kg of COD removed from substrate (cassava solid waste and waste water) yields 0.35m^3 of methane (0.5m^3 of biogas) at STP (Grady *et al*., 1991). Carbohydrate $(C_6H_{10}O_5)_n$ contains 1.19g-COD/g-VS which can produce 0.415(STPlCH4/g-VS) or 0.35(STPlCH4/g-COD) (Angelidaki and Sanders, 2004).

(iii) BMP estimated from the Volatile Solid (VS) or Total solid (TS) content of the cassava wastes substrate. The maximum BMP of 0.7m^3 can be produced per kg of volatile (VS) destroyed (Grady *et al*., 1999). Cassava peelings contain 0.53l of ethanol/kg-TS and 366ml methane/g-VS (Thomsen *et al.*, 2014). Okudo *et al.* (2014) stated a biogas yield of 0.61m^3kg^{-1}VS from cassava peelings.

Cuzin *et al*. (1992) reported 25-35%TS and VS equivalent to 90-97%TS as composition of cassava peels, that 1.15 tons of cassava peels is needed to produce 121m^3CH_4.

(iv) BMP can be estimated using Buswell's equation at STP.

$C_aH_bO_c$ +(a–b/4–c/2)H_2O → (a/2–b/8+ c/4)CO2 +(a/2+b/8c/4)CH_4 (4)

Where a, b, c are the number molecules of C, H and H respectively.

Thomsen et al. (2014) reported the highest biogas of 382lCH4/kgTS.

An illustrative example of how data contained in Table 6 is obtained from the wastes substrate:

1L of wastewater contains 37.5g starch (Table 1)

10 g of starch yields 8.5 g fermentable sugar (Nywamanya *et al.*, 2012)

In 37.5 g starch we will have 8.5 g-sugar * 37.5 g-starch/10 g-starch= 31.875 g-sugar.

$C_{12}H_{12}O_6 \rightarrow 2CH_3CH_2OH + CO_2$ (5)

Considering equation 5, it is above that 180 g of sugar is required to produce 2*46 g of EtoH, hence in 31.875 g-sugar we will have 2*46*31.875/180= 16.29 g-EtoH in 1L of wastewater.

A similar procedure is followed for other cassava wastes substrate.

TABLE 6. Summary of biofuel yield estimated based on method (i).

Substrate	Ethanol (g/L)	Methane (g/L)	Ethanol (g/kg)	Methane (g/kg)
Cassava peelings	-	-	225.9	117.9
Cassava wastewater	16.29	8.5	-	-
Stillage	19.64	10.25	-	-

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TABLE 7. Summary of BMP estimated based on methods (ii-iii).

Substrate	COD*0.35 (STPlCH4/gCOD)	VS*0.7 (STPlCH4/gVS)	TS*0.6 (STPlCH4/gTS)
Cassava peelings	-	0.240	0.21
Cassava wastewater	23.17	23.10	22.92
Stillage	49	98	84

TABLE 8. Summary of BMP estimated based on methods (iv).

Substrate	Buswell's(a/2+b/8c/4)*22.4*(STPlCH4/gCOD) /12a+b+16c
Cassava peelings	-
Cassava wastewater	0.414
Stillage	-

Table 6 presents a more acceptable yield data compared to Table 7 and 8 since it accounts for amount of starch (carbohydrate) and sugars present in the various cassava wastes substrate. It can as well be compared with the works of Zang *et al*. (2016); Thomsen *et al*. (2014) and Okudo *et al*. (2014).

VI. Conclusion

Based on the above assertions, we can estimate that 1 kg of cassava peelings can produce 118 g of bio-methane and 226 g of bio-ethanol whereas 16 g of bio-ethanol and 9 g of bio-methane is obtained in 1L of cassava wastewater. Also 20 g and 10 g of bio-ethanol and bio-methane, respectively are obtained in 1L of bagasse. A common trait is that the biogas potentials which are based on COD, VS and TS are higher than the one estimated with the Buswell's equation. (Thomsen *et al*., 2014; Kwietniewska and Tys, 2014).

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