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Cassava peels as feed resource for animal production - A review

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ABSTRACT

Feed constitutes about 70-80% of the total cost of production in any animal enterprise. As a result of the foregoing, non conventional feedstuffs are being beckoned on for inclusion as substitutes for expensive conventional feed stuff like maize. This trend has necessitated the urgent need to explore the use of cassava peels; that have constituted environmental hazard, as feed resource for animal production. Despite its content of lethal hydrogen cyanide, various treatments can be used to reduce it to a tolerable level after which it serves as energy source in animal feed. Therefore, this paper has highlighted the different treatment options that could be used to reduce cassava peels' cyanide to a tolerable level and concomitantly enhanced the nutritive value ready for use as veritable feed resource for animal feed compounding.

***Keywords*:** Animal, Cassava peels, Cyanide, Feed resource, Treatment, Fermentation

1. INTRODUCTION

In Nigeria, processing cassava for food and industry yields around 15 million tons of wet peels annually. These peels are usually dumped near processing centres to rot or dry enough to

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be burnt. Decomposing heaps of cassava peels release methane into the air, which aid in ozone depletion and a stench that pollutes the air. Bodies of water (surface and underground) are also contaminated, while open-air burning produces clouds of acrid smoke. However, when properly dried, peels can be an ingredient in animal feed (Okike *et al*., 2022). Cassava has seen a steady increase in production, averaging 3% per year since 1995, reaching 59 million tons in Nigeria and 178 million tons in Africa (FAOSTAT, 2019). Several African governments are promoting cassava to reduce cereal imports through mandatory blending of wheat flour with high-quality cassava flour (Okike *et al*., 2022).

Cassava peel is the outer cover of the tuber, which is usually removed manually with little or no pulp (IITA, 1990). They may contain high amounts of cyanogenic glycosides and have higher protein content (< 6%) than other tuber parts (Tewe, 1984). Fresh cassava peels spoil very quickly, contain phytates (up to 1% DM) resulting in low phosphorus availability in non-ruminants (Ubalua, 2007) and contain high amount of cyanogenic glycosides. Aside from the lower values of crude protein and energy of the peel, the greatest limitation in the use of cassava peel is that of its hydrocyanic acid (HCN) content which is harmful particularly to the monogastrics (Salami and Odunsi, 2003). Processing of cassava peel such as fermentation, ensiling etc reduces its cyanogenic potential and phytate content (0.7%) (Oboh, 2006; Unigwe *et al*., 2017) and when well processed, its HCN content is below 50 mg/kg (Nwokoro *et al*., 2005; Unigwe *et al*., 2015; Unigwe *et al*., 2017). Therefore, this review tailored toward the abundant availability of cassava peels, the remedial treatment options that could assuage the inherent deleterious constituents of the peels thereby making them a cheap energy option for animal feed production.

2. ANALYSIS AND DISCUSSION

2. 1. Impact of cassava by - products on the environment

Cassava processing produces large amounts of waste and is generally considered to contribute significantly to environmental pollution (FAO, 2001). A cassava starch production unit, processing 100 tons of tubers per day, has an estimated output of 47 tons of fresh by-products, which may cause environmental problems when left in the surroundings of processing plants or carelessly disposed of (Aro *et al.*, 2010). In Nigeria, for example, cassava wastes are usually left to rot away or burnt to create space for the accumulation of yet more waste heaps.

The heaps emit carbon iv oxide and produce a strong offensive smell (Adebayo, 2008; Aro *et al.*, 2010). Cassava peels (large amounts of cyanogenic glycosides) and pomace (large amounts of biodegradable organic matter) may cause surface water pollution especially if they are stored under heavy rain or simply disposed of in surface waters (Pandey *et al.*, 2000; Barana and Cereda, 2000). The presence of a large processor or several small processors can cause the eutrophication of slow moving water systems, notably during the dry season (FAO, 2001). However, cassava processing does not seem to affect groundwater supply, except occasionally in the immediate surroundings of processing units, due to leaching through the soil (FAO, 2001). Starch extraction requires large volumes of water and may cause water depletion, but in most areas this problem is minimized by the adoption of processing technologies suitable for the water resources available (FAO, 2001). The use of cassava by-products as feedstuffs or as an alternative substrate for biotechnological processes is a positive way to alleviate environmental issues (Pandey *et al.*, 2000).

2. 2. Cyanogenic property of cassava peel

Cassava contains 2 cyanogenic glycosides, linamarin (2-β-D-glucopyranosyloxyl isobutyronitrile) (80% of total glycosides) and lotaustralin (methylbutyronitrile) (20% of total glycosides). A cell-wall enzyme liberates hydrogen cyanide (HCN), which is lethal to animals. Hydrogen cyanide concentrations depend on cultivar, environmental conditions, plant age, number of harvest (for the foliage) and on the plant component that is being considered. There is a continuous gradient of HCN content between varieties (Peroni *et al.,* 2007), which is usually divided into two groups:

Bitter varieties with roots containing 0.02-0.03% HCN (DM basis) and leaves containing up to 0.2% HCN (fresh basis) (Murugesrawi *et al.*, 2006). These have to be processed before being used as feed. Sweet varieties with roots containing less than 0.01% HCN (DM basis) and leaves, 0.1% of HCN (DM basis) (Murugesrawi *et al.*, 2006). These can be fed raw. Most commercial varieties belong to this group. Bitter varieties have often longer and thicker roots than the sweet varieties, but there is no simple and safe method to assess HCN content. However, HCN can be relatively easily removed from cassava by-products, as shown in processes. Well-processed cassava peels have generally acceptable levels, below 50 mg/kg (Osei and Twumasi, 1989; Nwokoro *et al.*, 2005). However, mass HCN poisoning in an intensively managed Nigerian pig farm, where more than half of the herd died within a few hours after consuming boiled and overly ripe cassava peels from a bitter variety, has been reported. Treating the surviving pigs with antibiotics and palm oil saved some of them (Sackey, 2002).

2. 3. Phytate property of cassava peel

Cassava peels have a high phytate content (up to 1% DM), resulting in low Phosphorus availability in non-ruminants (Ubalua, 2007). Fermentation can slightly reduce phytate content (down to 0.7%) (Oboh, 2006).

2. 4. Cassava peels

Cassava peels are wastes generated as a result of mechanical removal of the two outer coverings of cassava roots prior to its subsequent processing to other cassava products like starch, flour, chips, "garri", "fufu" etc. Tewe *et al*. (1976) and Aro *et al.* (2008) gave the proportion of peel in a whole tuber in a factory-processed and hand processed cassava peels as 5 and 8%, respectively. Most of these peels are left to root away with unwholesome consequence on the environment in spite of their great nutritional potentials especially for livestock feeding. The constraints to their use in livestock nutrition are their high fibre content, low caloric value and their heavy loads of anti-nutrients like cyanide, tannins and phytates (Iyayi *et al.,* 1977; Akpan and Ikenebomeh, 1995).

The use of biotechnological option by way of microbial inoculation of cassava wastes has presented a very viable and cost effective panacea to these constraints militating against the use of agro-industrial waste like cassava peels (Israelides *et al.*, 1998; Olowofeso *et al*., 2003). A trial was conducted by Oboh and Akindahunsi (2003) on the fermentation of cassava peels with a consortium of microorganisms in which the sundried fermented peels were analyzed for proximate, mineral, anti-nutrient composition and protein digestibility. These authors concluded that in view of the significant increase in protein content and digestibility of the microbially treated peels versus the untreated control, such fermented cassava-by product could be a good supplement in compounding animal feed. Nwafor and Ejukonemu (2004), in Nigeria, experimented with three species of amylolytic fungi (*Saecharomyces cerevisiae*, *Mucor spp.* and *Rhizopus spp.*) in a solid substrate that contained 80g of cassava waste powder, 1.25g of $(NH_4)_2SO_4$, 1.25g of urea and 1.0g of K_3PO_4. The results of their trial after 6 days of fermentation are presented and concluded that protein content of cassava wastes could be enhanced substantially using some micro-organisms that are capable of utilizing the wastes as the sole carbon source and that moulds are better protein enhancers than yeasts because the hyphal growth of moulds was able to penetrate and spread through the substrate better than the yeast. Olowofeso and Omisanmi (2008) treated cassava peel with yeast culture at a graded level of 0-0.6% inclusion and concluded that sun-dried cassava peels treated with yeast culture resulted in better economic gain without compromise on performance.

2. 5. The need for fermentation of cassava by-products

Fermentation of cassava by-products automatically qualifies such products as fermented feed stuffs, which according to Campbell *et al.* (2009), are defined as plant tissues subjected to the action of micro-organisms and/enzymes to give desirable biochemical changes and significant modification of food quality. The general reasons advanced for such fermentation as outlined by Stainkraus (1995) are as listed below:-

i) Detoxification of food/feed anti-nutrients during the process of fermentation.
ii) Biological enrichment of food substrates with proteins, essential amino acids, essential fatty acids and vitamins.
iii) Enrichment of the fermented products through the importation of an array of aroma/flavours and textures.
iv) Preservation of the fermented products through the production of lactic acid, acetic acid, alcohol and alkali in the substrate as a result of fermentation and
v) Decrease in cooking time and fuel requirements.

All the reasons outlined above have been achieved through the fermentation of cassava by-products. Research works of Gray and Abou-Ei-Seoud (1996) and Sukara and Doelle (1988) gave clear evidence of protein enrichment of cassava products through fermentation. Akinrele *et al.* (1962) and Akindahunsi *et al.* (1999) reported on the flavor-enriching ability of microorganisms in the fermentation of cassava pulp and its conversion to a popular starchy staple (Garri consumed extensively in Nigeria). The detoxification of anti-nutrients in cassava and its by-products, especially of hydrogen cyanide, tannins and phytates was reported by Hahn (1992) and Oboh and Akindahunsi (2003) while the safety and preservation of the fermented products such as garri and lafun in Nigeria through acidification and dehydration was reported by Oboh *et al.* (2000).

2. 6. Different processing methods for cassava peels

Fresh cassava peels have 3 main disadvantages: they spoil very quickly; they contain phytates and large amounts of cyanogenic glycosides. They should thus be processed in order to reduce cyanogenic potential and phytate content and to preserve their nutritive quality (Salami and Odunsi, 2003; Oboh, 2006). Different processes are effective in reducing cyanogenic glycoside including sun-drying, ensiling, and soaking plus sun-drying. All these methods have yielded satisfactory results (Tewe, 1992; Salami and Odunsi, 2003).

Good quality silage can be obtained after chopping the peels to equal lengths of about 2 cm for easy compaction, and wilting for 2 days to reduce moisture content from 70-75 % to about 40%. Under these conditions, cassava peel silage after 21 days was light brown in colour, firm in texture and had a pleasant odor. The pH was 4.4 and no fungal growth was observed (Asaolu, 1988).

In Nigeria, drying cassava peels on black plastic sheets has been drawing the attention of smallholders. Using cassava waste to raise goats is possible (Winning project of the 2008 Global Development Marketplace (a grant program held by the World Bank). Solid fermentation of a mixture of cassava peels and waste water from fermented cassava pulp with *Saccharomyces cerevisiae* and *Lactobacillus* spp resulted in a product with a higher protein content, lower cyanogenic glycosides and lower phytate content (Oboh, 2006; Ubalua, 2007).
Different processing methods usually engaged in treating cassava peels for feed compounding:

a) Fermentation

Cassava peel wastes are generated in the production of farihna, garri and chikwangue. Inappropriate storage of the peels for long periods is the main issue especially with heavy rainfall. Utilization of the peel is limited by its low digestibility and toxicity from extremely high levels of hydrocyanic acid. Fermentation not only reduces toxicity, but the enzyme-resistant lingo-cellulose material is converted into a more digestible substrate. Following fermentation, cassava peel can be formulated into pig and poultry feeds (Ofuya and Obilor, 1993).

Oboh (2006) studied the nutrient environment of cassava peels using a mixed culture of *Saecharomyces cerevisae* and *Lactobacillus Spp* in solid media fermentation techniques. Two treatments (mixing of 150 ml of waste water from fermented cassava pulp with 200g of washed, dried and ground cassava peels and mixing of 150 ml of waste water from the fermented inoculated pulp with 200g of washed, dried and ground cassava peels) were observed for fermentation. The fermented cassava peels served as T_2, T_3 and T_4. The result of the analysis of the cassava peels fermented with waste-water from the inoculated cassava pulp showed increase in protein content to up to 350%. The increase in the protein content of the cassava peels fermented with waste-water from the inoculated fermented cassava pulp could be attributed to the possible secretion of some extra-cellular enzymes (proteins) such as amylases, linamarase and cellulase (Oboh and Akindahunsi, 2003) into the cassava mash by the fermenting organisms (Rainbault, 1998), as well as increase in the growth and proliferation of the fungi/bacteria complex in the form of single cell proteins (Antia and Mbongo, 1994; Oboh *et al.*, 2002). Conversely, a decrease in the carbohydrate content of the cassava peels fermented with waste-water from the inoculated cassava pulp (51.1%) was observed when compared to the unfermented cassava peels (64.6%). The decrease could be attributed to the ability of the fungi/bacteria complex to hydrolyse starch into glucose and ultimately the glucose will be used by the same organisms as a carbon source to synthesize fungi/bacteria biomass rich in protein (Oboh *et al.*, 2002). However, Oboh (2006) observed that there was no discernible trend in the fat, crude fibre, ash and the mineral content of the cassava peels.

Cassava peels normally have higher concentration of cyanogenic glycosides than the parenchyma (pulp) and this makes the peels unsuitable for animal feed. Its fermentation with waste water from the fermented cassava pulp reduced the cyanide content of the peels when compared with unfermented cassava peels (Oboh, 2006). However, the cassava peels fermented with waste water from cassava pulp fermented with a mixture of *S. cerevisae, and Lactobacillus* *coryne* had lower cyanide content (6.2 mg/kg) than those cassava peels fermented with wastewater from the naturally fermented cassava pulp (23.5 mg/kg). Results showed that waste-water from the inoculated cassava pulp were very efficient in cyanide detoxification than that of naturally fermented cassava.

The fermented cassava peels could be considered safe in terms of cyanide poisoning in view of the fact that the cyanide was below the deleterious level of 30 mg/kg (Twenygyere and Katongole, 2002). A decrease in phytate content of the fermented cassava peels (705.1-789.7 mg/100g) was reported by Oboh (2006) and this decrease was more in cassava peel fermented with waste water from naturally fermented cassava pulp (705.13 mg/100g), while the unfermented cassava peels had 1043.56 mg/100g phytate content. Such a decrease could be as a result of possible secretion of the enzyme phytase by the micro-organisms in the waste-water.

The enzyme is capable of hydrolyzing phytate thereby decreasing the phytate content of the fermented cassava peels (Oboh and Akindahunsi, 2003). In view of the increase in protein content of the cassava peel fermented with waste-water from fermented cassava pulps (inoculated and natural) and the significant decrease ($p<0.05$) in the anti-nutrients (cyanide and phytate), this by-product could be a good supplement in compounding animal feed provided that it is acceptable and highly digestible.

b) Sun-drying

Cassava peels can be chopped manually or by means of mechanical chopper. Chopping not only increases cyanide elimination, but also shortens the drying time. To speed up the drying process, the forage material is first chopped into 3-5 cm lengths, allowing quicker evaporation of moisture and subsequently the release of volatile toxic substances such as HCN. Sun-drying is probably the cheapest method in the tropics for preserving feeding materials for animal use. Sun-drying is a common practice in the dry season, which is the usual harvest time of cassava, due to strong sunlight, high temperatures, low humidity and availability of space. Cassava leaves and peels dry easily and drying is completed to about 10 – 12% moisture content in two days during dry sunny weather. Simple sun drying alone eliminates almost 90% of the initial cyanide content (Ravindran, 1992).

c) Soaking

Soaking of cassava roots/peels normally precedes cooking or fermentation. It provides a suitably larger medium for fermentation and allows for greater extraction of the soluble cyanide into the soaking water. The process removes about 20% of the free cyanide after 4 hours, although bound cyanide is only negligibly reduced. Bound cyanide begins to decrease only after the onset of fermentation (Cooke and Maduagwu, 1985). A very significant reduction in total cyanide is achieved if the soaking water is routinely changed over a period of 3–5 days (Tewe, 1991).

d) Grating

This process takes place after peeling and is sometimes applied to whole tubers. Grating of the whole tuber ensures the even distribution of the cyanide in the product, and will also make the nutrients contained in the peel available for use. In the grated product, the concentration of cyanide depends on the time during which the glucoside and the glucosidase interact in an aqueous medium (Tewe, 1991). Grating also, obviously, provides a greater surface area for fermentation to take place.

e) Boiling/parboiling

Boiling cassava peels also removes an appreciable amount of cyanide. After cooking, in contrast to sun-drying, thin cassava peels/chips have lower residual cyanide than thicker cassava chips (Garcia and Dale, 1999). The free cyanide of cassava peels is rapidly lost in boiling water as in soaking. About 90% of free cyanide is removed within 15 minutes of boiling, compared to a 55% reduction in bound cyanide after 25 minutes (Cooke and Maduagwu, 1985). Cooking destroys the enzyme linamarase at about 72 °C thus leaving a considerable portion of the glucoside intact. The increase in the volume of water increases the leaching out of cyanogens (Nambisan and Sundaresan, 1985). Boiling is less efficient in removal of cyanogens than sun drying. It is also evident from the studies conducted by Esonu and Udedibie (1993) and Salami (2000) that parboiling prior to sun drying had no advantage over sun drying alone in terms of reduction of cyanide content of cassava peels. According to Eshiett and Ademosun (1981) and Salami (2000), parboiled cassava peel meals (PCPM) contain 5.31% crude protein, 12.30% crude fibre, 1.13% ether extract, 63.29% nitrogen-free extract and 9.88% total ash.

f) Ensiling

The optimal inclusion level and utilization of the processed cassava peel would therefore depend upon the processing method used. Studies (Obioha and Anikwe, 1982; Tewe and Kasali, 1986) indicated that ensiling and fermentation are the most efficient methods while oven-drying is the least efficient method for cyanide reduction in fresh cassava peels.

2. 7. Nutritional attributes of cassava peels

Cassava peels have low protein content (< 6% DM) and high and variable fibre content (crude fibre in the 10-30% DM range). Cassava peels can be used as roughage and as an energy feed in ruminant and non ruminant diets. However, sun drying, ensiling and fermentation should be used to prevent HCN poisoning when feeding bitter cassava varieties (Pipat *et al.*, 2011). Cassava peels should not be fed alone, as their protein and mineral content cannot support optimum rumen function and productivity in ruminants. Their optimal utilization requires supplementation with readily fermentable protein and by-pass protein, as well as micronutrients including sulphur, phosphorus and vitamin B. If fed in a balanced diet, cassava peels are a valuable feed for animals (Smith, 1988).

2. 8. Digestibility and degradability of cassava peels

Cassava peels are highly digestible products, with reported values of 78% and 81% for DM and OM total tract digestibility respectively (Baah *et al.*, 1999). Dry matter degradability is also high, with reported values more than 70% (Smith, 1988). In Ghana, weight gains of 0.29 or 0.33 kg/day (vs 0.07 kg/day for the control diet) were recorded with cross-bred grazing bullocks supplemented with dried or ensiled peels (Larsen and Amaning-Kwarteng, 1976). In an experiment with bulls in Vietnam, total DMI increased with the amount of cassava peels while grass DMI decreased (Pham and Preston, 2009). Because of their high degradability, cassava peels are also used as an energy supplement in cattle. Cassava peels can partly replace

(30% of total DMI) energy concentrates, with no influence on the intake, digestibility, microbial efficiency and nitrogen retention (Azevêdo *et al.*, 2011).

Many trials have been carried out with sheep in Sub-Saharan Africa. In Ghana, Djallonké lambs lost weight after consuming a total diet of cassava peels. Supplementation with *Ficus exasperata* leaves resulted in weight gains and in a significant increase in cassava peels DMI (from 44 to 58 g W0.75/d) (Baah *et al*., 1999). In Cameroon, sheep fed 0, 35 and 70% of the diet as cassava peels (and 70, 35 and 0% *Pennisetum purpureum*), with cottonseed cake as the protein source, gained 45, 107 and 227 g/d respectively. Dry matter intake, digestibility and growth rate increased linearly with increasing dietary levels of cassava peels (Fomunyan and Meffeja, 1987). Sheep may use ensiled cassava peels better than sun-dried peel. In Nigeria, sheep fed a diet containing 80% ensiled cassava peels had greater daily gains (81 vs 59 g/d) than those fed sun-dried peels (Asaolu, 1988).

In Nigeria, a 60 : 20 : 20 ensiled mixture of grass-legume (guinea grass and tropical kudzu (*Pueraria phaseoloides*), cassava peels and poultry excreta fed to West African Dwarf goats resulted in favorable consumption and digestibility, as well as normal rumen and blood metabolites. It was recommended to use cassava peels as an energy supplement in anticipation of dry-season feeding (Okeke and Oji, 1987). In Red Sokoto goats, ensiling cassava peels with *Pennisetum purpureum* had beneficial effects on silage properties, intake and digestibility, and it was proposed that cassava leaves form at least 30% of silage made from *Pennisetum purpureum* to improve productivity during the dry season (Olorunnisomo, 2011). Sun-dried cassava peels included up to 74% in supplement rations where they completely replaced maize offal did not affect live weight changes in pregnant Red Sokoto goats grazed on native pasture (Lakpini *et al.*, 1997).

2. 9. Cassava peels in different feeds of animals

Cassava peels are a good feed for pigs, but they must be supplemented with protein and lipids in order to improve their palatability and digestibility (Iyayi and Tewe, 1992). The fibrous nature of the feed may also limit its inclusion in pig diets (Adesehinwa *et al.,* 2011). Most studies on the use of cassava peels in pig diets have been carried out in Nigeria. Typical inclusion rates are about 30% though rates up to 60% have been found economically sustainable due to the lower price of cassava peels compared to that of maize. Cassava peels can be introduced at up to 30% in piglet diets without affecting growth rate. In older pigs (35 kg), up to a 57% inclusion had no deleterious effect on daily gain, feed intake, feed conversion ratio and carcass characteristics and the use of cassava peels as a partial replacement for maize in young pig diets was shown to be cost effective (Balogun and Bawa, 1997). In a similar experiment, a 40% level of cassava peels in place of maize was adequate for growing pigs, though a dietary protein content of at least 15% was necessary for satisfactory performance (Iyayi and Tewe, 1992). Other authors have also concluded that cassava peel meal can be included in the diets of growing pigs up to 30%, in order to reduce feed cost without any detrimental effect on performance (Irekhore *et al.*, 2006), or up to 60% (total replacement of maize) when the maize price is high (Bawa and Damisa, 2007). In growing pigs, inclusion of cassava peel meals up to 38% with 5.4% palm oil gave a better economic performance than other combinations of peels and palm oil (Damisa and Bawa, 2009).

Several methods have been tested to enhance the feeding value of cassava peels for pigs. In pigs fed a diet containing 30% cassava peels, adding an enzyme cocktail enhanced diet utilization and was as effective as the maize-based control diet (Adesehinwa *et al.,* 2011).

Biodegradation of cassava peels with *Trichoderma viridae* resulted in higher protein content (16%) but was more expensive and did not significantly improve performance (Arowora *et al.*, 2005).

Cassava peels can be used for poultry feeding after sun-drying, as well-processed peels contains HCN levels that are acceptable for poultry (Osei *et al.*, 1990; Nwokoro *et al.*, 2005). Method of fermentation of cassava peels has been tested by several authors, either to lower HCN or fibre content (Osei and Duodua, 1988) or to increase crude protein content (Buitrago, 1990), but the results are inconclusive. Unigwe *et al*. (2017) subjected cassava peels to various treatments and had the crude protein rose from 4.86% for sundried cassava peels (CP) to 9.25 and 10.69% for fermented and ensiled ones respectively whereas the cyanide reduced from 46.44 mg/kg (sundried CP) to 16.88 and 21.62 mg/kg for fermented and ensiled cassava peels respectively.

In some experiments, growth performance was maintained with broiler diets containing up to 15% cassava peel meal (Osei, 1992; Nwokoro and Ekhosuehi, 2005). Feed intake is generally not highly affected but depends on the feed formulation (iso-caloric diets or not). However, in some experiments, performance decreased with 5% cassava peel meal in the diets (Osei and Twumasi, 1989; Egbunike *et al.*, 2009). This can be due in part to problems in feed formulation since there is evidence that performance is degraded with inadequate protein inclusion (Egbunike *et al.*, 2009). There can be an advantage in feeding fresh cassava peels for slow growing chickens (Ogbonna and Dredein, 2000). The recommendation in broilers is to limit the incorporation of cassava peel meal to 5-10% depending on its quality, with an appropriate feed formulation. Higher levels of cassava peel meal could be fed to slow growing chicken or in situations where depression in growth performance is counterbalanced by a lower feed cost.

Sun-dried cassava peels at 10 to 40% inclusion rates resulted in significantly lower productive performance in layers, with an average of 15% less egg-lay when 20% cassava peel meal was included in the diet (Obioha *et al.*, 1984; Salami and Odunsi, 2003). The effect on feed intake was not constant in these studies. Different processing techniques were tested to alleviate the negative effect of cassava peels: ensiling or boiling resulted in improved performance, but the rate of egg-lay was always lower than for the maize control diet (Salami and Odunsi, 2003). Fermented cassava peel even in layers' diets was not efficiently used (Osei *et al.*, 1990). These results suggest that cassava peel meal should be used carefully in layer diets, with low inclusion rates (e.g. 5%). In conditions where the cost of raw materials is very high, the economic advantage of using higher levels of cassava peel meal could be tested.

Dried cassava peels could be introduced at up to 30% of the diet, in balanced rations for growing rabbits, as a source of energy to replace the corresponding amount of maize grain (Agunbiade *et al.*, 1999; Olorunsanya *et al.*, 2007). Because the detoxification of cyanogenic glycosides requires the presence of methionine, balanced feeds that include cassava peels must contain enough sulphur-containing amino acids (Okeke *et al*., 1986).

Fermentation or ensiling is at least as efficient as sun-drying to detoxify cassava peels and the resulting products can be used safely to feed growing rabbits (Okeke *et al.*, 1986; Ahamefule *et al.*, 2006). Water-soaking fresh peels for 1 to 5 hours before sun-drying also significantly reduced cyanogenic glycosides in amounts proportional to the duration of soaking (Shoremi *et al*., 1999). Water-soaked cassava peels replacing 20% maize in the control diet gave growth and slaughter performance identical or significantly better than those obtained with control diet (maize only) (Oluremi and Nwosu, 2002).

However, extrusion of a diet based on dried cassava peels (totally replacing maize) was inefficient in all indices of measurement, as growing rabbits fed on this diet showed poor performance compared to those fed the non-extruded diet (Agunbiade *et al.,* 1999).

Cassava meal residue is a mixture of cassava roots, unsuitable for human consumption, and of root tips from the pre-processing cleaning stage. Its composition is close to that of the roots, with a high starch level (64%). It was reported that cassava meal residue may be added up to 26% of the diet of growing rabbits from weaning to slaughter, replacing completely the digestible energy from maize without any impairment in performance and carcass quantitative characteristics (Scapinello *et al.,* 2005).

2. 10. Use of cassava peels in feeding different domestic animals

a) Ruminants

Cassava peels can be used as a roughage and as an energy feed in ruminant diets. However, sun drying, ensiling and fermentation should be used to prevent HCN poisoning when feeding bitter cassava varieties (Pipat *et al*., 2011; Unigwe *et al*., 2017). Cassava peels should not be fed alone, as their protein and mineral content cannot support optimum rumen function and productivity. Their optimal utilization requires supplementation with readily fermentable protein and by-pass protein, as well as micronutrients including sulphur, phosphorus, and vitamin B. If fed in a balanced diet, cassava peels are a valuable feed for ruminants (Smith, 1988). Cassava peels are highly digestible products, with reported values of 78% and 81% for DM and OM total tract digestibility respectively (Baah *et al*., 1999). Dry matter degradability is also high, with reported values more than 70% (Smith, 1988).

b) Cattle

In Ghana, weight gains of 0.29 or 0.33 kg/day (vs 0.07 kg/day for the control diet) were recorded with cross-bred grazing bullocks supplemented with dried or ensiled peels (Larsen and Amaning-Kwarteng, 1976). In an experiment with bulls in Vietnam, total DMI increased with the amount of cassava peels while grass DMI decreased (Pham and Preston, 2009). Because of their high degradability, cassava peels are also used as a energy supplement in cattle: cassava peels can partly replace (30% of total DMI) energy concentrates, with no influence on the intake, digestibility, microbial efficiency, and nitrogen retention (Azevêdo *et al*., 2011).

c) Sheep

Many trials have been carried out with sheep in Sub-Saharan Africa. In Ghana, Djallonké lambs lost weight after consuming a total diet of cassava peels: supplementation with *Ficus exasperata* leaves resulted in weight gains and in a significant increase in cassava peels DMI (from 44 to 58 g W0.75/d) (Baah *et al*., 1999). In Cameroon, sheep fed 0, 35 or 70% of the diet as cassava peels (and 70, 35 and 0% *Pennisetum purpureum*), with cottonseed cake as the protein source, gained 45, 107 and 227 g/d respectively. Dry matter intake, digestibility and growth rate increased linearly with increasing dietary levels of cassava peels (Fomunyan and Meffaja, 1987). Sheep may use ensiled cassava peels better than sun-dried peel: in Nigeria, sheep fed a diet containing 80% ensiled cassava peels had greater daily gains (81vs 59 g/d) than those fed sun-dried peels (Asaolu, 1988 cited by Smith, 1988).

d) Goats

In Nigeria, a 60:20:20 ensiled mixture of grass-legume (guinea grass and tropical kudzu (*Pueraria phaseoloides*), cassava peels and poultry excreta fed to West African Dwarf goats resulted in favorable consumption and digestibility, as well as normal rumen and blood metabolites. It was recommended to use cassava peels as an energy supplement in anticipation of dry-season feeding (Okeke and Oji, 1987). In Red Sokoto goats, ensiling cassava peels with *Pennisetum purpureum* had beneficial effects on silage properties, intake and digestibility, and it was proposed that cassava leaves form at least 30% of silage made from *Pennisetum purpureum* to improve productivity during the dry season (Olorunnisomo, 2011). Sun-dried cassava peels included up to 74% in supplement rations where they completely replaced maize offal did not affect live-weight changes in pregnant Red Sokoto goats grazed on native pasture (Lakpini *et al*., 1997).

e) Pigs

Cassava peels are a good feed for pigs, but they must be supplemented with protein and lipids in order to improve their palatability and digestibility (Iyayi and Tewe, 1992). The fibrous nature of the feed may also limit its inclusion in pig diets (Adesehinwa *et al*., 2011). Most studies on the use of cassava peels in pig diets have been carried out in Nigeria. Typical inclusion rates are about 30% though rates up to 60% have been found economically sustainable due to the lower price of cassava peels compared to that of maize. Cassava peels can be introduced at up to 30% in piglet diets without affecting growth rate. In older pigs (35 kg), up to a 57% inclusion had no deleterious effect on daily gain, feed intake, feed conversion ratio and carcass characteristics and the use of cassava peels as a partial replacement for maize in young pig diets was shown to be cost effective (Balogun and Bawa, 1997). In a similar experiment, a 40% level of cassava peels in place of maize was adequate for growing pigs, though a dietary protein content of at least 15 % was necessary for satisfactory performance (Iyayi and Tewe, 1992). Other authors have also concluded that cassava peel meal can be included in the diets of growing pigs up to 30%, in order to reduce feed costs, without any detrimental effect on performance (Irekhore *et al*., 2006), or up to 60% (total replacement of maize) when the maize price is high (Bawa and Damisa, 2007). In growing pigs, inclusion of cassava peel meals up to 38% with 5.4% palm oil gave a better economic performance than other combinations of peels and palm oil (Damisa and Bawa, 2009).

Several methods have been tested to enhance the feeding value of cassava peels for pigs. In pigs fed a diet containing 30% cassava peels, adding an enzyme cocktail enhanced diet utilization and was as effective as the maize-based control diet (Adesehinwa *et al*., 2011). Biodegradation of cassava peels with *Trichoderma viridae* resulted in higher protein content (16%) but was more expensive and did not significantly improve performance (Arowora *et al*., 2005).

3. CONCLUSION

Cassava peels despite having been regarded as waste for ages, has a lot of values in compounding feed for domestic animals particularly when subjected to treatments in order to reduce the hydrogen cyanide content. It can partially or completely substitute energy source in the diet of animals. This review has brought out the need to see and utilize cassava peels as energy resource rather than waste in animal production. Further research can also be conducted on it to ascertain other treatment options that will enhance its nutritive value.

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