Preparation of cassava leaf products and their use as animal feeds

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INTRODUCTION

The high protein content and nutritive value of cassava leaves are well documented. Cassava leaf yields amounting to as much as 4.60 tonnes dry matter per hectare may be produced as a by-product at root harvest (Ravindran and Rajaguru, 1988). The current practice, in most instances, is to return this valuable feed resource to the soil as a green manure. It is the intent of the present paper to review the available literature on the use of cassava leaves in animal feeding and, to examine their potential usefulness in animal production systems in the tropics.

Fresh cassava forage, including tender stems, could be utilized directly for ruminant feeding. For monogastric animals, however, the leaves should be processed into a dehydrated leaf meal. The review will also discuss methods of processing cassava leaves, with emphasis on the detoxification of hydrocyanic acid.

NUTRIENT COMPOSITION

Cassava leaves contain an average of 21% crude protein, but values ranging from 16.7 to 39.9% have been reported (Table 1). This wide variability is related to differences in cultivars, stage of maturity, sampling procedure, soil fertility and climate. Almost 85% of the crude protein fraction is true protein (Eggum, 1970).

The genetic variability that exists between cultivars in leaf protein content is suggestive of the potential response to selection and this appears to be a fruitful area for further research. Optimization of cultural practices such as fertilizer application may offer another means of increasing the protein content of cassava leaves.

Although cassava leaves are rich in protein, factors such as high crude fibre may limit its nutritive value for monogastric animals (Table 1).

TABLE 1.
Proximate composition and metabolizable energy values of cassava leaf meal and alfalfa meal

	Cassava leaf meal	Alfalfa meal[a]
Dry matter, %	93.0	93.1
Crude protein, %	21.0 (16.7-39.9)[b]	20.0
Crude fat, %	5.5 (3.8-10.5)	3.5
Crude fibre, %	20.0 (4.8-29.0)	20.0
Ash, %	8.5 (5.7-12.5)	10.5
Metabolizable energy (Kcal/kg) Poultry	1.80 (1.56-1.94)	1.63
Swine	2.16	2.03

[a] *Allen (1984)*
[b] *Values in parentheses refer to ranges reported in the literature*

TABLE 2. **Mineral contents of cassava leaf meal and alfalfa meal**

	CLM[a]	Alfalfa meal[b]
Macromineral, %		
Potassium	1.28	2.50
Calcium	1.45	1.50
Magnesium	0.42	0.32
Phosphorus	0.45	0.25
Sodium	0.02	0.08
Microminerals, mg/kg		
Zinc	149	19
Manganese	52	34
Iron	259	281
Copper	12	9

[a] *Ravindran and Ravindran (1988)*
[b] *Allen (1984)*

Stage of maturity is the major factor contributing to the variability in fibre content, but environmental and cultivar effects are also implicated (Rogers and Milner 1963).

Cassava leaves are good sources of minerals. They are particularly rich in Ca, Mg, Fe, Mn and Zn (Table 2). Cassava leaves are also rich in ascorbic acid and vitamin A, and contain significant amounts of riboflavin . But considerable losses of vitamins, particularly of ascorbic acid, occur during processing.

AMINO ACID COMPOSITION

Cassava leaf protein is deficient in methionine, possibly marginal in tryphtophan, but rich in lysine (Eggum 1970; Rogers and Milner 1963). Some variation in the amino acid content of leaves has been reported and may be attributed to differences in stage of leaf maturity, sampling procedures, analytical methods and ecological conditions. Yeoh and Chew (1976) observed that variation among cultivars grown under identical conditions was insignificant suggesting little, if any, genotypic variation with respect to amino acid content.

The changes in amino acid composition in relation to maturity of leaves has been studied by Ravindran and Ravindran (1988). As the leaves matured, the general trend was for the amino acid concentrations to decrease. Of the essential amino acids, lysine and histidine showed the greatest decrease. The essential amino acid profile of cassava leaf meal compares favourably with that of alfalfa meal (Table 3).

PROTEIN QUALITY

Eggum (1970), using rat bioassays, studied the nutritional availability of individual amino acids in cassava leaves. The availability of amino acids varied widely ranging from 55% for valine and isoleucine to 84% for serine. Only 59% of the methionine was biologically available, resulting in a low biological value of 49 to 57%. Supplementation with methionine improved the biological value to 80%. The low protein utilization values may be attributed to the high fibre content and the presence of condensed tannins in cassava leaves. Tannins are known to lower the protein digestibility and amino acid availability by forming indigestible tannin-protein complexes with dietary proteins and/or by inhibiting digestive enzymes.

TABLE 3. **Essential amino acid profile of cassava leaf meal and alfalfa meal (g/16 gN)**

	CLM[a]	Alfalfa meal[b]
Arginine	5.3 (4.0 -5.7)[c]	4.9
Lysine	5.9 (3.8 - 7.5)	4.4
Methionine	1.9 (1.3 - 2.0)	1.7
Cystine	1.4 (0.7 - 1.4)	1.2
Total sulphur amino acids	3.3 (2.0 - 3.3)	2.9
Tryptophan	2.0	2.3
Histidine	2.3 (1.1 - 2.5)	2.1
Isoleucine	4.5 (3.9 - 5.0)	4.9
Leucine	8.2 (7.2 - 8.9)	7.5
Phenylalanine	5.4 (5.3 - 5.4)	5.2
Threonine	4.4 (3.2 - 5.0)	4.4
Valine	5.6 (5.1 - 5.7)	6.0

[a] *Eggum (1970)*
[b] *Allen (1984)*
[c] *Values in parentheses refer to ranges reported in the literature*

PRODUCTIVITY OF CASSAVA LEAVES

The potential yield of cassava leaves varies considerably, depending on cultivar, age of plant, plant density, soil fertility, harvesting frequency and climate. Ahmad (1973), investigating the leaf DM productivity of two 12-month cultivars, reported yields of up to 7.5 t/ha. In this study, five leaf harvests were made at intervals of six weeks starting from three months after planting. Leaf harvesting, however, lowered the root crop yields by almost one-half of the normal. Normanha (1962) harvested 9.0 t DM/ha in two harvests over a two-year period and obtained less than a 30% reduction of the normal yield of roots.

The leaf DM yields are generally lower, if cassava leaves are to be obtained as a by-product at root harvest. Gomez and Valdivieso (1984), evaluating two 12-month cultivars, reported the leaf DM yields at root maturity to be only 1.2 - 1.8 t/ha. In contrast, Ravindran and Rajaguru (1988) obtained a much higher leaf DM yields of 4.64 t/ha. The higher yields in the latter study may be related to agronomic, climatic and soil fertility differences.

Leaf production can be enhanced by harvesting cassava leaves during the growing season, but this would adversely affect root yields. However, several studies now have demonstrated that it is possible to harvest cassava leaves while maintaining acceptable yields of roots. Ravindran and Rajaguru (1988) harvested 6.75 tonnes kg DM/ha by defoliating once during a seven-month growing season and obtained within 86% of the normal yields of roots. Dahniya *et al.* (1981) recommended a harvesting frequency of two to three months, starting from 4 months, for best all-round yields in 12-month cultivars. However, the variation that appears to exist among cultivars in their tolerance to defoliation needs be taken into consideration before making any recommendation of harvesting frequency.

When the cultivation of cassava is exclusively aimed towards leaf production, the plant density could be increased and the harvesting frequency can be shorter. Foliage can be harvested from 4 months of age in a cycle of 60 - 75 days. With adequate irrigation and fertilization, cassava plants can withstand this defoliation for several years (Montaldo 1977). Under such conditions, annual leaf DM yields of over 21 tonnes per hectare can be obtained. This corresponds to a possible production of about 4 tonnes of protein per hectare per year.

CYANOGENIC GLUCOSIDES

The cyanide content of cassava leaves has been extensively studied. The normal range of cyanide content is from 20 to 80 mg HCN per 100 g fresh leaf weight, but samples containing as low as 8 mg/100 g or over 400 mg/100 g have also been reported. On a dry basis (assuming 25% DM in fresh leaves), the normal range of HCN content would correspond to 800 to 3200 mg/kg. These levels are substantially higher than the normal range of HCN reported for fresh cassava roots.

The wide variations observed in leaf cyanide levels may be attributed to genetic, physiological, edaphic and climatic differences, but have been exaggerated by problems associated with methodology of cyanide assay. Stage of leaf maturity is perhaps a major factor causing variations in the cyanide content. As in other cyanogenic plants, the glucoside concentration in cassava leaves decrease with age. Cyanide levels in the leaves are also influenced by the nutritional status of the plant. De Bruijn (1973) reported that leaf cyanide levels were increased by fertilizer nitrogen, whereas potassium and farmyard manure had the opposite effect.

TANNINS

The presence of condensed tannins in cassava leaves presents ground for some concern (Reed *et al.* 1982). They are capable of forming indigestible complexes with protein, thus increasing the amino acid requirements of animals fed diets containing cassava leaf meal. The reported values for tannins in cassava leaves, however, are similar or lower to those of most plant leaves, including alfalfa, and are within safe limits if judiciously used for animal feeding.

HARVESTING

The appropriate harvesting method under the current practice of small-scale cassava production is to manually harvest the foliage by stem-pruning. The foliage, including tender stems, could be wilted, green-chopped and used directly for ruminant feeding. Alternatively, the leaves could be stripped, dried and ground into a meal. However, if large scale foliage production is envisaged, development of a mechanical harvesting device would be desirable.

PROCESSING

The existence of cyanogenic glucosides has made some form of processing a pre-requisitive for the use of cassava leaves in animal feeding. Several studies have demonstrated that it is possible to produce cassava leaf meal (CLM) with low cyanide levels (Gomez and Valdivieso 1985; Ravindran *et al.* 1987a). Simple sun-drying alone eliminates almost 90% of the initial cyanide content. When combined with chopping and wilting, cyanide in the dried meal was reduced to levels which are safer for monogastric animals (Table 4). This reduction is due to the action of endogenous linamarase on glucosides following loss of cell integrity (wilting) or tissue damage (chopping).The free tannin contents of cassava leaves are also considerably lowered during drying.

TABLE 4.
Hydrocyanic acid content (mg/kg dry matter) of cassava leaf meal as influenced by processing methods[a]

	Sun-drying	
Wilting (days)	Full leaves[b]	Chopped leaves[c]
0	173 (88.0)[d]	109 (92.4)
1	141 (90.2)	88 (93.4)
2	114 (92.1)	72 (95.0)
3	93 (93.5)	53 (96.3)

[a] *Ravindran et al. (1987a)*
[b] *Freshly harvested cassava leaves contained an average of 1436 mg HCN/kg dry matter*
[c] *Freshly harvested cassava leaves contained an average of 1045 mg HCN/kg dry matter*
[d] *Values in parentheses represent the reduction in HCN as a percentage of initial level in freshly harvested leaves*

From a practical point of view, sun-drying would be the method of choice in the developing countries of the tropics. Since sun-drying is entirely dependent on the weather, the duration of drying will vary considerably. In general, cassava leaves dry easily and drying is completed, to about 10-12% moisture content, in two days during dry, sunny weather. In a large scale operation, artificial heat-drying would be attractive. This will enable scheduling of drying independent of weather, but the capitol investment will be higher. However, artificial drying appears to be less effective in eliminating the cyanide than sundrying. A simple procedure of processing cassava leaf meal is outlined below.

1. Chopping - Leaves can be chopped manually or by means of a mechanical chopper. Leaves may also be bruised instead of chopping. Chopping not only increases cyanide elimination, but also shortens the drying time.
2. Wilting - Leaves need be wilted by spreading out in shade or in a room with cross-ventilation. Duration of wilting may vary from few hours to few days. Leaves must be turned over regularly to avoid fermentation and mould formation.
3. Drying - Wilted leaves should be uniformly distributed in the drying floor and turned over as necessary. Once 12% moisture level is reached, the dry leaves can be preserved either in the form of leaf meal or pellets. Processing has little influence on the crude protein content of the leaf meal (Ravindran *et al.*, 1987a).

STORAGE

Preliminary investigations indicate that CLM has excellent storage qualities. There was no moulding or insect infestation even after 8 - months of storage. Interestingly, the cyanide content declines during storage, but a gradual decline in the crude protein content was also observed (Ravindran *et al.* 1987a).

FEEDING VALUE FOR POULTRY

At low levels of inclusion, the feeding value of CLM for poultry is similar to that of dehydrated alfalfa meal. Ravindran *et al.* (1983) compared the performance of quails fed iso-nitrogenous diets containing 0, 2.5, 5.0, 7.5 and 10.0% levels of either CLM or dehydrated alfalfa meal. Gains were not significantly influenced by leaf meal inclusion, but feed intake and feed/gain were increased as the leaf meals were incorporated above 5% level. The performance of birds fed CLM and dehydrated alfalfa meal were similar.

Ross and Enriquez (1969), in a series of trials, investigated the possible use of CLM in corn-soybean meal diets for chicks. Progressive depression in performance was observed with increasing levels of CLM. However, supplementation of diets containing 20% CLM with methionine and energy resulted in performance comparable to the control .

Montilla *et al.* (1976) reported depression in gains and feed efficiency when CLM was included at 10, 20 or 30% levels in broiler rations. Cassava leaf meal was used to replace parts of the cottonseed meal, sesame meal and corn in the basal ration. The depressing effects were largely overcome by pelleting. Montilla (1977) concluded that CLM could be incorporated up to 20% level in pelleted broiler rations.

Wyllie and Chamanga (1979) found CLM to be a superior substitute for cottonseed meal in broiler rations. Replacement of cottonseed meal with 5 and 10% CLM resulted in significant improvements in gains. However, when CLM was substituted for sesame meal and sunflower meal the performance of broilers was poorer.

Ravindran *et al.* (1986) evaluated CLM as a substitute for coconut meal and concluded that up to 15% level can be used with satisfactory results. Broiler performance was depressed at higher levels. The reported values of metabolizable energy of cassava leaf meal for poultry (Table 1) are higher than those reported for alfalfa leaf meal and Leucaena leaf meal.

The available literature suggest that poultry producers in the tropics could benefit economically by incorporating low levels of CLM. It can play useful role as a source of protein, minerals, xanthophylls and unidentified growth factors for poultry. The unfavourable effects of high dietary levels of CLM are due to bulkiness, reduced energy intake and methionine deficiency. The roles of methionine as a methyl donor in tannin detoxification and as a source of labile sulphur in cyanide detoxification further aggravates its inherent deficiency in CLM. At high levels of inclusion, bulkiness is probably the major limiting factor and, in this context, pelleting may prove beneficial.

FEEDING VALUE FOR SWINE

Limiting published information exist regarding the use of CLM in swine feeding. Early studies of feeding fresh cassava leaves showed that palatability was depressed and growth performance was lowered with increasing proportions of leaves in swine rations (Mahendranathan, 1971). The adverse effects were evidently due to the high hydrocyanic acid levels in fresh leaves, since supplemental methionine and thiosulphate improved performance. Sarwat *et al.* (1988) found that inclusion of 15% fresh cassava leaves had no adverse effects on the performance of growing - finishing swine.

Ravindran *et al.* (1987b) evaluated CLM as a substitute for coconut meal. The results showed that CLM can replace up to 66 percent of coconut meal (26 percent of the total diet) in growing swine diets without adverse effects on performance. Most efficient gains were obtained at 33 percent replacement (13 percent of the total diet), suggesting that use of low levels of CLM feed formulations will permit greater savings in feed cost compared to higher levels.

Attempts to utilize CLM as a replacement for other protein supplements in swine diets have been less encouraging. Alhassan and Odoi (1982) reported depressions in gains and feed efficiency when CLM included at 20 and 30% levels in diets for growing - finishing swine. Cassava leaf meal was used to replace part of peanut meal, fish meal and corn in the basal ration.

Ravindran (1990) substituted 10, 20 and 30% CLM for a corn - soybean meal basal diet, and reported that the gains and feed efficiency of growing pigs were lowered linearly with increasing levels of leaf meal. The performance of pigs on diets containing 10% CLM was improved by methionine and energy supplementation.

There is unexplored potential for the use of CLM as a source of protein in breeder diets. Evidence suggest that energy in fibrous feedstuffs, such as alfalfa meal, are well utilized by sows.

USE OF CASSAVA FORAGE IN RUMINANT FEEDING

The low nutritive value of tropical grasses and roughages, commonly available for use in ruminant production systems for the tropics, highlights the need for low-cost supplementation to improve animal productivity. In this context, tree legumes such as Leucaena, Gliricidia and Sesbania are being promoted as protein supplements for livestock. Surprisingly, despite its availability and high protein content, there was little interest until recently to utilize fresh cassava forage in ruminant feeding. This reluctance is probably related to possibilities of cyanide toxicity. Today it is no longer necessary to make a case for the supplemental protein value of cassava foliage. An abundance of published data is available on this aspect.

Fresh cassava foliage is a satisfactory protein supplement, but it should be wilted before feeding and prudently used for good results. Wilting not only lowers potential cyanide toxicity, but also reduces the free tannin levels and improves its acceptability to animals. The supplementation value of cassava foliage is comparable to those reported for tropical tree legumes (Johnson and Djajanegara 1989). No adverse effects on performance have been reported even when higher levels of wilted cassava foliage were offered to goats and sheep. Cassava foliage could also be satisfactorily preserved as a silage and could be used as a dry season feed.

CASSAVA LEAF PROTEIN CONCENTRATE

Although the potential for the use of cassava leaves in the feeding of monogastric animals is great, factors such as high fibre and cyanide limit their use as a major source of protein. These limitations could be largely overcome if the protein is separated from the fibre and a protein concentrate is prepared by a juice extraction step and steam coagulation. Though cassava leaf protein concentrate contains a high level of crude protein (over 45%), good amino acid content and low resuidal cyanide, nutritional evaluation has shown poor animal performance. Clearly further research is needed to exploit this potential.

CONCLUSIONS

The most immediate prospects for the use of cassava leaf products are in the following areas:

1. Low level (5 - 10%) inclusion of cassava leaf meal in poultry and swine formulations. The type of ingredients generally used in tropical countries are very diverse and CLM could be easily accepted into this diversity. A commercial-scale process for the preparation of CLM has been outlined by Muller (1977). With experience, the possible use of moderately high levels of CLM may be considered particularly in layer and swine rations. Due to overpigmentation of carcasses, use of higher levels in broiler rations is not recommended.
2. Cassava forage as a supplement to low-quality roughages in ruminant feeding. It can be stated that today's knowledge of cassava leaves is equivalent to what was known about the alfalfa about 60 years ago. Many, if not most, of the advances made with regard to alfalfa utilization may have similar applications to cassava leaves. The task ahead is to solve the limitations, both biological and economical, that will allow the development of an acceptable system of cassava leaf production and utlization. In this context, the following research needs are emphasized:

(i) breeding or selection of cassava varieties which can be grown specifically for foliage production. The characters to be considered inter alia are forage yields, protein content, cyanide content, tannin content and ease of harvesting,

(ii) development of suitable agronomic practices to obtain high yields of forage with better nutritive value,

(iii) development of appropriate technology for the processing of CLM and pellets,

(iv) study effects of processing on the feeding value of CLM,

(v) study the possibility of using cassava leaf products in combination with the energy-rich roots,

(vi) study the economics of cassava grown only for leaf production and for production of cassava root/leaf combination, and

(vii) study market prospects for cassava leaf products.

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