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TURNING CASSAVA PEELS FROM WASTE TO WEALTH

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Resumé

Le traitement des tubercules de manioc pour l'alimentation et la production d'amidon génère de grandes quantités de déchets solides tels que les épluchures et résidus de manioc rejetés de manière incontrôlé dans l'environnement en s'accumulant en tant que décharges sur les sites où le manioc (Manihot esculenta) est traité. Ces déchets de manioc produits au cours du processus d'épluchage se décomposent et génèrent des gaz toxiques et odeurs désagréables accroissant ainsi, le risque de pollution environnementale mettant en péril la vie humaine et aquatique. Pourtant, les épluchures de manioc, en tant que biomasse lignocellulosique, peuvent être utilisées comme matière première pouvant être converties en bioproduits à haute valeur ajoutée. Cet article de synthèse présente les différents processus de conversion des épluchures de manioc utilisées pour obtenir des biocarburants (bioéthanol et biogaz) et le charbon actif mais aussi les aliments pour bétails et comme substrat pour la culture de champignons. En outre, il est possible de convertir l'amidon des épluchures de manioc en bioplastiques biodégradables. L'utilisation des déchets de manioc comme matière première pour fabriquer les bioproduits si elle est mis à profit, pourrait épargner à notre monde la pollution environnementale pendant de nombreuses années à venir.

Mots clés : -

Abstract

Cassava roots Treatment for food or starch, leaves a large amount of solid wastes such as peels and stillages which are indiscriminately discharged into the environment and amassed as waste dumps on sites where cassava (Manihot esculenta) is processed. All types of cassava wastes produced during the process or peeling are decomposed to generate obnoxious gas and unpleasant odor, enhancing the risk of environmental pollution which is dangerous for the living being and water resources. However, cassava peels as lignocellulosic wastes could be used as starting matter to be converted into the value-added bioproducts. This review article highlights and bring to date different conversion processes of cassava peels used to obtain biofuels (bioethanol and biogas) and activated carbon. The peels could be used to prepare animal feed and as substrate for mushrooms culture. Besides, it is possible to convert cassava peels starch into biodegradable bioplastic. Using cassava wastes as raw matter to produce value-added products could save free for more years our world to environmental pollution.

Key words : Activated carbon, Animal feeds, Biofuel, Bioplastic, Cassava peels, Mushroom.

1. INTRODUCTION

Waste generated by agriculture is an environmental nuisance but can constitute a starting material for nutrition, energy, chemicals if adequately processed. Hence, valorization of food and agricultural waste, especially in developing countries, should be an attractive concern because of its potential to create alternative source of wealth. Cassava (*Manihot esculenta*), also called *manioc* or *tapioca* is a very important source of diet in Sub-Saharan Africa and particularly in the Democratic Republic of Congo where not only the roots is consumed but also the leaves. Cassava has seen a steady increase in production, averaging 3% per year since 1995, reaching nearly 200 million tons in Africa in 2021, around 60 per cent of the world's total production [1]. In Africa over 90 % of cassava is consumed as food and very little for industrial processing [2]. Today Cassava is considered a commodity with many uses, supporting rural development, poverty alleviation, and food security [3, 4]. Several African governments are promoting mandatory blending of wheat flour with high-quality cassava flour in order to reduce wheat importation. Processing cassava roots for food or starch leaves behind large quantity of peels which constitute an environment hazard. The peels could make up to 10 to 13 % of net weight of the roots REF. This agriculture waste consists of cellulose (37.9 %), hemicellulose (37.9 %), lignin (7.5 %) and other materials called extractives REF. Fresh cassava peels have 3 main deficiencies: they spoil very quickly, they contain phytates and large amounts of

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cyanogenic glycosides. For many uses of the peels, they should thus be processed in order to reduce cyanogenic potential and phytate content while preserving their nutritive quality [5-7]. Different processes are effective in reducing cyanogenic glycoside including sun-drying, ensiling, and soaking in water followed by sun-drying. All these methods have yielded satisfactory results [8-10].

Many uses of cassava peels have been described in literature among other as substrate for bioethanol and biogas production, as starting material for bioplastic, for activated carbon, for mushroom culture, and as animal feed. We herein reviewed all these uses and highlighted their recent development.

2. BIOFUELS

2.1. Ethanol from cassava peels

The depletion of the fossil fuel and global warming caused by the emission of greenhouse gases from the combustion of fossil fuel is currently driving researchers in the direction of finding alternative and environmentally friendly fuel. Biofuels are one of the numerous options being considered. Bioethanol is considered as the most promising biofuel to replace gasoline since it can be used directly in vehicles or blended with the gasoline [11]. Most bioethanol produced from edible feedstocks such as corn, sugar cane and cassava are called first generation bioethanol The USA and Brazil are the two major ethanol producers with respectively 56.72 % and 26.72 %, of the world production REF. The USA get their bioethanol from corn starch whereas Brazil gets his own from sugarcane. Recently, some major cassava producers' countries such as Thailand, Indonesia, Nigeria and Vietnam, are using cassava roots starch to produce bioethanol [12, 13]. The usage of corn, sugarcane and cassava as the raw materials to produce first generation bioethanol reduces their availability and raise the debate between the importance of their use for food and feed for energy production. Meanwhile, lignocellulosic biomass such as agriculture wastes : corn straw, saw dust, grasses, woody crops and cassava peels have been shown able to provide bioethanol which is called the second generation [14]. Major cassava producing countries are focusing attention on cassava peels to produce bioethanol [15-17], Cassava peels is a lignocellulosic biomass which is made up of cellulose, hemicellulose, lignin, protein, ash, and minor extractive matters. The main composition of cassava peels is summarized in table 1.

Table 1. Chemical composition of cassava peels [18]

N°	Analyses	Value (%)
1	Dry matter	89.70 ± 0.06
2	Ash (% DM)	6.39 ± 0.34
3	Lignin (% DM)	1.92 ± 0.07
4	Starch (%DM)	47.16 ±3.19
5	Protein (%DM)	2.40 ± 0.28
6	Cyanide mg/Kg	9.30 ± 0.42
7	Glucose (%DM)	83.41 ± 0.82
8	Xylose (%DM)	2,31 ± 0.08
5	Arabinose (%DM)	2.35 ±0.08

The use of lignocellulose as raw material in bioethanol production is sustainable and attractive. This material is abundant in nature and could be converted to ethanol after undergoing some processes including pretreatment, hydrolysis, and fermentation. Pretreatment involves unwinding cellulose from hemicelluloses and lignin in which cellulose is embedded and make cellulose more susceptible for enzymatic hydrolysis after which the product is fermented and distilled. The conversion technology of cassava peels to bioethanol is already at the demonstration stage [19]. Nowadays efforts are being done to optimize bioethanol production process of cassava waste. The key step is to get maximum free sugar for fermentation by pretreatment. The main aims of an effective pretreatment process is formation of sugars directly or subsequently by hydrolysis for fermentation. Physical, chemical and biological treatments are three types of pre-treatment process used [20-23]. Table 2 gives bioethanol production with the appropriate pretreatment used.

Table 2. Bioethanol production from cassava peels

Pretreatment	Microbial saccharification	Glucose (g/L)	Ethanol (g/L)	Yield (%)	Ref.
Ultrasonic assisted HCl	Saccharomyces Cerevisiae			20.73	[24]
Acid hydrolysis using sulfonated palm oil fruit bunch	Saccharomyces Cerevisiae	13.53	3.75	27.2	[13]
Enzymatic, simultaneous saccharification fermentation (SSF)	Saccharomyces Cerevisiae			14.46	[25]

Alpha amylase then SSF	Saccharomyces Cerevisiae			1.91	[22]
Acid hydrolysis	Saccharomyces Cerevisiae	78		45	[20]
Enzymatic, then SSF			35.02	83	[23]
Enzymatic, cellulase and beta glucanase			14.67		[18]
Enzymatic	Saccharomyces Cerevisiae			8.5	[17]
Physical	Saccharomyces cerevisiae and Zymomonas mobilis			30	[26]

The main characteristics of each pretreatment are:

Physical pretreatment involves breaking down the size of the lignocellulosic biomass and crystallinity by methods like milling, grinding, chipping, irradiation and extrusion. The resultant effect of which are increased surface area and pore size of the biomass enabling increase in the enzymatic hydrolysis efficiency. Physical pretreatment is often combined with chemical pretreatment to enhance the efficiency of lignocellulose deconstruction [24, 26].

Chemical pretreatment includes acid, alkali, oxidative delignification, and organic acid (organosolvation) methods. They are highly selective for specific type of feedstocks, and are used to deconstruct and remove lignin and/or hemicellulose from the polymer matrix. Chemical pretreatment is the most efficient and hence predominantly used [13].

The biological pre-treatment involves the use of microorganisms like brown rot fungi (scientific name), white rot fungi (scientific name) and soft rot fungi (scientific name) to degrade the lignocellulosic complex to liberate cellulose. This pre-treatment also helps to degrade lignin and hemicelluloses to produce amorphous cellulose. The rate of biological pretreatment is very low but safe and energy saving. This method is also known as Cellulose Solvent-based Lignocellulose Fractionation (CSLF) [18, 25, 26].

Enzymatic hydrolysis of cellulose obtained from pretreatment is a critical step to the release of sugar monomers which then undergo fermentation with yeast, especially *saccharomyces cerevisiae* to ethanol isolated by fractional distillation.

2.2. Biogas from cassava peels

Cassava roots are the third largest source of food carbohydrates in the tropics after rice and maize [27]. It generates in the processing step a large quantity of waste, about 20 to 35 % of the weight per Kg of tubers [28]. The peels are discarded in nature and constitutes an environment problem [29, 30]. Several researchers reported the possibility of using cassava peels as starting material to produce biogas, an alternative renewable energy [28, 31-34]. Turning cassava peels into biogas leads to reduced solid organic waste and provides energy to the population.

Bio-digestion of cassava peels alone give very poor yield in biogas but combined with animal waste the yield improves tremendously [35]. Bio-mechanization of fresh cassava peels mixed with cow dung produced 95.592 L of biogas in 40 days of digestion whereas stale cassava peels mixed with cow dung gave 104.961 L REF. Basic pre-treatment with $Ca(OH)_2$ and NaOH did not significantly improve biogas production on one hand. On the other hand, using NH_4Cl to pre-treat cassava peels significantly improves biogas production [33, 34, 36, 37].

A mixture of 30% by weight of cassava peel with 70 % by weight of pig waste produced after 30 days a higher yield of biogas (68.5 L) than that recorded for the 10:90 mixture (61.7 L) [32].

By fermenting cassava peels and stems under mesophilic conditions in a laboratory anaerobic digester with an operating volume of 2L at a loading rate of 0.0756 g COD/L for 25 days, a production of 15 L of biogas was recorded with cassava peels inoculated with a compost slurry obtained from vermicomposting plant waste. It is worth mentioning that anaerobic digestion of waste such as cassava peels can be a solution to the objectives of integrated waste management, either waste reduction or the use of renewable energy [38].

Bio-digestion of 25 kg of cassava peels mixed with 25 kg of cow dung and 100 kg of water in a 200 L reactor produced a cumulative volume of 937.3 L of biogas for a digestion time of 30 days. What's more interesting, the digestate from the anaerobic digestion process is rich in NPK, can be used as an organic fertilizer [39]. .

Adelekan and Bamgboye [34], compared the production of biogas from cassava peels to which poultry waste, pig waste and cow dung were added in selected proportions in a 220L reactor under mesophilic conditions. Their results showed that biogas production efficiency depends on the ratios and the type of used substrates.

Nkodi et al. [28] studied the co-digestion of cassava peels with different concentrations of urea for 14 days under mesophilic conditions; the highest biogas yield obtained (80.79 L/KgTS) was with 0.01% urea. In co-digestion of composted mixtures of cassava peel and coffee pulp with or without cow dung, the highest cumulative biogas volume of 16.50 L/kgTS was produced when cow dung was added to the mixture.

In investigating parameters which affect biogas production from cassava peels, fractional factorial design method was used. It was demonstrated that organic loading rate, particle size and co-substrate have significant effect on the yield of biogas. The highest volume of biogas (2252 mL) was obtained at pH 7.8 for a loading rate of 5% , ≤ 2 mm of particle and urea as co-substrate, while a slightly low biogas yield (2129.5 mL) was recorded for pH 7.8, 10% of loading rate, >2 mm of particle and urea as co-substrate. Thus, the best conditions to produce biogas from cassava peels are pH 7.8, 5% of loading rate, ≤2 mm of particle and urea as co-substrate [40].

In order to determine the impact of cassava peel starch on the biogas produced by the anaerobic digestion process, Alrefai et al. [41] used pretreatment by heating to isolate the starch and mechanically pretreat the substrate. By using a design of experiment to analyze the influence of temperature, volatile solids and the amount of sludge, and by applying an optimization process to calculate the energy balance for the optimum results, the authors showed that the influence of starch on biogas quality is fairly small and, as such, negligible. The largest volume of biogas obtained was 3.830 L at 37 °C, 4.2 g-VS and 50 % of sludge quantity, while the maximum CH_4 g^{-1}VS was 850 mLg^{-1}-VS at 37 °C, 1.1 g-VS and 50% of the quantity of sludge. The optimum results show that it is possible to achieve an energy gain on the basis of the criteria set.

Response Surface Methodology (RSM) was used to find optimal conditions for biogas production from cassava peels mixed with urea in mesophilic conditions during 14 days. Organic Loading Rate (OLR) and Urea Concentration (UC) were the two studied parameters. Two values of each parameter were considered 5 and 15 % for OLR; 0.01 and 0.05 % for UC. Central Composite Design (CCD) made from rsm package of R Software 4.1.1 was used to determine variations. The optimum values obtained were 6.588 % and 0.0067 % for OLR and UC respectively, with an optimal biogas yield of 3260.694 mL. The analysis of variance (ANOVA) showed a high coefficient of determination value (R2=0.8146) at 95 % confidence level and a p-value of 0.002 [29].

3. BIOPLASTIC FROM CASSAVA PEELS

The accumulation of plastic waste and excessive use of plastic is a common environmental issue in many Sub-Saharan Africa cities such as Kinshasa. Plastics are synthetic polymers derived from fossil fuels and petroleum, that are stable, water-resistant, light, flexible and firm but very difficult to break down by microorganisms. Plastics are not biodegradable and constitute a severe environment problem. Effort is being done to replace petroleum plastic with bioplastic, which are biodegradable and environment friendly. Bioplastic is created to overcome plastic contamination while maintaining the characteristics of plastics which are flexible, cost effective and durable. Therefore, modifying starch into biodegradable plastics that are less harmful to the environment than conventional plastics have attracted attention over the years because of its environmental sustainability [42]. Major sources of starch-for bioplastics are starches from potato, wheat, rice, barley, oat, soy sources and cassava [43,44]. Cassava peels starch, derived from lignocellulosic waste attract a lot attention, since it is available and cheap and doesn't pose the problem of food versus industrial starting material that most others source of starch may posed [44].

Starch based bioplastic have poor resistance to moisture and poor mechanical properties which restrict their use. Therefore, different formulations and various materials are being tested to improve physical properties and biodegradability of starch-based bioplastic. Bioplastics were prepared from mixture of cassava peels starch with different amount of glycerol (20, 30 et 40 %) and constant amount of $CaCO_3$ as filler. It was found that plastic with 20 % of glycerol had the highest strength and higher mechanical properties although it was the lowest in water absorption level [45]. In another study a mixture of cassava peels starch with various amount of sorbitol and microcrystalline cellulose (MCC) was found that sorbitol increase water uptake while MCC enhance physical and biodigestibility properties of bioplastics [45,46, 47].

Bioplastics were also prepared from mixture of cassava peels starch with different ratio of chicken eggshells. It was found that 1:1 ratio gave rise to the optimal bioplastic in biodigestibility and tensile strength [48].

An interesting bioplastic was prepared from cassava peels starch with glycerol as plasticizer and nanoclay as reinforcement. The results show that addition of nanoclay into bioplastic increase the tensil strengh from 5.2 MPa to 6.3 Mpa and the degradation could be achieved on the 6th day [49].

Production of biodegradable plastics from cassava peel starch is a well-established technology but effort is continued to be made to improve their mechanical qualities to that of the well establish petrochemical plastic.

4. ACTIVATED CARBON FROM CASSAVA PEELS

Activated carbon is a porous form of carbon that has been treated with oxygen or chemical to create a network of tiny low volume pores that increase its surface area. The high surface area makes activated carbon effective at separating and purifying liquid and gaseous phase mixture [50]. Several raw materials are used to produce activated carbon such as coal, coconut shell, corn cob, saw dust, cassava peels and others [51]. Activated Carbon is an important industrial material in constant increase in international market [52].

Activated carbon has complex porous structure with associated energetic and chemical inhomogeneities. Pore size depends on the premises on degree of initial impregnation, the catalyst used and conditions of activation.

Due to a great interest worldwide to mitigate climate change and its destruction effects, activated carbon derived from fossil fuel is being replaced nowadays by that obtained from lignocellulosic agriculture wastes. These wastes are available and can be acquired at low cost.

Activated carbon from cassava peels has attracted a lot of interest lately, especially in major cassava producing countries such as Nigeria [53] and Indonesia [54].

The main steps to make activated carbon are: carbonization, chemical activation and physical activation. The catalyst uses and the conditions of activation determine the qualities of the obtained activated carbon [54].

Carbonization is carried out usually between 500 and 800°C while chemical activation is done with strong base KOH or NaOH and also with phosphoric acid H_3PO_4. Better results are obtained with KOH and H_3P0_4. [55] carbonized cassava peels at 500°C, then activated it using either NaOH or KOH. The physical activation was carried by heating the material at 175°C under nitrogen flow for 1 hour. KOH was found to be a better activator than NaOH. The activated carbon obtained had an iodine number of 721 mg/gr. Yuliusman et al. [55] have used the same chemical activator, KOH, but carried the physical activation at 750°C under N_2 flow and obtained 24,3 % of activated carbon with an iodine number of 602 mg/gr. Sudaryanto et al. [54] used also KOH for chemical activation and the maximum pore volume of activated carbon was obtained when the impregnation, ratio of cassava peels to KOH was 5:2 and the carbonization at 750°C.

Activated carbon is used to remove impurities in solutions; Brice et al.[56] prepared activated carbon from cassava peels and used it to remove Nickel II from aqueous solution. Activated carbon from cassava peels was also used to removed Zinc and Chromium from tannery liquid waste and yellow synthetic dyes in aqueous solutions [57,58,59]. Magnetic activated carbon form cassava peels were prepared by Rinawati et al. [60] and used it to remove tetracycline antibiotic in aqueous solution with a very good efficiency.

Ekekwe et al.[58] prepared activated carbon from cassava peels by carbonization at 700°C for 2 hours then treated with H_3PO_4 at 800°C for 1 hour. This material was used to remove Zinc in aqueous solution with 88% efficiency.

Mesoporous activated carbon was obtained by Kayiwa et al. [61] by pre-leaching cassava peels with NaOH followed by KOH activation and carbonization at 780°C. The pore volume obtained was 0,756 $cm^3.g^{-1}$ and the surface area was 168,4 $m^2.g^{-1}$.

Activated carbon from cassava peels activated with either KOH or H_3P0_4 gave a product with a high surface area of 398,46 $m^2.g^{-1}$ which was used to prepare supercapacitor electrode with a maximum capacitance of 64,18 F/gr [62, 63, 64].

A composite material was prepared from activated carbon from cassava peels and copper oxide and was found very efficient for thermal and electrical conductivity [65].

Zhang et al. [66] prepared a solid carbon-based acid catalyst by sulfonation of incompletely carbonized cassava stillage residue (CSR) with concentrated sulfuric acid. The resulting catalyst was successfully used in the esterification reaction of free fatty acids from used cooking oil with methanol. These authors had systematically studied the influence of carbonization and sulfonation temperature on the activity of the prepared catalyst. They highlighted the fact that low-temperature carbonization followed by high-temperature sulfonation resulted in changes to the carbon network structure; whereas high-temperature carbonization proved not to be conducive to the attachment of $-SO_3H$ groups to the surface. This type of catalyst proved to be very active. The catalyst was recycled five times for esterification, and its activity did not change significantly. It was concluded that CSR can be considered a promising raw material for the production of a new, environmentally-friendly solid acid catalyst

Bonganga et al. [30] prepared four solid acid catalysts (A-D) from cassava peels by carbonization at 500°C for 15, 30, 45 and 90 min. Catalyst A was obtained by treating carbonized peels with concentrated H_2SO_4 at 160°C for 15h, followed by cleaning and drying. Catalyst B was obtained by treating carbonized peels with H_3PO_4 40% prior to sulfonation.

Catalysts C and D were first heated at 800°C in a muffle furnace for 5 minutes. The obtained material was treated directly with sulfuric acid to give thermally activated carbon acid (C) or treated with phosphoric acid prior to sulfonation with sulfuric acid to give thermally phosphated and sulfonated carbon acid (D). Total acid densities of these catalysts ranged from 2.26 to 3.49 mmol/g, while $-SO_3H$ densities ranged from 0.92 to 2.20 mmol/g. All of them were effective in the esterification of free fatty acid in palm kernel oil with conversion rates ranging from 70 to 90%, depending mainly on the density of sulfonic acid on the catalyst. The solid catalysts were found stable and could be recovered and reused in the esterification reaction with a slight decrease in the conversion of free fatty acids to esters. It was found also that catalyst D was more stable than all the other prepared catalysts.

5. CASSAVA PEELS AND MUSHROOM CULTURE SUBSTRATE

Mushrooms are very nutritious and low in calories. They have more protein content than most vegetables and have a high amount of minerals and essential amino acids recommended for a daily diet. Mushrooms are ideal food for people having certain types of diseases such as, heart and kidney problems, infectious disease, cancer and others. They are also characterized by having antioxidant and immunomodulated substance that can stimulate the immune system [67].

Mushrooms are cultivated on various lignocellulosic wastes, among other cereal grains, rice straw, wheat straw, cottonseed hulls, soybean meal, sawdust and cassava peels. These substrates are sources of nutrients for their growth; hence mushroom yield depend on the quality and the quantity of nutrient in the substrate [68].

Cassava peels have been used as substrate to cultivate edible mushroom. However, the yield is rather low compare to the usual substrate of saw dust. The are two ways to increase protein content in cassava peels to make it an effective substrate. First by supplementing it with other substrate having high protein content [69, 70, 71, 72] such as a mixture of 75 % of cassava peels with rice bum or wheat bum used to cultivate *Pleurotus estreatas* and P. *Pulmonomas.* The efficiency found was 38 % while colonization occurred in 15 to 16 days and the spawning between 18 to 24 days [70].

The second method is to compost cassava peels alone or with other substrate as reported by Kortei et al. [72] who composted cassava peels with corn hobs and chicken manure and used the compost obtain to cultivate *Pleurotus ostreatus*. The yield obtained was similar to that of using saw dust as substrate. Similar results were also obtained when 70% of cassava peels was mixed with corn brun, rice hull, urea and lime. The yield obtained in the culture of *Oyster* mushroom was superior to that using saw dust as substate [73, 74].

Mushroom culture on cassava peels is used also as a mean to digest carbohydrate in peels and increase the protein content. Tijani et al [75] prepared a substrate composed of cassava peels with 4 % wheat flower, 0,7% magnesium sulfate and cultivate white red fungus (?????). It was found that 61.6 % of lignin was degraded and protein content increase was up to 71.31 %.

In fact, mushroom and other microorganisms can excrete several extracellular enzyme within the compost and directly attack lignin, cellulose and hemicellulose. After collecting mushrooms, the spend compost could be used as a soil conditioner [73]. Antai and Mbongo [74] use this procedure by preparing a mash of cassava peel supplemented either with ammonium sulfate, urea or sodium nitrate. The mash was then inoculated with *sacchoromycea* or *candida tropicaleum*. The amount of protein found in the peels almost double. The highest amount was obtained with cassava peels supplemented with urea at 30°C, pH 6,5 and moisture of 130 %.

Cultivation of edible mushroom requires the use of viable mushroom spawn which is generally termed mushroom seeds. In the mushroom industry, spawn is a substrate into which a mushroom mycelium impregnated and developed which will be used for propagation of mushroom production. Span for mushroom culture is usually prepared from sorghum seeds but Akinrinola-Akinyemi et al.[76] prepared span using cassava peels and used it for spawing cassava peels and saw dust substrate and compare cassava span to conventional sorghum span It was found that cassava peels supplemented with rice brun gave excellent results with cassava span [76].

Mushroom culture on cassava peels as substate, especially in majors cassava producing countries is an important activity which provide excellent food and adequate material for soil conditionnement.

6. CASSAVA PEELS AS FEED FOR ANIMALS

In any animal production, feed constitutes about 70-80% of the total cost. Therefore, non-conventional feedstuffs are being search for inclusion as substitutes for expensive conventional feed stuff like soja and maize. This trend has

necessitated the urgent need to explore the use of cassava peels as animal feeds by major cassava producer countries because cassava peels constituted an environmental hazard. Fresh cassava peels spoil very quickly and contain phytates and large amounts of cyanogenic glycosides. It's very important that cassava peels to be processed in order to reduce cyanogenic potential and phytate content while preserving their nutritive value [77]. Chemically, cassava peels contain on dry mater basis, crude fibres (21%), crude proteins (4.8%), carbohydrates (22.33%), ash (5.7%), lignin (7.2%), lipids (1.38%) and they can therefore be used as animal feed [78, 79, 80].
However, their high levels of cyanogenic glycosides and fiber limit their use as cattle feed. [81]. A number of projects have been undertaken to reduce the cyanogenic glycoside content, either by retting, steaming or sun-drying and so to enhance the feeding value of cassava peels [6, 82, 83]. One of the simplest and effective method to remove cyanide by sun drying was developed by scientists at ILRI (International Livestock Research Institute). This procedure gives a High Quality Cassava Peels (HQCP) excellent food ingredient for animals at low cost which can be stored for up to 6 months [84].
Many studies have been conducted to remove cyanide such as a comparative study carried out to evaluate the mode of reduction of cyanide in cassava peels below 100 mg cyanide equivalent in one kilograms of dry matter at 48, 72 and 96 h respectively by sun drying, heap fermentation and dry-soaking. It was found that sun-dying caused an early sharp fall in the cyanide potential, but heap fermentation or dry-soaking gave the lowest residual cyanide after 120 h [85].
Ensiling cassava peels with other substrate such as palm kernel meal increase crude protein content and lower cyanogenic glycoside. The nutritious composition of the material obtained was examined and evaluated in case of poultry farm and found to be very effective [86, 87].
Supplementation of cassava peels with protein rich waste has been shown as an appropriate procedure to get access to nutritious animal feed. As Aguihe et al. [88] who supplemented cassava peels with Maxigrain enzyme and found that the obtained mixture could replace up to 75 % maize in broiler finish diet [88]. Another study report that supplementation of cassava peels with essential amino acid could replace up to 60% maize in pig feed [89]**.**
Cassava (*Manihot esculenta*) peels supplementation in feed was also evaluated on the quality and quantity of dairy cattle production of Friesian Holstein cross breed cattle. They results indicated that supplementation of cassava peels with Odot grass (*Pennisetum purpureum*) feed to cattle can produce higher total solid and protein level of milk than in the control group. They also have high potential as a feed source to cut production cost; therefore, the farmer income increased slightly [90]**.**
Replacement of maize by cassava peels up to 60% in cockerel starter diets had no significant effect on final weight of the birds. The incorporation level of cassava peel in birds diet could be said commercially viable for optimum performance of cockerels at the starter phase of production [91].
In other hand, 10% of sun-dried ensiled or fermented cassava peels can conveniently replace equal amount of maize in rabit diet without any adverse effect on gut functions and growth. It has also been shown that 10% sun-dried ensiled or fermented cassava peel can easily replace an equal quantity of maize in the diet of rats without any negative effect on intestinal function or growth. [92].
Fermented cassava peel used to prepare a starter diet for young poultry had led to an increase in body weight after 20 days, from 40 g to 134.8 g; that of the birds fed on the control diet containing unfermented peel was only 42.8 g. Mortality rate was extremely low (12.5%), whereas it was very high (100%) with the unfermented peel [92].
Cassava peels treated by various methods such as ensiling, steaming, retting and sun-drying were incorporated into the feed ration of Isa Brown laying hens aged 56 to 72 weeks, replacing maize in proportions of 50, 75 and 100%. Performance in terms of hen-day production and egg weight showed that cassava peels treated with retting could satisfactorily replace up to 75% of the maize, whereas those treated by other methods could not replace more than 50% of the maize without jeopardising these two parameters (Salami and Odunsi, 2003). It has been also proved that cassava peels with rice husk in a ratio of 60:10 has a potential to replace guinea grass in the diet of West African Dwarf (WAD) Sheep [94].
In a study on the nutritional evaluation of cassava peel in the diet of weaner pigs, Onyimonyi and Okeke (2008) have demonstrated that sun dried cassava peel could replace 10% of maize in a diet for weaner pigs with significant effect on red blood cells, white blood cells, neutrophils and monocyte levels.
Replacing 40% of the maize in the hens' feed with cassava peels has been shown to reduce the performance of broilers during their growth and finishing phases. Adding fat or enzymes restores weight gain. This replacement allows a significant reduction in poultry diet costs and environmental protection [95].
It is possible to improve the digestibility of cassava peels, which are a substrate with high fiber e content, and to considerably reduce its anti-nutritional effect by adding the maxagrain enzyme. Supplementing cassava peels meal with this enzyme up to 50% inclusion gives the best results and is therefore recommended to poultry breeders [96].
Although it is undeniable that feed from cassava peel may be deficient in other nutritional values, but supplementation with amino acid or protein sources such as soya beans can be included in animal diets to nourish them. If livestock feed producers in Africa should turn their attention and resources to adding value to cassava peels, post-harvest waste could be curbed and the "waste" could generate millions OF WHAT to boost the African continent at large.

7. CONCLUSION

This work attempted to take a broad analysis of most of research carried out on different process to add value to cassava waste ~~often~~ discarded at processing site and considered as an environmental hazard. It has been shown that cassava peels could be used as starting material to produce bioethanol and biogas, its starch can be used to make bioplastic; activated carbon from peels can be used to remove impurities in liquid or gas or converted to solid acid catalyst much needed in green chemistry; edible mushroom can be grown on cassava peels as substrate and excellent animal feeds can be obtained from cassava peels. The different converting methods of cassava peels to value-added bioproducts need to be brought to attention of cassava producers, especially to those in rural area where major cassava production is done.

8. CONFLICT OF INTEREST

The authors declare that they have no conflict of interest.

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