Detoxification of cassava products and effects of residual toxins on consuming animals

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INTRODUCTION

The use of cassava in livestock feeding has been limited. Reasons include the presence of toxic cyanogenic glucosides, deficiency in nutrients other than energy, dustiness of the dried products, mouldiness during processing and the high fibre and ash content of the peel, which limits the selection of other ingredients which are high in these components. Nevertheless, the development of cassava products which meet minimum requirements for incorporation into commercial livestock feed production, in cassava producing areas, would certainly relieve the pressure on demand for available cereal grains. Additionally it would help guarantee the supply of energy for livestock feeding, in these regions, that are perennially acutely short of animal feed ingredients and due to unfavourable trade balances are unable to make up deficiencies with imports.

As the presence of cyanogenic glucosides constitute a major limitation to the use of cassava in both human and animal foods there is the need to review current findings for the elimination of the toxic glucoside in cassava products and also to examine the implications of feeding cassava and its products on livestock production.

Nature of Cassava toxin

Cassava is fed to livestock in the fresh or processed form. In the whole unbruised plant the cyanogenic glucoside remains intact in the form of linamarin and lotaustralin. When the cellular structure is disrupted, the intracellular glucoside becomes exposed to the extracellular enzyme linamarase. Hydrocyanic acid (HCN) is then produced. The reaction has been shown to proceed in two steps by Nartey, (1978) viz:

(i) Cyanogenic glucoside is degraded to sugar and cyanohydrin (x - hydroxynitrile);

(ii) Cyanohydrin then dissociates to ketone and hydrocyanic acid. Thus, for linamarin the glucoside is first hydrolysed by linamarase to produce B-D-glucopyranose and 2 - hydroxyisolentyronotrite or acetone - cyanohydrin, after which the latter is degraded to acetone and HCN . Cyanohydrin produced as a result of linamarin activity is stable only under moderately acidic condition (pH 4.0); in neutral or alkaline condition it undergoes spontaneous hydrolysis to yield HCN (Cooke *et al.* 1985).

In spite of the relative instability of cyanohydrin it coexists with intact glucoside and HCN in differently processed cassava products. It is therefore clear that the cyanide in cassava products exists in three forms: (i) the glucosides (linamarin and lotaustralin), (ii) the cyanohydrin and (iii) the free hydrocyanic acid (HCN).

However, the quantitative estimation of cyanide by various methods has produced incomparable results, and in many cases a gross underestimation, emanating from quantification of free HCN alone in the reports of earlier investigators. The harmonization of current analytical and presentation methods is therefore suggested.

EFFECT OF CASSAVA PROCESSING ON CYANIDE LEVEL

Cassava tubers are traditionally processed by a wide range of methods, which reduce their toxicity, improve palatability and convert the perishable fresh root into stable products. These methods consist of different combinations of peeling, chopping, grating, soaking, drying, boiling and fermenting. While all these methods reduce the cyanide level, the reported loss in cyanide content differs considerably due to analytical methods, the combination of methods and extent to which the process(es) is(are) carried out.

The specific effects of various processing techniques on the cyanide content of cassava are discussed below:

Peeling

Many methods of processing cassava roots commence with the peeling of the tubers. Generally the cassava peel contains higher cyanide content than the pulp. Removal of the peels therefore reduces the cyanogenic glucoside content considerably. In studies carried out by the author, the peel of the "bitter" cassava variety was shown to contain on average 650 ppm and the pulp to contain 310 ppm total cyanide; the corresponding values for "sweet" varieties were 200 ppm and 38 ppm respectively. The above classification is conveniently based on the cyanide content; with the sweet varieties having most cyanide in the cortex and skin and little or no cyanide in the pulp, whereas the bitter varieties, more or less, have an even distribution of cyanide throughout the tuber. For these reasons the former can be eaten boiled while the latter has to be processed before it can be consumed.

Peeling, therefore, can be an effective way to reduce the cyanide content by at least 50% in cassava tubers. However, it should be noted that while the peel contains a high glucoside content relative to the pulp, the glucosidase level is higher in the latter.

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.

Grating also, obviously, provides a greater surface area for fermentation to take place.

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, 1978). A very significant reduction in total cyanide is achieved if the soaking water is routinely changed over a period of 3-5 days.

A variation to the soaking technique known as retting, was described by Ayenor (1985). This process involves prolonged soaking of cassava roots in water to effect the breakdown of tissue and extraction of the starchy mass. A simulation of the technique, followed by sundrying showed a reduction of cyanide of about 98.6% of the initial content in the roots.

Boiling/Cooking

As with soaking, the free cyanide of cassava chips is rapidly lost in boiling water. 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, 1978). Cooking destroys the enzyme linamarase at about 72^{0}C thus leaving a considerable portion of the glucoside intact.

Fermentation

Microbial fermentations have traditionally played important roles in food processing for thousands of years. Most marketed cassava products like "garri", "fufu", "pupuru", "apu" etc., in Africa are obtained through fermentation. The importance of fermentation in cassava processing is based on its ability to reduce the cyanogenic glucosides to relatively insignificant levels. Unlike alcoholic fermentation, the biochemistry and microbiology is only superficially understood, but it is believed that some cyanidrophilic/cyanide tolerant microorganisms effect breakdown of the cyanogenic glucoside. It has been shown that the higher the retention of starch in grated cassava the better the detoxification process. This could be attributed to the fermentative substrate provided by the starch. Also, the longer the fermentaion process the lower the residual cyanide content.

In Nigeria, investigation of the effect of fermentation period on the

residual cassava toxins is currently being carried out. As a preliminary stage, the use of starter cultures recovered from fermentation effluents is being tested to increase the conversion of substrate to product and reduce fermentation time.

However, Cooke and his co-workers using irradiated cassava found that mircroorganisms are not necessarily involved in the breakdown of cyanogenic glucosides. It is therefore clear that the effect of the microorganisms on cyanide detoxification requires further investigation.

Generally, fermented cassava products store better and often are low in residual cyanide content. Onabowale (1988) developed a combined acid hydrolysis and fermentation process at FIIRO (Federal Institute for Industrial Research, Oshodi, Nigeria) and achieved a 98% (approx.) reduction in total cyanide after dehydration of the cassava flour for use in the feeding of chickens.

A process, which can be described as "dry fermentation", is believed to occur in cassava peelings which are usually heaped for days, in many parts of Africa, before feeding to ruminants. The process generates heat and mould growth is common. However, the measurement of HCN losses during such a process has not been documented.

Ensiling

The ensiling process causes the disintegration of the intact glucoside via marked cell disruption, drop in pH of ensiled medium and intense heat generation.

Ensiled cassava roots have been used for livestock feeding. Gomez and Valdivieso (1988) reported that ensiling cassava chips reduced the cyanide content to 36% of the initial value after an ensiling period of 26 weeks. We have also found that about 98% of the free cyanide was lost by ensiling cassava roots with poultry litter for 8 weeks.

Drying

Since cassava root contains about 61% water, coupled with the solubility of its cyanogenic glucoside component, the dehydration (dewatering) process results in a substantial reduction in the content of this toxin in the

pressed pulp. Drying is carried out using solar radiation (sundrying) or Driers (electric or fuel) depending on economic viability. The process is achieved at varying temperature.

Work by the author has shown that sundrying:

(i) Results in a greater loss of total cyanide compared to laboratory oven-drying at 60°C for 48 hours. Oven-drying apparently affects the stability of linamarase which decomposes at 72°C.

(ii) Tends to produce greater loss of bound cyanide due to slower drying rate relative to oven drying.

(iii) Allows a longer contact period between the glucosidase and the glucoside in the aqueous medium. The effectiveness of enzyme/substrate interaction will, however, be dependent on the particle size and environmental factors such as ambient temperature, insulation, relative humidity and wind velocity. Thus proper sundrying is achieved in between 1-3 days in the dry season and in up to 8 days during the rainy season.

(iv) Facilitates the continuation of the fermentation process.

(v) Is cost effective, but slow and often encourages the growth of mould and other micro organisms including *Aspergillus flavus* (pathogenic), *A. fumigatus*; *A. cherahen*; *A. teirenus*; *A. flaripes*; *A. japonicus*; *A. niger*; *A. ochracuss*; and *Penicillium rubrum* (Clerk and Caurie 1968; Oke, 1978). This microbial growth can expose the consuming animal to aflatoxicosis and/or mycotoxic infection.

Because of the poor microbiological properties of sundried cassava products, there is a need for quicker drying methods which will reduce or eliminate microbial proliferation and ensure optimal cyanide detoxification.

An improvement in sundrying of cassava roots using inclined tray-drying instead of drying on concrete floors was reported by Gomez *et al.* (1984). The residual total cyanide content was 10-30% of the fresh sample, with about 60-80% of the cyanide in the dried chips occurring as free cyanide. The comparative advantage of this method could be due to good conductivity of the tray. Gomez *et al.* (1984) indicated that

more than 86% of HCN present in cassava was lost during sundrying. Bound cyanide which is less volatile can be a greater contributor to cyanide toxicity in sundried products than free HCN which vaporizes at about 28°C. yet the former is frequently unestimated though potentially toxic.

Table 1 shows the hydrocyanic acid content of cassava and its products used for livestock feeding.

TABLE 1. **Hydrocyanic acid content of Nigerian cassava and some products used for animal feeding (air dry basis)**

Cassava/Products	Hydrocyanic acid content (ppm)
Fresh whole root	88.3 - 416.3
Fresh pulp	34.3 - 301.3
Fresh peel	364.2 - 814.7
Sundried whole root	23.1 - 41.6
Sundried pulp	17.3 - 26.7
Sundried peel	264.3 - 321.5
Oven-dried whole root	51.7 - 63.7
Oven-dried pulp	23.7 - 31.3
Oven-dried peel	666.8 - 1250.0
Dried cassava waste (peels and discarded small tubers)	240.0

Source: Tewe and Iyayi (1989)

EFFECTS OF RESIDUAL TOXINS

Cassava toxicity

The cyanogenic glucosides were initially thought to be of little consequence to mammals as long as the cassava hydrolytic enzyme had been inactivated. However, the ingestion of high concentrations of cyanogenic glucosides from fresh cassava roots and leaves have been reported to be lethal in numerous species of animals. This was because the possibility of hydrolysis during digestion was not adequately understood, despite early reports that oral doses of pure linamarin produced physiological and biochemical changes in rats and chick embryos even in the absence of linamarase activity (Philbrick *et al.* 1977; Maduagwu and Umoh 1988).

The subject is now better understood. On excess consumption of unprocessed cassava there is the enzymatic breakdown of the glucoside releasing HCN and thereby causing poisoning.

Cassava toxicity may be acute and/or chronic. Acute toxicity results from ingestion of a lethal dose and death is caused by the inhibition of cytochrome oxidase of the respiratory chain by cyanide. This has been reported in goats ingesting cassava leaves (Obioha, 1972), and also in non-ruminants, like pigs, when fed fresh uncooked tubers.

The level of total HCN varies widely in cassava tubers, and death has been more common with the "bitter" varieties containing levels of HCN higher than 500ppm (Tewe and Iyayi, 1989). Where sub-lethal doses of cyanide are consumed, the inhibition of cellular respiration can be reversed by the removal of HCN by respiratory exchange or the detoxification process. The latter proceeds via many pathways, though probably the most important is the reaction of cyanide with thiosulphate to form thiocyanate and sulphite. The cyanide is initially trapped in the erythrocyte fraction of the blood and later converted to the less toxic thiocyanate.

Chronic cyanide toxicity on animals can affect both the growth and reproductive phases of development, each of which will be considered later.

It should be pointed out that, while the lethal dose has been estimated at between 0.5 and 3.5 mg/kg body weight or 30 and 210 mg for 60 kg

adult human, the lethal dosage for various animal species has not been established. Bolhuis (1954) classified the toxicity of cassava cultivars as follows:

(i) Innocuous: less than 50ppm fresh peeled tuber;
(ii) Moderately poisonous: 50-100ppm fresh peeled tuber;
(iii) Dangerously poisonous: more than 100ppm fresh peeled tuber.

A reclassification should take into consideration the potentially releasable, bound cyanide, and so correct the deficiency of that of Bolhuis, which assumed that all cyanide was available as free HCN.

Effect of chronic Cassava toxicity on the growth phase

The ingestion of fresh or processed cassava based diets causes reduced growth rates in rats, pigs, African giant rats, sheep and goats (Tewe *et al.*, 1977; Tewe and Maner, 1981; Tewe, 1983). The animals also have increased serum and urinary levels of thiocyanate, which is a continuous cause of depletion of sulphur containing amino acids (Tables 2 and 3). The thiocyanate also inhibits the intra-thyroidal uptake of iodine, causes an increase in secretion of thyroid stimulating hormone (TSH) and causes a reduction in thyroxine level which is necessary for growth. It is thus a goitrogenic factor, which was demonstrated by Tewe *et al.* (1984), who reported a significant reduction in serum thyroxine levels in growing pigs fed cassava peel diets containing 96 ppm total cyanide (Table 4).

In rats and pigs consuming inadequate amounts of protein and sulphur amino acids, the serum thiocyanate concentration becomes lower as the animals become unable to adequately detoxify cyanide. Additionally, this condition can also aggravate deficiencies in selenium, zinc, copper and vitamin A. Even with sufficient protein intake, consumption of cassava flour based rations can result in parakeratosis in pigs, attributable to zinc deficiency, aggravated by the cyanide in cassava diets. Other features include paralysis of the hind limbs and muscular weakness.

TABLE 2. **Performance and metabolic changes in African giant rats fed corn or processed cassava peel diets**

Parameters	Corn	Sundried peel	Oven-dried peel	Fermented peel
HCN content (ppm) of feed	0	130.2	595.2	42.5
Daily feed Intake (g)	28.45^{b}	27.70^{b}	31.25^{ab}	32.63^{a}
Daily weight gain (g)	10.97^{a}	9.02^{c}	9.43^{c}	10.30^{b}
Daily Cyanide Intake (mg)	0^{b}	1.80^{b}	9.30^{a}	0.69^{b}
Feed/gain ratio	2.59^{b}	3.07^{b}	3.32^{a}	3.18^{a}
Protein Efficiency Ratio	1.90^{a}	1.64^{b}	1.53^{b}	1.58^{b}
Nitrogen Retention %	70.63^{a}	64.50^{a}	56.09^{a}	55.97^{b}
Serum total protein (g. $100m^{-1}$)	6.12	6.00	5.97	5.97
Serum Urea (mg. $100ml^{-1}$)	92.18^{b}	1.53^{a}	114.65^{a}	97.12^{b}
Serum thiocyanate (mg. $100ml^{-1}$)	1.09^{b}	1.19^{b}	1.65^{a}	1.24^{b}
Urinary thiocyanate (mg. $100g^{-1}$ feed intake)	2.47^{c}	5.69^{b}	10.91^{a}	5.99^{b}
Liver thiocyanate ($mg.g^{-1}$ fresh weight)	0.41^{b}	0.39^{b}	1.18^{a}	0.39^{b}

a, b, c: means with different superscripts in horizontal rows are significantly different $P<0.01$).
Source: Tewe and Kasali, (1986).

TABLE 3. **Performance and metabolic changes in sheep and goats fed cassava/urea based rations containing varying elemental sulphur**

	% Dietary sulphur			
Parameters:	0%	0.25%	0.50%	0.75%
HCN (mg/kg)	247.0	246.0	248.0	247.0
Body Weight Change (%)	-75.0	-25.0	83.34	68.34
Ruminal NH_3N (mg/100ml)	2.45[a]	2.40[a]	0.75[a]	1.05[b]
Blood Urea (mg/100ml)	3.0	2.89[a]	2.49[ab]	1.91[b]
Urinary Thiocyanate (mg/100ml)	0.03	0.026	0.026	0.024
Serum Thiocyanate (mg/100ml)	0.035[a]	0.073[b]	0.060[b]	0.073[b]
Ruminal Thiocyanate (mg/100ml)	4.01	3.10	3.60	2.80

[a], [b] *Means without common superscript in horizontal rows are significantly different ($P<0.05$)*

TABLE 4. **Metabolic changes in pigs fed cassava peel based diets containing varying cyanide levels**

	Dietary variables		
	1	2	3
Total HCN (ppm)	0	96	400
Protein level %	20.19	20.42	20.12
Parameters:			
Serum thyroxine (T_4) (mg/dl)	4.47[a]	3.63[b]	3.32[b]
Serum total protein (g/dl)	6.9	6.9	6.9
Serum urea (mg/dl	24.0[a]	42.0[b]	47.0[b]

[a], [b] *means without common superscripts in horizontal rows are significantly different ($P<0.05$).*
Source: Tewe et al., 1984

In poultry, there are scant reports of toxicity due to cassava cyanide. However, depression in growth rates of broilers consuming cassava diets is common, and especially when a significant amount of the grain is replaced without proper protein supplementation. This observation is ascribed to a lower protein content in cassava and the extra need for sulphur amino acids. The author has shown, however, that the performance of poultry on cassava diets is satisfactory as long as the total HCN content in the final ration does not exceed 100 ppm. Such rations must however be nutritionally balanced, and in particular contain sufficient sulphur containing amino acids.

Effect of cassava chronic toxicity in the reproductive phase

Chronic cyanide toxicity appears to pose more problems with breeding stock as they remain on farms longer than growing animals. However, very few studies have been conducted in this area.

Studies carried out with gestating pigs (Tewe and Maner, 1981), showed that, when fed fresh cassava containing 0, 250 and 500 ppm cyanide, maternal and foetal serum thiocyanate levels only increased in those receiving the 500 ppm CN diet (Table 5). In this study a slight increase in the thyroid weight, with increasing levels of cyanide, was only observed, in pigs fed the two lower levels of CN, with definite pathological changes noted in the thyroids of those fed the 500 ppm CN diet.

Although the consumption of the cassava diet during gestation did not affect performance during lactation, milk thiocyanate and colostrum iodine concentrations were significantly higher ($P > 0.05$) in the animals fed diets containing the highest level of cyanide. Otherwise, the size of litters and weights of the young produced from pregrant rats and pigs fed on the various cassava diets were essentially normal.

Maner (1972) reported that a fresh cassava based diet had an identical nutritional value to a corn based diet fed gestating pigs. However, in this study the cassava fed sows, also maintained on pasture, had an increased still-birth rate and slightly inferior weight gains in post-lactation.

TABLE 5. **Influence of cassava-based rations fed during gestation, on metabolites and thyroid weight in gilts, fetuses, and suckling pigs**

	Dietary HCN level (ppm)		
	0	250	500
Gestating gilts			
Serum thiocyanate (mg/100 ml)	2.01	2.15	2.29
Serum protein bound iodine (mg/100ml)	3.1	3.2	3.1
Amniotic fluid thiocyanate (mg/100ml)	0.90	0.45	1.18
Thyroid (g/100 g body weight)	5.52	7.44	7.98
Fetuses			
Thyroid (g/kg body weight)	0.54[a]	0.36[b]	0.52[a]
Serum thiocyanate	0.85[b]	0.87[ab]	1.02[a]
Lactating sows			
Serum thiocyanate (mg/100ml)	0.74[ab]	0.58[b]	0.78[a]
Serum protein bound iodine (mg/100 ml)	3.2	3.6	3.7
Colostrum thiocyanate (mg/100 ml)	1.32	1.19	1.41
Milk thiocyanate (mg/100 ml)	1.15[b]	1.15[b]	1.35[a]
Colostrum iodine (mg/100 ml)	4.9[b]	6.0[b]	15.2[a]
Milk iodine (mg/100 ml)	0.7	1.0	0.07
Suckling pigs			
Serum thiocyanate (mg/100 ml)	0.63	0.50	0.78
Serum protein (g/100 ml)	6.61	6.38	5.86
Serum protein bound iodine (mg/100 ml)	4.7	4.9	4.9

Source: Tewe, 1983

Means followed by different superscripts, in horizontal rows, are significantly different ($P < 0.05$).

Studies have also been carried out at Obafemi Awolowo University, Ile-Ife, Nigeria on the reproductive performance of rabbits fed cassava based diets. These were carried out over three breeding periods and showed that the performance of pregnant and lactating does, were insignificantly different, from those receiving non cassava diets, in terms of litter size and birth and weaning weight of offspring (Omole and Onwudike 1982).

SUPPLEMENTAL VALUE OF NUTRIENTS

Protein and amino acids

The quantity and quality of protein supplementation in cassava based diets is critical, and especially with regard to the content of sulphur containing amino acids. Elemental sulphur as well as methionine supplementation have been reported to significantly improve protein utilization in pigs (Job, 1975). The requirement for sulphur-containing amino acid is for use in the rhodanase detoxification pathway.

Iodine and other dietary minerals

There are little or no reports of specific extra-requirements for other minerals in the diets of animals consuming cassava products. However, as already discussed, since thiocyanate resulting from cyanide detoxification competitively inhibits iodine uptake, there is a need for iodine supplementation to avoid the thyroid malfunctioning. Cyanide aggravation of selenium, zinc, and copper deficiencies also calls for the supplementation of cassava diets with these minerals.

Palm Oil

The use of palm oil has been shown to be of benefit when feeding cassava based diets. Omole and Onwudike (1982) found that when rabbits fed diets containing up to 50% of cassava peel meal, were supplemented with palm oil, their serum thiocyanate levels remained unaltered. The improved performance with feeding the palm oil was attributed to the increased calorie intake of the animals. Formunyan *et al.* (1981) also reported that the rate of hydrolisis of cyanogenic glucosides in cassava, to produce the toxic hydrogen cyanide, is greatly reduced in the presence

of palm oil. They suggested that this occurs because the supplemental oil delays the decomposition and therefore prevents the absorption of the cyanogenic glucosides.

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