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Utilisation of Cassava Products for Poultry Feeding: A Review

Ngiki Y. U.
Department of Animal Production, Faculty of Agriculture
Adamawa State University, Mubi, Adamawa State, Nigeria
Igwebuike J. U.
Department of Animal Science, Faculty of Agriculture
University of Maiduguri, Borno State, Nigeria
Moruppa S. M.
Department of Animal Production, Faculty of Agriculture
Adamawa State University, Mubi, Adamawa State, Nigeria

Abstract:
World cassava production stands at 250 million tonnes in 2011, out of which Nigeria produces 39 million tonnes leading the World in cassava production. Cassava being a tropical crop is high in energy and crude fibre and very low in crude protein compared to cereals. The cassava root is gaining high interest in its use to substitute for more than 50% of maize in poultry diets. The high content of hydrocyanide acid (HCN) limits its utilisation if not properly processed especially the bitter cassava. Cassava leaf is a good source of protein and carotene, rich in minerals, low in energy and high in crude protein. Both broilers and layers can tolerate 20% inclusion levels. Cassava peels which may be considered as nuisance to the environment as it constitute about 15% of the whole cassava root, can be used in poultry feed. It contains higher HCN, crude fibre and lower energy and protein than that of the cassava root. Various methods of cassava processing have been used to reduce the toxicity of the HCN to a safe level. These include chopping and sun-drying, heat treatment, grating, soaking, fermentation, etc. which are known to reduce the HCN between 50 mg/kg and 140 mg/kg. These are acceptable levels in compounded layer and broiler diets. The protein content of cassava peels can be improved from 2.4% (non-fermented) to 14.1% (fermented) when pure culture of Saccharomyces cerevisiae fungi is used in the fermentation. In conclusion, properly processed cassava products supplemented with critical amino acid (methionine) will greatly reduce the HCN and improve utilisation and performance of poultry.

Keywords*: Utilisation; cassava products; broilers; layers, feeding*

1. Introduction

Chickens constitute one of the most common sources of animal protein in developed countries but this is not the case in developing countries mostly due to the cost which is beyond the reach of the common man. Daily intake of animal protein per caput falls far below the normal intake as recommended by ILCA (1980) and FAO (1986). However, feed cost is presently very high and makes up to 70 - 80% (Oruwari *et al*., 1995) of the total cost of production in Nigeria compared to 50 to 70% in developed countries (Thackie and Flenscher, 1995).

Maize has traditionally been the ingredient of choice for the supply of energy in monogastric animal diets with inclusion levels varying from 50 to 70% (PAN, 1995). Its important role as a human and industrial food ingredient coupled with drought in some parts of Africa have sometimes caused relative scarcity of the ingredient and an attendant increase in price invariably leading to an increase in feed costs. These among other factors have prompted the need to explore other potential energy sources which are either not consumed by humans, not in relative high demand or resistant to drought. One of such is cassava (*Manihot esculenta* Crantz) also known as “tapioca”, “manioc”, “mandioca” or “yucca” in many countries.

Cassava is grown in tropical countries in Africa, Asia, and Latin America, with 70% of the world’s cassava production coming from Nigeria, Brazil, Thailand, Indonesia, and the Democratic Republic of Congo (FAO, 2008). Nigeria, the world's leading producer, produced 39 million tonnes, a 4 percent increase from 2010 (FAO, 2011). Cassava roots require few inputs, can be left in the ground for over one year and harvested when food shortages arise or when prices of preferred cereals become prohibitive. Cassava root can be used to produce cassava chips, cassava pellets, and cassava starch, which are in high demand throughout the world. Thailand, Indonesia, and Brazil are the most prominent exporters of cassava starch, with their production accounting for 95% of the world’s supply (FAO, 2008).

In view of the high cost of poultry feed resulting from the cost of maize and vegetable protein sources such as soyabean meal, it is almost not profitable to feed protein at a level which will maximize animal performance. Hence, there is a need to find an appropriate alternative feed resource which can replace a certain proportion of maize and vegetable protein sources in the diets of poultry at a lower cost of production (Sogunle *et al*., 2009). Many research efforts were initiated in the search for alternative energy sources for poultry e.g. (Aina, 1990; Eruvbetine *et al.*, 2003). One of such alternatives is cassava. Though it is a staple food for humans, there is increasing interest in its use as a substitute for maize in feeding livestock.

Cassava is the highest supplier of carbohydrates among staple crops (FAO, 1995). There is thus the likelihood of continued use of cassava in animal feeding in the 21st century and beyond. Limitations to the use of cassava in animal feeds amongst others are its relatively low protein content. Furthermore, its protein is of poor quality particularly with respect to the essential amino acids compared to that of cereal grain (Adeyemi *et al*., 2008; Olugbemi *et al*., 2010). When utilized in replacing cereals in diet for monogastric animals, it becomes imperative to balance for protein deficiencies, which are sometimes expensive (Agunbiade *et al.*, 2001).

Numerous options have continually been advocated to alleviate these problems. These include the inclusion of synthetic amino acids, supplementing with richer protein sources such as seed, cakes or leaves and utilization of cassava in various forms apart from powder.

The objective of this paper is to review the utilization of cassava products for poultry feeding and to evaluate what is still required to improve on the efficient use of the products for poultry.

1.1. Availability of cassava and cassava products

Cassava, one of the world top calorie products for human consumption, is generally grown without fertilization on soils with poor fertility where other crops would fail (Howeler and Cadavid, 1990). Cassava can survive prolonged water deficit (Alves and Setter, 2000), and is tolerant to acid soils, but the yield is limited by poor phosphorus (P) supply (Howeler, 1985). It is also one of the most potentially valuable tropical crops due to its high tuber yield and simplicity of cultivation. However, it has been shown that the fertility of the soil decreases after the cultivation of cassava for root production without fertilization. In cassava-producing countries, better soils are almost always devoted to more profitable crops, leaving those areas with soil problems for cassava (high aluminium content, low exchangeable base content, high phosphorus fixation, and various degrees of erosion) (Howeler, 1991). Presently, cassava is widely grown throughout tropical and some sub-tropical areas. Cassava is generally cultivated for root production for both humans and animals. The world cassava production in 2011 was estimated at about 250 million tonnes, 47% of which was produced in Africa (FAO, 2011). About 30% of Africa's production is produced from Nigeria. More than a third of cassava production is used for animal feeding (FAO, 2011). Cassava root production has been increasing steadily since the 1960s and surged in the 2000s (+40% between 1997 and 2007, from 161 to 224 million tonnes). Its use in animal feeding also grew from 25% in 1997 to 34% in 2007 (76 million tonnes).

This is broken down into various continent as follows; Africa 132 million tonnes, Latin America 35 million tonnes, Asia 82.5 million tonnes, and Oceania 277,000 tonnes and Nigeria 39 million tonnes being the leading producer in the world (FAO, 2011) as shown in Table 1.

Regions	**Year 2008 ('000)**	**Year 2009 ('000)**	**Year 2010 ('000)**	**Year 2011 ('000)**
World Production	239,843	241,980	237,917	250,062
Africa	125,039	123,180	126,627	132,119
Nigeria	44,582	36,804	37,504	38,982
Latin America	34,201	32,773	33,029	35,170
Asia	80,404	85,785	78,086	82,587
Oceania	284	278	271	277

Table 1: World cassava production (tonnes)
Source: FAO (2011)

2. Composition of Cassava Products

2.1. Cassava Root Meal

The root is composed almost entirely of carbohydrate which can be used as important food source. However, it contains 1- 3% CP and cyanogens depending on cultivars (Stupak *et al*., 2006); and large amount of cyanogenic glucosides in the cassava flour (Cumbana *et al*., 2007) could limit cassava root utilization for consumption and for livestock feeding. The linamarine and lotaustralin which are cyanogenic compounds in cassava are changed to hydrocyanic acid (HCN) by the action of the linamarase enzyme when roots are crushed or sliced (Wanapat *et al*., 1999; Cardoso *et al.*, 2005). Cassava root meal contains a range of metabolizable energy values for poultry from 2.87 to 4.27 kcal ME/g of dry matter depending on the variety. They also contain very low levels of protein (2.5% of DM) and are deficient in all other nutrients (Khajarern and Khajarern, 2007). The proximate composition of cassava root meal is shown in Table 2.

Constituents	1	2	3	4
Dry Matter (%)	--	85.0	--	92.28
Crude Protein (%)	2.8	2.0	2.5	5.13
Crude Fibre (%)	2.6	4.4	3.5	4.05
Ether Extract (%)	1.2	2.0	0.3	1.5
Nitrogen-Free Extract (%)	90.20	72.1	89.9	83.22
Ash (%)	3.2	5.1	3.8	6.1
Metabolisable Energy (kcal/kg)	3000-3200	3200	3145	3279
Source:	1.Buitrago *et al*. (2002)	2.Egena (2006)	3.Khajarern and Khajarern (2007)	4.Olugbemi *et al*. (2010)

Table 2: Proximate composition of cassava root and metabolizable energy (ME)

2.2. Cassava Peel Meal

The peel is low in protein and energy, while the root is low in protein but high in energy although slightly lower than that of maize. The leaves on the other hand contain low energy and high protein, minerals and vitamins. The peels contain higher levels of cyanogenic glucosides than the root meal (Adegbola and Asaolu, 1986). The potentials of cassava as a feed ingredient notwithstanding, cassava is much lower in protein content. Furthermore, its protein is of poorer quality compared to that of cereal grain. When utilized in replacing cereals in diet for monogastric animals, it becomes imperative to balance for protein deficiencies, which are sometimes expensive (Agunbiade *et al*., 2001). The proximate composition of cassava peel meal is presented in Table 3.

Constituents	1	2	3
Dry matter (%)	29.6	--	80.95
Crude Protein (%)	4.9	4.5	5.5
Crude Fibre (%)	16.6	7.0	21.36
Ether Extract (%)	1.3	2.0	0.67
Nitrogen-Free Extract (%)	68.5	81.5	66.49
Ash (%)	5.9	5.0	5.98
Source:	1.Smith (1992)	2.Onyimonyi and Ugwu (2007)	3. Sogunle et al. (2009)

Table 3: Proximate composition of cassava peel

As a rough estimate, about 10 million tonnes of cassava are processed for 'gari' annually in Nigeria alone (Okafor, 1992). In the processing of cassava fermented products, the roots are normally peeled to rid them of two outer coverings: a thin brown outer covering, and a thicker leathery parenchymatous inner covering. These peels are regarded as wastes and are usually discarded and allowed to rot. With hand peeling the peels can constitute 20-35% of the total weight of the tuber (Ekundayo, 1980). The wastes generated at present pose a disposal problem and would even be more problematic in the future with increased industrial production of cassava products such as cassava flour and dried cassava "fufu". Since these peels could make up to 10% of the wet weight of the roots, they constitute an important potential resource if properly harnessed by a biotechnological system (Obadina *et al*., 2006). Cassava peel has been a constant part of household waste product and even constitute nuisance in waste disposal. It is traditionally offered to small ruminants in Southern Nigeria (Obioha, 1972). Cassava peel constitute about 8-15 percent of the whole root (Onyimonyi and Ugwu, 2007). The peel of the "bitter" cassava variety was shown to contain an average of 650 ppm and the pulp to contain 310 ppm total cyanide; the corresponding values for "sweet" varieties were 200 ppm and 38 ppm respectively (Tewe, 1991).

2.3. Cassava Leaf Meal

Cassava leaf is another potential feed source for poultry. The leaf blade accounts for 10 to 40% by weight of the plants aerial part, depending upon the age and ecological condition of the plant. Leaves can be harvested within 4 to 5 months of planting, without adversely affecting root production, yielding up to 10 tonnes of dry foliage per hectare. After drying, the leaf or foliage can be ground into meal which is a good source of protein and carotene for poultry. The protein content in cassava leaf is between 20-23% (Gomez *et al*., 1985; Nwokolo, 1987; Ravindran, 1991). Rogers and Milner (1963) reported a range of 17.8 to 34.8% crude protein in 20 cassava cultivars. Ravindran and Ravindran (1988) found a decrease of CP content from 38.1% in very young leaves to 19.7% in mature leaves, and a similar trend for most amino acids, while crude fibre, hemicellulose and cellulose contents increased. The proximate composition of cassava leaf is provided in Table 4.

Constituents	1	2	3	4
Dry matter (%)	93.0	92.7	93.3	25.30
Crude Protein (%)	21.0	18.0	23.2	25.1
Crude Fibre (%)	20.0	14.1	21.9	11.4
Ether Extract (%)	5.5	9.4	4.8	12.7
Nitrogen-Free Extract (%)	53.5	43.3	42.2	46.1
Ash (%)	8.5	7.9	7.8	9.1
M E (kcal/kg)	1800	---	1590	---
Source:	1.Ravindran (1992)	2.Akinfala et al. (2003)	3.Khajarern and Khajarern (2007)	4.Iheukwumere et al. (2008)

Table 4: Proximate composition of cassava leaf and metabolizable energy (ME)

Cassava leaf is also a rich source of most minerals, especially calcium and micro-minerals (Ravindran and Ravindran, 1988). Cassava leaves have been reported to have higher protein content than stems and petioles (Khieu *et al.*, 2005), and therefore cassava leaves will be suitable for monogastric animals such as pigs and poultry. Cassava root products are deficient in carotene and other carotenoids. Consequently, supplementation of cassava-based diets with these compounds is needed for the maintenance of normal egg yolk and broiler skin pigmentation (Khajarern and Khajarern, 2007). Supplementation with well-dried cassava leaf meal may address this problem. Furthermore, cassava leaf meal has fair concentration of essential amino acids as presented in Table 5.

Amino Acid	Cassava Leaf Meal	Alfalfa
Arginine	5.3	4.9
Lysine	5.9	4.4
Methionine	1.9	1.7
Cysteine	1.4	1.2
Total sulphur amino acid	3.3	2.9
Tryptophan	2	2.3
Histidine	2.3	2.1
Isoleucine	4.5	4.9
Leucine	8.2	7.5
Phenylalanine	5.1	5.2
Threonine	4.4	4.4
Valine	5.6	6.0
Source:	Ravindran	(1992)

Table 5: Essential amino acid profile of cassava leaf meal compared with alfalfa (g/16gN)

The nutritional limitation of cassava leaves include the HCN content, low digestible energy, bulkiness and the high tannin content (Ravindran *et al.*, 1986). The cyanogenic glycosides, which on hydrolysis yield toxic HCN, may limit its use as a monogastric animal feed. The HCN concentration, produced after the action of hydrolytic enzymes occurring in the plant on the cyanogenic glycosides, is influenced by the nutritional status and age of the plant (Ravindran and Ravindran, 1988), and higher HCN levels were found in leaves from bitter than in sweeter varieties (Tewe and Iyayi, 1989). The average HCN content found in a Sri Lankan variety (Ravindran *et al*., 1987) was over 4,000 mg kg-1. However, the HCN concentration and the bitterness associated with high cyanogenic glycoside contents in leaves (Sundaresan *et al.,* 1987) decreases with the maturity of the leaves.

2.4. Cassava Starch Residue

Cassava starch residues are the fibrous wastes left behind after the extraction of starch from mechanically rasped cassava tubers in the cassava starch processing factories. It is constrained by its high water content; very low protein and high fibre level (Aro *et al*., 2008). Cassava pulp is the solid, moist by-product of cassava starch manufacture, and it represents approximately 10 to 15% of the original root weight. As cassava starch production increases, so does the large volume of waste by-product generated. After drying, the by-product is used to produce fertilizer or included in diets for ruminants and swine. However, an abundance of by-product still remains. The proximate composition of cassava starch residue is presented in Table 6. Dried Cassava Pulp (DCP) is low in protein (approximately 2% on a DM basis) and deficient in carotene contents. Thus, inclusion of DCP in diets should take these factors into consideration (Khempaka *et al*., 2009). The fibre content of DCP is reportedly in the form of insoluble fibre. High levels of fibre, bulkiness, and dustiness in DCP are possible factors leading to decreased growth performance and digestibility.

Constituents	1	2
Dry matter (%)	15.80	---
Crude Protein (%)	1.12	1.55
Crude Fibre (%)	19.25	27.75
Ether Extract (%)	0.12	0.12
Nitrogen-Free Extract (%)	74.41	70.58
Ash (%)	2.84	1.70
Source:	1. Sriroth *et al*. (2000)	2. Khempaka *et al*. (2009)

Table 6: Proximate composition of cassava starch residue.

3. Performance of Poultry Fed Cassava Products

The maximum level of cassava root meal in broiler diets has ranged from 10% (Vogt, 1966; Montilla, *et al*., 1969; Armas and Chicco, 1973; Gomez *et al*., 1984; Osei and Duodu, 1988) to 30% (Montilla *et al*., 1969; Armas and Chicco, 1973; Lopez *et al*., 1976; Enriquez *et al*., 1977; Gomez *et al*., 1987), and as high as 40 to 60% (Enriquez and Ross, 1967; Olson *et al*., 1969; Tejada and Brambilla, 1969; Chou and Muller, 1972; Muller *et al*., 1974; Christensen *et al*., 1977; De Brum *et al*., 1990). A similar range in level of incorporation is found in the diets of laying hens, with the cassava inclusion level ranging from 15% in chick diets (Thirumalai *et al*., 1990) to 30 or 40% in layer diets (Khajarern *et al*., 1979; Eustace and Olumide, 1994; Garcia *et al*., 1994). This variation has been due to differences in many factors that will affect its inclusion in poultry diets, such as anti-nutritional factors, cassava root processing methods, and nutritional and physical factors. Palatability of cassava-based ration is an important factor limiting feed intake of poultry. Physical properties such as dustiness and bulkiness are closely related to palatability and limit feed intake. Further processing of cassava-based diets including pelleting, the addition of molasses or fat to minimized dustiness and improve texture of the diets, were observed to improve performance. Apart from improving the palatability of feeds, fat supplementation has also been reported to supply essential fatty acids needed for normal egg size as well as provide additional energy to allow the diets to meet the requirements of chickens (Khajarern and Khajarern, 2007). The normal methionine supplementation of high cassava based diets is 0.2 to 0.3% (Adegbola, 1977).

Gomez (1991) suggested that 100 mg HCN kg-1 feed on dry matter basis, as indicated by the Council of the European Community, could be the permissible maximum level. However, in poultry it was reported that broilers could tolerate diets containing 141 mg total cyanide kg-1 without any negative effects on growth performance (Panigrahi *et al*., 1992).

Depressed performance of cassava-fed chickens has been reported by Vogt (1966). Cassava cultivars contain varying amounts of cyanogenic glucosides, and are classified as "bitter" or "sweet" based on the level of these compounds. The cyanide level varies from about 75 to 350 ppm (Oke, 1978; Cheeke, 1989), but can be l000 ppm or more (Piva, 1987), depending on the variety, plant age, soil condition, fertilizer application, weather, and other factors (Gomez and Valdivieso, 1983). However, the use of new varieties with low cyanogenic glycoside content is increasingly common. Cassava pellets are high in potassium, limiting their inclusion to reduce the moisture content of faeces may be appropriate (Nesheim *et al*., 1964). Chronic cassava toxicity in chickens has been reported to lower egg production and egg quality in layers (Jalaludin and Leong, 1973; Omole, 1977) and reduce shell thickness (Tobayayong, 1935) and hatchability of eggs (Ngoka *et al*., 1982). The maximum inclusion level of cassava products are shown in Table 7.

Cassava Products	Broilers	Source
Cassava root meal	40 – 60 %	Enriquez and Ross (1967); Olson *et al*. (1969); Tejada and Brambilla (1969); Chou and Muller (1972); Muller *et al*. (1974); Christensen *et al*. (1977); De Brum *et al*. (1990).
Cassava leaf meal	15 – 20 %	Montilla (1977); Ravindran *et al*. (1986).
Cassava peel meal	15%	Tewe and Egbunike (1992)
Cassava starch residue	8%	Khempaka *et al*. (2009).
Cassava root meal	**Layers** 30 – 50%	Khajarern *et al*. (1979); Tewe and Egbunike (1992). Eustace and Olumide (1994). Enyenihi *et al*. (2009).
Cassava leaf meal	15 – 20 %	Khempaka *et al*. (2009);
Cassava peel meal	27%; 40%	Sonaiya and Omole (1977).

Table 7: Maximum possible inclusion levels of cassava products in poultry rations

3.1. Cassava Root Meal

Enyenihi *et al*. (2009) reported that 50% of maize can be effectively replaced with sun-dried cassava tuber meal for laying hens if the diet is balanced for crude protein. Gowdh *et al*. (1990) reported that cassava root meal depressed growth when included in the diet at 486 g/kg (48.6%). Stevenson and Jackson (1983) observed that weight gain was unaffected by diet containing 50% cassava root meal. However, the excreta were sticky and the authors considered the meal to be suitable only up to a level of 30%. Panigrahi *et al*. (1992) reported that the cyanogen content of the diet may depress performance at concentrations of less than 140 mg total cyanide per kg. They also observed watery excreta and higher food spillage. Several studies by Tewe (1984b) concluded that performance of poultry on cassava diets was satisfactory if the HCN content in the final ration did not exceed 100 ppm. Unhydrolysed linamarine, remaining in cassava roots and leaves after fermentation, can constitute a health problem for the consumers (Nartley, 1968; Cooke, 1978; Ikediobi *et al*., 1980; Gomez *et al*., 1985). Indeed, the chronic exposure to cyanide due to the consumption of non-detoxified cassava products is associated to a certain number of diseases caused by the cyanide, including goitre, dwarfism and the tropical ataxic neuropathy. It is particularly a problem in the regions where cassava is the major source of calories (Oke, 1980; Tewe, 1984a; Umoh *et al*., 1985; Balagopalan *et al*., 1988). Cyanohydric acid is lethal at a consumption dose of 0.5 to 3.5 mg per kilogram body weight.Traditional technologies have been developed in Central Africa to eliminate cyanohydric acid in cassava roots and leaves, such that they are suitable for human consumption (Kobawila *et al*., 2005).

3.2. Cassava Peel Meal

There is evidence in literature that cassava peel and blood meal could be utilized to a great extent in the feeding of pigs and poultry (Ewane, 1996). Some work has been reported on the value of cassava peel as dietary sources for non-ruminant. Tewe and Egbunike (1992) reported that cassava peels can be satisfactorily used up to 40 % for pigs, 15 and 27% for broilers and layers, respectively. Cassava peel increased feed intake, reduced body weight gain and reduced nutrient utilisation when included in starter and finisher diets at levels between 0 and 30% as replacement for maize (Tewe, 1983). The same author reported that inclusion of up to 27% of cassava peels in layers rations will result in increased feed intake, egg production and feed per unit egg produced, while Sonaiya and Omole (1977) reported inclusion level of 20 – 40% for feeding chicken.

3.3. Cassava Leaf Meal

Available data on cassava leaf (CLM) and foliage meal (CFM) indicate that these products might be used at low levels (5 – 6 %) of inclusion in broiler diets as pigmenting agents or at higher levels (10 – 20 %) as partial substitutes for the conventional protein sources in poultry diets. Available studies suggest a range of 10 – 40 % of cassava leaf meal inclusion, or 60% of a mixture of cassava products (flour, peel and leaves plus stem) that could be included in poultry and pig diets without adverse effect on performance.

However, the level of inclusion or supplementation of Cassava Leaf Meal (CLM) depends on the other dietary ingredients and/or preparation techniques. Montilla (1977) reported that CLM could be included up to 20 % in pelleted broiler diets, while Ravindran *et al*. (1986) recommended that up to 15% could substitute for coconut meal. The substitution of 10 % cassava product (50:50 of cassava root and leaf meal) in the diet (Eruvbetine *et al*. 2003) had no adverse effect on broiler chicken performance in terms of growth, feed conversion, and carcass characteristics.

3.4. Cassava Root and Leaf Meal

Cassava products had been in use for a long time as an energy source in place of cereal grains for poultry (Eruvbetine *et al*., 2003). Akinfala *et al*. (2003) reported growth impairments of 13 and 19% relative to the control (containing 0% of cassava) when starter broilers were fed diets containing 12.5 and 25% of whole cassava plant meal respectively. Eruvbetine *et al*. (2003) explained that the decline in body weight of birds with increasing concentration of cassava root:leaf meal concentrate (50:50) might have been due to the presence of high fibre. Eruvbetine (1995) reported that in experiments with both layers and broilers, there were marked reduction in the abdominal fat content of broilers at market weight and layers after 40 weeks in lay as a result of cassava inclusion. The reason for this reduction can be related to the crude fibre component of the diet. A similar reason can be adduced for the higher weights of proventriculus and caecum in this study with increasing concentration of Cassava Cage Layer Waste (CCLW). Agunbiade (2000) observed a similar reduction in the gizzards of broiler fed pelleted diets and opined that the gizzard easily broke down pelleted diets. Attempts by birds on the meal diet for increased capacity of the GIT (particularly the gizzard) to allow for improved nutrient utilization and growth performance could lead to the enlargement of the gizzard.

3.5. Cassava Starch Residue

Dried cassava pulp (DCP) contains starch that can be used as an energy source in poultry diets. Increasing DCP up to 8% did not significantly influence body weight (BW) when compared with the control treatment, which contained no DCP. The decline in BW was most likely due to the high fibre content of DCP (13.59%). Most of the previous studies have reported that a high-fibre-content diet can depress feed intake (FI), and consequently can cause growth depression (Hetland and Svihus, 2001; Hetland *et al*., 2005). The depression in FI in the 14 to 35 day period by inclusion of 12 and 16% DCP could be due to the increased bulkiness of the diet and limited digestive tract capacity in broilers. In addition, the increase in bulk has also been reported to reduce palatability (Weiss and Scott, 1979) and thus may limit the FI of broilers. Even though information on using DCP in broilers is limited, the results of experiments with broilers fed various levels of cassava have been widely reported (Muller *et al*., 1974; Oke, 1978). The authors summarized that when cassava was provided in mash form at all levels, poorer growth and feed conversion were obtained than with corn-based diets. However, similar performance was obtained when the diets were pelleted (Muller *et al*., 1974; Oke, 1978). Therefore, offering DCP in pellet form may overcome the problem of bulkiness and ensure an optimal FI by poultry. A strong negative correlation between the fibre fractions and nutrient digestibility has been reported in previous studies (Hetland and Svihus, 2001; Hetland *et al*., 2003; Hetland *et al*., 2005). It has also been reported that poultry fed diets with high fibre levels have reduced performance and abdominal fat content and that the length and weight of the digestive organs are altered negatively (Eruvbetine, 1995; Hetland and Svihus, 2001; Eruvbetine *et al*. 2003).

4. Processing and Ways of Eliminating the Toxic/Anti-Nutritional Factors in Cassava

Cassava is processed by various methods to reduce toxicity and improve palatability and storage characteristics. Processing practices vary considerably from region to region, but all seek to reduce the toxic cyanoglucosides to a safe level. The processing techniques for cassava tubers include peeling, sun-drying, oven-drying, boiling, steaming, roasting, and fermenting. Drying is the most popular practice to reduce cyanide in many tropical countries. Because the time of linamarase contact with the glucosides is higher with sun-drying, this method eliminates the cyanide more effectively than oven-drying. Approximately 80 to 95% cyanide reduction can be achieved through the various stages of gari production (Padmaja, 1995). Levels of cassava usage lower than 50% inclusion (Wood, 1992) or less than 50 mg HCN equivalent per kg (Tewe, 1994) are acceptable in compounding feeds.

Highly toxic hydrocyanic acid (HCN) is released from the cyanogenic glucosides during hydrolysis by the enzyme linamarase (present in the root peel of cassava), by the glucosidic enzymes of intestinal microflora (Fomunyam *et al*. 1984), by acid hydrolysis in the intestine (Casadai, 1988), and by glucosidases of the liver and other tissues (Padmaja and Panikkar, 1989). The respiratory process in animal tissues is obstructed by HCN through deactivation of the cytochrome-oxidase enzyme system (Pudek and Bragg, 1974). The HCN is transformed in the liver by the enzyme rhodanese to thiocyanate (SCN), which is excreted in the urine (Oke, 1973). This detoxification process utilizes sulphur from methionine (Westley, 1981), thus increasing the requirement for this amino acid (Adegbola, 1977). The amount of methionine needed for detoxification depends on the amount of HCN ingested. The HCN content in fresh, sun-dried and oven-dried cassava components are shown in Table 8.

Cassava Products	HCN (ppm)
Fresh whole root	88.3 – 416.3
Fresh pulp	34.3 – 301.3
Fresh peel	364.2 – 814.7
Fresh leaves	1436
Sundried whole root	23.1 – 41.6
Sundried pulp	17.3 – 26.7
Sundried peel	264.3 – 321.5
Sundried leaves	173
Oven dried whole root	51.7 – 63.7
Oven dried pulp	23.7 – 31.3
Oven dried peel	666.8 – 1250
Source:	Tewe and Iyayi (1989)

Table 8: Hydrocyanic acid content of Nigerian cassava and some products used for animal feeding (air - dry basis)

4.1. Chopping and Sun drying

Roots and Leaves 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. Small-scale farmers preserve cassava tubers by manually chopping and sun-drying them before selling them to middlemen. Sun-drying is a common practice in the dry season, which is the usual harvest time of the tubers and leaves, due to strong sunlight, high temperatures, low humidity and availability of space. Cassava leaves 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). However, when cassava roots and leaves are harvested in the rainy season sun-drying is difficult due to the lack of sun and high frequency of rain. Prolonged drying due to bad weather creates favourable conditions for bacterial and fungal growth producing mouldy products harbouring mycotoxins (Oke, 1994).

4.2. Soaking

Soaking of cassava roots 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 in fresh root chips 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).

4.3. 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.

4.4. Boiling/Cooking

Boiling cassava chips also removes an appreciable amount of cyanide. After cooking, in contrast to sun-drying, thin cassava chips have lower residual cyanide than thicker cassava chips (Garcia and Dale, 1999). The free cyanide of cassava chips is rapidly lost in boiling water as in soaking. About 90% of free cyanide is removed within 15 minutes of boiling fresh cassava chips, 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.

4.5. Improvement of the cassava products by fermentation

Fermentation ensures not only increased shelf life and microbiological safety of a food, but also makes some foods more digestible and in case of cassava fermentation reduces the toxicity of the substrate (Caplice and Fitzgerald, 1999). Cassava peels by virtue of its relatively low cost and abundance in developing nations is considered to be suitable substrates for microbial fermentation and protein enrichment (Ubalua, 2007). Processing of cassava wastes to meet minimum requirements for incorporation into commercial livestock feed production, would certainly relieve the pressure on demand for available cereal grains. The high-energy value of cassava makes it a very attractive carbohydrate ingredient in animal diet. The low protein content of cassava tubers (0.7-1.3% fresh weight) is a disadvantage, restricting the use of cassava as animal feed, but this can be improved on by upgrading the feed with protein additives, such as soybean, or by using microbial techniques or both. Fermentation of cassava peels by pure culture of *Saccharomyces cerevisiae* could increase its protein content from (2.4%) in non-fermented cassava to (14.1%) in fermented products (Antai and Mbongo, 1994). The fermented cassava flour with *S. cerevisiae* enhanced the protein level (from 4.4% to 10.9%) and decreased the amount of cyanide content (Oboh and Kindahunsi, 2005). Noomhorm *et al.* (1992) reported that the conversion of a part of the starch in cassava root meal (CRM) to protein by microbes during the process of solid-state fermentation has great potential as a means of improving the feeding value of cassava root meal. Adeyemi and Sipe, (2004) reported an improvement in crude protein concentration of cassava root when fermented with rumen filtrate with or without ammonium sulphate as the source of nitrogen. Adeyemi *et al.* (2004) obtained a value of 237.8 % increase in the crude protein value of whole cassava root meal fermented with rumen filtrate using caged layer waste as source of nitrogen.

Ubalua and Ezeronye (2008) have identified fermentation as one of the less expensive means of increasing the protein quality of cassava and cassava wastes. The use of microorganisms to convert carbohydrates, lignocelluloses and other industrial wastes into foodstuffs rich in protein is possible due to the following inherent nature of microorganisms:

- Ability to multiply rapidly;
- Their amenability to modification genetically for growth on a particular substrate under particular cultural conditions;
- They have high protein content varying from 3.5- 60%; and
- They have growth versatility in both slurry and on solids.

Dried products from roots, which have been fermented or ensiled to detoxify the HCN or to increase their protein content, are other ways of root processing (Khajarern and Khajarern, 2007).

5. Conclusion

Based on the literature reviewed, the permissible levels of cassava products in broiler and layer diets are as follows:-

Cassava root meal: Up to 50 – 60% inclusion level can replace maize in broiler diets, while 30 – 40 % can be replaced in layer diets.

Cassava peel meal: 15% of cassava peel can be included in broiler diets while 27 – 40 % can be included in layer diets.

Cassava leaf meal: 15 – 20% of cassava leaf can be included in broiler diets when used as protein source and 5 – 6 % when used as pigmenting agents in both broiler and layer diets.

Cassava starch residue: Only 8% level of inclusion is recommended for broiler diets.

Proper processing of cassava products will reduce the toxic/anti-nutritional factors to safe levels of about 140 mg/kg in broiler diets and less than 100 mg/kg in layer diets. Therefore the processing of cassava and cassava products by soaking, sun-drying, cooking/boiling, grating and fermentation are recommended to obtain safe products for poultry feeding.

6. Recommendations

Research should be intensified on the use of cassava products. Government should establish units in cassava-producing areas that will really gather and process cassava products for poultry feeds. Livestock Extension Services should be intensified so that innovations on the utilization of cassava products will be disseminated to poultry farmers. The processing of cassava products by soaking, sun-drying, cooking/boiling, grating and fermentation are recommended to obtain safe products for poultry feeding.

7. References

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