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Changes in the Nutritional Composition of Cassava (*Manihot esculenta* Crantz) Leaves During Maturity

G. Ravindran[a] & V. Ravindran[b]

[a]Department of Food Science and Technology,
[b]Department of Animal Science,
University of Peradeniya, Peradeniya, Sri Lanka

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ABSTRACT

The nutritional composition, in vitro *organic matter digestibility (IVOMD) and anti-nutritive properties of cassava (*Manihot esculenta *Crantz) leaves were investigated at three stages of leaf maturity (very young, young and mature leaves). The crude protein and carbohydrate contents decreased with maturity, whereas all other proximal and fibre components increased.*

The mineral profile showed cassava leaves to be good sources of most minerals, particularly of calcium and trace minerals. The P and Na contents, however, were low. The values for K, Mg, P, Zn and Mn decreased with leaf maturity, while those for Ca, Na and Fe increased.

Cassava leaves were found to be rich in all essential amino acids, except methionine and phenylalanine. As the leaves matured, the tendency was for the amino acid concentrations to decrease. Only glutamic acid, proline and glycine contents increased, while those of valine and phenylalanine were unaffected.

The levels of phytic acid increased with leaf ageing, while tannin and hydrocyanic acid contents decreased. The nutritional significance of these anti-nutritive factors is discussed. The IVOMD values indicate the potential value of cassava leaves as a ruminant feed.

INTRODUCTION

Cassava (*Manihot esculenta* Crantz) is an all-season crop of the tropics where its starchy roots provide the staple food for over 500 million people

(Lancaster *et al.*, 1982). The cassava plant also produces a lush crop of leaves which are high in protein. While cassava leaves could play a significant role in improving the nutritional status of a tropical population (Terra, 1964), consumption of leaves is not as widespread as that of roots. The lack of tradition in consuming the leaves is evidently related to the presence of hydrocyanic acid (HCN).

Several studies have documented the proximate composition (Rogers, 1959; Rogers & Milner, 1963; Ramos-Ledon & Popenoe, 1970; Yeoh & Chew, 1976), amino acid profile (Eggum, 1970; Ravindran *et al.*, 1982; Rogers & Milner, 1963), and mineral content (Ravindran *et al.*, 1982) of cassava leaves, but in none was the nutritional composition elucidated in relation to the maturity of leaves. Rogers (1959), who analyzed 50 cultivars, found a range of 20·6% to 30·4% crude protein on a dry matter basis. In a subsequent study, involving 20 cultivars, Rogers & Milner (1963) reported an even greater variability of 17·8% to 34·8%. While part of this variability may reflect cultivar differences, it is probable that sampling procedures, particularly sampling of leaves at different stages of maturity, may also have contributed to the observed differences. The present series of investigations was undertaken to study the effects of maturity on the proximate composition, amino acid profile, mineral contents and levels of anti-nutritional factors of cassava leaves.

Due to the escalating costs of traditional feedstuffs, there has recently been a strong upsurge of interest in the use of cassava leaves as a livestock feed. For this reason, an extended evaluation was made of the fibre composition and *in vitro* organic matter digestibility (IVOMD) in cassava leaves of different maturity.

MATERIALS AND METHODS

Sampling and preparation of samples

An early maturing local variety of cassava (MU 22) was planted during October, 1983 at the experimental unit of the Department of Animal Science, University of Peradeniya. The plots received a basal application of one tonne of poultry litter per hectare (equivalent to 52 kg N, 36 kg P_2O_5 and 35 kg K_2O per hectare) at planting. No fertilizers were applied thereafter. The rainfall during the study period (October, 1983–June, 1984) was 1512 mm and was well distributed. Three months after planting, thirty plants were randomly selected and the uppermost eleven leaves were stripped. The leaves, with petioles, were then bulked into samples of different maturities. This was followed by two more samplings at two-monthly intervals.

To obtain more reliable data, the study was repeated with another crop of

cassava planted during August, 1985. The cultural practices employed during the second study period (August, 1985–April, 1986) were similar to those of the first crop, and the climatic conditions were also remarkably similar.

The leaves were initially sun-dried and subsequently dried in a unitherm oven at 60°C for 24 h. The dried samples were ground and stored in air-tight containers prior to chemical analysis.

Analysis of samples

Proximate analyses were performed according to standard methods. (Association of the Official Analytical Chemists (AOAC) 1970). The carbohydrate content was calculated by the difference method. Food energy was determined using a Gallenkamp ballistic bomb calorimeter.

The samples were ground to pass through a 40-mesh screen and analyzed for acid detergent fibre (ADF), permanganate lignin and cellulose according to the procedures of Goering & Van Soest (1970). Neutral detergent fibre (NDF) was determined using the modified method of Robertson & Van Soest (1977). Hemicellulose was calculated as the difference between ADF and NDF.

Mineral analyses were carried out on samples digested with perchloric and nitric acids. Phosphorus was determined colorimetrically using ammonium vanadate (Chapman & Pratt, 1961). All other minerals were determined using an atomic absorption spectrophotometer (Perkin Elmer 2830).

The amino acid analysis of the acid-hydrolyzed samples was done using an automatic amino acid analyzer (Model TSM, Technicon Instruments, New York). The sulphur-containing amino acids were determined by oxidation with performic acid according to the procedure of Moore (1963).

The HCN contents of fresh cassava leaves were determined by a modified alkaline titration method (AOAC, 1970). In the modified method, the final titration of the distillate is carried out with N/50 sodium thiosulphate using 1 ml iodine and a drop of starch as the indicator. Phytic acid was estimated by the colorimetric method of Wheeler & Ferrel (1971) as modified by Reddy *et al.* (1978). The tannin was determined by the vanillin-HCl reagent method described by Swain & Hillis (1959).

The IVOMD valves were estimated in triplicate using the two-stage technique of Tilley & Terry (1963). The *in vitro* procedure utilized 0·5 g of leaf material for a 48 h rumen fluid digestion, followed by a 48 h acid pepsin digestion. The rumen liquor for the estimations was obtained from three ruminally fistulated cattle which had been fed a mixture of tree fodder leaves and straw for ten days.

RESULTS AND DISCUSSION

The proximate and fibre compositions of cassava leaves, as influenced by the stage of maturity, are presented in Table 1. The crude protein and carbohydrate contents decreased with maturity, whereas other proximal and fibre components increased. Similar trends have been reported with other plant species (Gohl, 1981), but the present results show a more pronounced effect, probably because of a more specific separation of leaf maturity. The crude fibre contents increased from 8·3% in very young leaves to 27·4% in mature leaves.

The crude protein content decreased from 38·1% in very young leaves to 19·7% in mature leaves. These values fall within the ranges reported for cassava leaves in the literature (Rogers, 1959; Rogers & Milner, 1963; Ramos-Ledon & Popenoe, 1970). The protein contents, which are high for a non-legume, demonstrate the potential usefulness of cassava leaves as a source of protein in the tropics. The values obtained are comparable with, or superior to, those reported for many other edible tropical leafy vegetables (Oke, 1968; Ezeala, 1985; Kailasapathy & Illeperuma, 1985). Based on the protein content, even the mature leaves could play a significant role as a

TABLE 1
Proximate and Fibre Composition of Dehydrated Cassava Leaves as Influenced by Stage of Maturity in Per Cent Dry Weight[a]

	Very young leaves[b]	*Young leaves*[c]	*Mature leaves*[d]
Moisture (wet weight)	89·1 ± 0·6	82·6 ± 0·8	79·4 ± 0·6
Food energy (kcal)[e]	452	464	478
Crude protein	38·1 ± 1·5	28·6 ± 0·9	19·7 ± 0·9
Crude fat	3·8 ± 0·5	5·9 ± 0·7	6·8 ± 0·4
Crude fibre	8·3 ± 0·8	16·4 ± 0·4	27·4 ± 0·6
Ash	4·0 ± 0·2	5·5 ± 0·6	7·9 ± 0·3
Carbohydrate	45·8 ± 0·9	43·6 ± 1·0	38·2 ± 1·4
Neutral detergent fibre	18·1 ± 0·6	32·0 ± 2·1	46·3 ± 0·9
Acid detergent fibre	9·0 ± 0·5	17·2 ± 0·6	30·3 ± 0·6
Hemicellulose	9·1 ± 0·2	14·8 ± 1·7	16·0 ± 0·5
Cellulose	8·4 ± 0·5	13·3 ± 0·6	22·1 ± 0·7
Lignin	0·9 ± 0·06	4·1 ± 0·2	8·4 ± 0·3

[a] Mean of six samples ± standard error.
[b] Leaf number 1–4 from the apex (expanding leaves).
[c] Leaf number 5–7 from the apex (just fully expanded leaves).
[d] Leaf number 8–11 from the apex.
[e] Mean of two samples.

protein source but high crude fibre levels (27·4%) make them more useful in livestock feeding rather than in human nutrition.

Food energy tended to increase with maturity (Table 1). The actual utilizable energy may, however, be lower in mature leaves because of the high fibre content. High levels of fibre are known to dilute nutrient concentration and to adversely affect nutrient utilization (Monte, 1981; Spiller & Shipley, 1977). Rajaguru & Ravindran (1985) reported that only 42% of the food energy contained in mature cassava leaves is metabolized by poultry. But it is noteworthy that fibre levels in mature cassava leaves could be lowered to about 17·1% by discarding the petioles (Ravindran, 1985).

Cassava leaves were found to be rich sources of most minerals, especially of Ca and microminerals (Table 2). The mineral profile of cassava leaves compares closely with those reported for other tropical leafy vegetables, but the P contents were lower (Oke, 1966). The contents of K, Mg, P, Zn and Mn decreased with leaf maturity, while those for Ca, Na and Fe increased. Calcium showed the most change, the values increasing from 0·43% in very young leaves to 1·14% in mature leaves.

The high content of K and low content of Na in cassava leaves need special mention. It appears that the cassava leaves preferentially accumulate K than Na. A similar phenomenon has been observed in *Amaranthus caudatus*, a tropical leafy vegetable (Ezeala, 1985).

TABLE 2
Mineral Composition of Cassava Leaves as Influenced by Stage of Maturity[a]

	Very young leaves	*Young leaves*	*Mature leaves*
Macrominerals (g/100 g dry weight)			
Potassium	2·26 ± 0·03	1·85 ± 0·04	1·38 ± 0·02
Calcium	0·43 ± 0·006	0·96 ± 0·01	1·14 ± 0·03
Magnesium	0·37 ± 0·004	0·31 ± 0·003	0·26 ± 0·004
Phosphorus	0·23 ± 0·004	0·20 ± 0·002	0·18 ± 0·002
Sodium	0·08 ± 0·002	0·11 ± 0·003	0·12 ± 0·003
Microminerals (mg/100 g dry weight)			
Zinc	20·9 ± 0·4	17·2 ± 0·4	16·4 ± 0·3
Manganese	24·0 ± 0·3	15·9 ± 0·3	15·9 ± 0·6
Iron	15·2 ± 0·1	24·4 ± 0·3	26·6 ± 0·3
Copper	3·9 ± 0·04	4·6 ± 0·04	4·0 ± 0·05

[a] Mean of six samples ± standard error.

The amino acid profile confirms the earlier suggestions (Eggum, 1970; Rogers & Milner, 1963) that cassava leaves could play a useful role in alleviating the protein malnutrition prevalent in tropical regions. The results, in general, show the cassava leaves to be rich in most essential amino acids (Table 3). Reports so far have indicated sulphur-containing amino acids to be the most limiting ones in cassava leaves (Eggum, 1970). A comparison of the present results with the FAO/WHO (1973) scoring

TABLE 3
Amino Acid Composition of Cassava Leaf Protein as Influenced by Stage of Maturity (g/16 g N)[a]

	Very young leaves	*Young leaves*	*Mature leaves*
Aspartic acid	10·9	10·7	7·6
Threonine	5·0	4·5	3·2
Serine	5·7	4·4	3·3
Glutamic acid	10·1	12·1	13·2
Proline	3·7	5·0	5·8
Glycine	4·7	5·7	12·1
Alanine	6·3	5·7	3·2
Valine	5·7	5·5	5·1
Cystine[b]	1·2	1·0	0·7
Methionine	2·0	1·8	1·3
Isoleucine	5·0	4·4	3·9
Leucine	8·2	8·9	7·2
Tyrosine	4·6	4·0	2·8
Phenylalanine	5·3	5·4	5·4
Lysine	7·5	5·6	3·8
Histidine	2·5	2·5	1·1
Arginine	5·7	4·2	4·0
Tryptophan[c]	—	—	—

[a] Mean of two determinations.
[b] Half cystine.
[c] Not determined.

pattern also confirms that sulphur-containing amino acids are the most limiting and that they become more critical as the leaves mature. The results suggest that phenylalanine is the second limiting amino acid in cassava leaves. Owing to its destruction during acid hydrolysis (Blackburn, 1968), the tryptophan content was not estimated in the present study. Rogers & Milner (1963) reported that cassava leaves are possibly marginal in tryptophan.

As the leaves matured, the general trend is for the amino acid concentrations to decrease. Only the non-essential amino acids, glutamic acid, proline and glycine, increased, while valine and phenylalanine were

unaffected. Of the essential amino acids, lysine and histidine showed the most decrease.

Most developing countries use cereals as their major food items and these are generally deficient in lysine and threonine (FAO, 1972). When judiciously used as a supplement, young cassava leaves can improve the protein quality of cereals owing to their high content of lysine and threonine (Table 3).

The phytic acid P and phytic acid contents increased with leaf maturity (Table 4). However, the levels obtained are much lower when compared to the range of 0·40 to 2·06% reported for cereals and food legumes (Reddy *et al.*, 1982) and are too low to be of any nutritional significance.

TABLE 4
Levels of Some Anti-nutritional Factors Present in Cassava Leaves

	Very young leaves	*Young leaves*	*Mature leaves*
Phytic acid P (mg/100 g dry weight)[a]	28	42	47
Phytic acid (mg/100 g dry weight)[a,b]	100	150	170
Tannins (g/100 g dry weight)[a]	1·35	0·59	0·24
Hydrocyanic acid (g/100 g fresh weight)[c]	0·44 ± 0·02	0·29 ± 0·01	0·16 ± 0·01

[a] Mean of two determinations.
[b] Calculated phytic acid content, assuming 28·2% phosphorus in the molecule
[c] Mean of six determinations.

The tannin contents decreased with the ageing of leaves (Table 4). Tannins, particularly the condensed types, are known to lower protein digestibility by forming indigestible tannin–protein complexes and/or by inhibiting enzyme activities (Price & Butler, 1980). Reed *et al.* (1982) implicated the presence of condensed tannins for the low protein digestibility of cassava leaf blades, but this hypothesis is yet to be verified. It is also relevant to note that the vanillin assay employed in the present study does not detect such complexed tannins (Deshpande & Cheryan, 1985). In any case, based on available information (Deshpande *et al.*, 1984), the levels of tannin found in young and mature cassava leaves may be considered safe in human nutrition.

The decrease in HCN content with leaf maturity is in accordance with the results of several workers (de Bruijn, 1973; Williams, 1979). The HCN levels

obtained (Table 4) fall within the range of 0·17–0·62 g/100 g fresh weight reported by Chew (1972). Although fresh cassava leaves contain high levels of HCN, available literature suggests that considerable detoxification can be achieved by simple processing methods. The most common way of preparing cassava leaves for human consumption is by pounding or chopping, followed by boiling for several hours (Lancaster & Brooks, 1983). In Sri Lanka, young leaves are chopped, washed in water, mixed with ingredients such as coconut scrapings, onion, chillies and spices, and fried in oil. Chopping cassava leaves prior to cooking makes the elimination of HCN effective (Williams, 1979).

Although it has been stated that simple boiling or cooking is sufficient to remove cyanide completely (Johnson & Raymond, 1968), an extensive review on this aspect reveals that small residual amounts of cyanide always persist (Lancaster & Brooks, 1983). Gondwe (1974) reported that boiling the leaves for one hour lowered the cyanide content to 5 mg per 100 g. Charavanapavan (1944) found that, even after chopping and boiling the leaves in two changes of water for 15 min, the product contained about 5 mg HCN per 100 g. Medical studies have shown that these levels may not be entirely harmless and continued ingestion of low levels of cyanide over a prolonged period may result in chronic cyanide toxicity as manifested by tropical ataxic neuropathy, goitre and cretinism (Dorozynski, 1978; Ermans *et al.*, 1980; Osuntokun, 1973).

Dehydrated cassava leaf meal may have potential in animal feeding. Simple drying of cassava leaves has been reported to eliminate almost 90% of the HCN (Ravindran, 1985). The IVOMD values presented in Table 5 confirm the feeding value of cassava leaves for ruminants. The values for even the mature leaves are comparable with, or superior to, those of most available tropical forages (Gohl, 1981).

The present results, in general, highlight the role that young cassava leaves can play as sources of protein and minerals in human nutrition in the tropics. Cassava leaves are also good sources of vitamin C (Caldwell, 1972), vitamin

TABLE 5
Percentage *in vitro* Organic Matter Digestibility of Cassava Leaves (dry matter basis)[a]

Leaf type	% in vitro *organic matter digestibility*[a]
Very young leaves	72·6 ± 0·4
Young leaves	70·1 ± 0·3
Mature leaves	65·7 ± 0·7

[a] Mean of six samples ± standard error.

A (FAO, 1972) and riboflavin (Caldwell & Enoch, 1972). Owing to their high fibre content, the mature leaves are probably more useful as an animal feed. It is interesting to note that the nutrient composition of mature cassava leaves compares well with that of lucerne meal (Allen, 1984), an animal feedstuff widely used in temperate regions.

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