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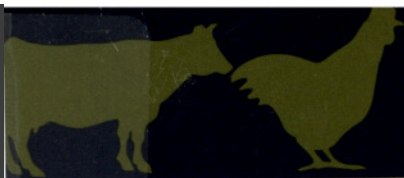

CASSAVA AS ANIMAL FEED

Proceedings of a workshop held at the University of Guelph 18-20 April 1977

Sponsored by the International Development Research Centre and the University of Guelph

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Contents

Additives Other than Methionine in Cassava Diets

R. I. Hutagalung[1,2]

The problems of nutritional insufficiencies and metabolic diseases associated with feeding cassava-based diets and the roles of feed additives intended to alleviate these are discussed. Improvements in the nutritive value of cassava-based diets with feed additives can be made through: (1) adjustments in the energy (nutrient) density by adding fats or oils, sugars, or molasses and balancing the source and level of protein, amino acids, minerals, vitamins, and pigments; or (2) enrichment by microbial fermentation. The primary consideration in the improvement of cassava products through either feed additive fortification or microbial enrichment should be the economic feasibility of substitution with conventional feedstuffs and their safety for animal feeds, and the suitability of the subsequent animal products for human consumption.

Cassava (*Manihot esculenta*) has been widely used as a feedstuff and provides a major source of energy for livestock in Asia, Africa, Europe, and South America (Nestel 1975). However, numerous research findings and field reports have indicated that its extensive use in poultry and swine feeds has encountered some nutritional problems and diseases, including: its low protein, mineral, and vitamin content (Table 1); variation in HCN content resulting in acute and chronic toxicity, i.e., ataxic neuropathy; suspected goitrogenic substances causing iodine deficiency (goitre); reduction in availability of certain mineral elements resulting in zinc parakeratosis in pigs; low palatability due to dry texture, high ash, and crude fibre content causing poor digestibility and diarrhea; enzyme-inhibiting factors causing poor absorption of vitamins and minerals; poor performance and lack of skin and egg yolk pigmentation; and contamination by pathogenic microorganisms causing aflatoxicosis (Hutagalung and Tan 1976). Nevertheless, these problems are not confined only to feeding of cassava but they have been encountered in feeding other feedstuffs, such as rice bran, soybean, and cottonseed meal.

Within the last decade, efforts have been made by various workers to overcome these problems and to improve the nutritive value of cassava by investigating the effects of supplementation of nutritive and nonnutritive feed additives to cassava-based diets. These additives include: source and level of energy and protein, synthetic amino acids, minerals, vitamins, antibiotics and antifungals, pigments, flavouring agents, hormones, and enzymes.

To cover such a wide range of subjects is a difficult one. Moreover, conflicting results from animals given diets containing high levels of cassava present problems of interpretation. It is hoped that from this workshop a uniform guideline for animal nutritionists to assess accurately the nutritional value of cassava products can be formulated. Likewise, standard specifications for the cassava products should be adopted to ensure valid comparisons can be made from different localities.

Nutritive Feed Additives in Cassava-Based Diets

Energy

Energy required by livestock for growth of body tissues, production of eggs, performance of vital physical activities, and maintenance of normal body temperature, is derived from carbohydrates, fats, and protein in the diet. The most efficient nutrition of livestock is obtained when the diet contains the exact proportion of energy to other nutrients required to produce the desired growth, meat, milk and egg production, or body finish. The energy level of the diet appears to be the most important factor determining feed intake. The nutritionist must consider energy in terms of the digestible starch, sugars, fats, and protein in the feedstuff and must consider how processing of the ingredients, balancing of the diet, and addition of special supplements such as antioxidants or enzymes may aid in providing the animals with the maximum amount of usable energy. Scott et al. (1969) stated that in diets containing adequate amounts of all required nutrients, the efficiency of feed utilization depends upon the metabolizable energy content of the diet.

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[2]The author acknowledges the assistance of IDRC for the travel grant sponsorship to attend and present this paper.

Table 1. Proximate analysis and amino acid composition of cassava roots and leaves (Hutagalung et al. 1973).

	Leaves	Roots
Proximate analysis[1]		
Dry matter	90.00	89.00
Ash	5.50	1.60
Crude fibre	15.90	2.70
Ether extract	6.30	1.20
N-free extract	37.30	81.20
Protein (N × 6.25)	25.00	2.30
Gross energy (kcal/g)	5.30	4.20
Calcium	1.40	0.35
Phosphorus	0.25	0.40
Copper (mg/kg)	8	—
Iron (mg/kg)	450	8
Manganese (mg/kg)	46	18
Zinc (mg/kg)	28	—
Amino acids[2]		
Arginine	1.48	0.29
Histidine	0.66	0.07
Isoleucine	1.67	0.03
Leucine	2.72	0.31
Lysine	1.87	0.07
Methionine	0.36	0.03
Phenylalanine	0.92	0.03
Threonine	1.35	0.03
Tryptophan	0.24	—
Valine	0.99	0.04
Alanine	1.70	0.15
Aspartic acid	2.44	0.13
Cystine	0.21	0.01
Glutamic acid	1.99	0.15
Glycine	1.73	0.01
Proline	0.88	0.03
Serine	1.68	0.04
Tyrosine	0.89	0.01

[1]Expressed as percentage or unit of "as fed" sample.
[2]Expressed as percentage of air dry sample.

Addition of fats to a nutritionally complete diet often produces a slight increase in growth and always improves efficiency of feed utilization in monogastric animals. This is due to the higher caloric density of the fat-containing diet. However, benefits from fat alone can be obtained when amounts of all other nutrients in the diet are increased in proportion to the increase in energy level.

Several workers have reported that a higher level of cassava root supplement in diets of poultry and pigs depresses growth and feed efficiency (Oyenuga 1961; Castillo et al. 1964; Enriquez and Ross 1967; Olson et al. 1969a,b; Hew and Hutagalung 1972; Müller et al. 1972). Similar reports have been made on the supplementation of a large concentration of cassava leaves in rat, chick, and pig diets (Rogers and Milner 1963; Terra 1964; Ross and Enriquez 1969; Adrian and Peyrot 1970; Eggum 1970; Lee and Hutagalung 1972; Hutagalung et al. 1973, 1974). The reasons given for this growth depression, apart from the HCN content are: powdery characteristic of the roots; dry and loose texture of leaves; bulkiness of both leaves and roots; high ash content of the roots; and high crude fibre content of the leaves.

Growth depression of animals fed cassava-based diets was corrected by the addition of fats and oils (Hutagalung 1972; Hew and Hutagalung 1972; Lee and Hutagalung 1972). Fats and oils have been used extensively as sources of energy for feeding livestock. Within the last decade Malaysia imported substantial amount of fats (tallow and lard) from other countries (USA, Australia, New Zealand) as feed ingredients. However, in view of the high cost of these imported fats, the feed manufacturers have substituted these with local sources such as crude palm oil and one of its by-products stearin. Studies in pigs and poultry on the use of palm oil and stearin as an energy source have shown favourable responses in rate of gain and feed efficiency (Hutagalung 1972; Ng and Hutagalung 1974; Hutagalung and Chey 1975; Hutagalung and Chang 1977a,b). In terms of energy and digestibility, palm oil is superior to fats of animal origin (Table 2). The energy values of the roots and leaves have been evaluated (Hutagalung et al. 1973; Müller et al. 1974) (Table 3).

The improved performance of animals fed palm oil may be attributed to the increased energy intake. Faster rate of gain was obtained from the addition of palm oil up to 8% to the cassava or sago diet, beyond which a plateau occurred (Hew 1975).

Various sources and levels of fats and oils have been added to cassava-based diets. Supplementation of 5% palm oil to the 50% cassava-0.2% methionine diet improved the performance of pigs (Hew and Hutagalung 1972). Hutagalung and Chang (1977b) studied the effects of palm oil, stearin, lard, and tallow addition to a cassava-based diet on the performance and carcass quality of growing and finishing pigs. Supplementation of either palm oil or stearin within the range of 5–10% to a 30% cassava-based diet significantly improved the rate of gain and feed efficiency of pigs compared with those on the basal and the lard

Table 2. Nutritive value of animal fats and vegetable oils (NRA 1974).

	Melting point (°C)	Digestibility (%) in monogastrics	ME (kcal/g) in monogastrics	Avg. fatty acid content (%) Saturated	Unsaturated	Linoleic acid
FGAF[1]	34–38	93	8.75	44	56	10
Lard	32–38	94	8.85	36	64	12
Poultry fat	28–35	96	9.00	28	72	25
All beef tallow	38–42	84	7.80	56	44	2
Palm oil	28–36	96	8.90	42	58	10

[1]Feed Grade Animal Fats are mixtures of poultry fat, lard, and beef tallow.

Table 3. Metabolizable energy values (ME, kcal/g) of cassava leaves and roots for livestock (on a dry matter basis).

	Roots	Leaves
Poultry[1,2]	3.23–3.65	1.59
Swine[1,2]	3.55–3.80	1.68
Sheep[2]	3.07	—
Cattle[2]	3.25	—

[1]Hutagalung et al. (1973, 1974); Hew (1975).
[2]Muller et al. (1974).

or tallow cassava-based diets. Carcass quality evaluation showed that palm oil or stearin addition at 5% to cassava-based diets produced better carcass quality compared with those on basal, lard or tallow supplemented diets (Table 4). Fatty acid composition of the tissues was studied and the results are being analyzed. Devendra and Hew (1977) fed pigs varying levels of palm oil (0, 5, 10, 20, 25, 30%) in diets containing cassava-root meal ranging from 10 to 24%. They found no apparent differences in rate of gain and feed efficiency due to levels of palm oil and cassava. With such a wide range of palm oil addition, carcass characteristics were not affected by either palm oil or cassava, even at the 30% palm oil level, except that the iodine value increased with increasing levels of palm oil supplementation. However, they suggested that the optimum level of palm oil inclusion in the cassava-based diet of pigs was 5%. Shimada et al. (1971) studied the effect of corn oil (0 vs. 3%) supplementation to cassava-based diets (30 vs. 60% cassava) in growing pigs. Supplementation of oil to cassava-based diet with or without methionine improved rate of gain and feed efficiency of pigs. Addition of corn oil was more effective in rate of gain and feed efficiency of pigs given diets containing a higher percentage of cassava. Fat from the carcasses of pigs fed cassava-soybean diets had a lower iodine number than those fed maize-soybean diets.

Using fat of animal origin, Maner (1974) reported that supplementation of 10% beef tallow to 55% cassava-meal diets of growing pigs with 0.1% methionine gave faster and more efficient feed conversion than those given cassava-based diets containing 0.1% methionine and cassava-based diets containing 0.2%

Table 4. Effect of levels of palm oil, stearin, lard, and tallow in 30% cassava-root based diets on the performance and carcass quality of growing and finishing pigs (Hutagalung and Chang 1977).

	Basal diet	Palm oil 5%	Palm oil 10%	Stearin 5%	Stearin 10%	Lard 5%	Lard 10%	Tallow 5%	Tallow 10%
Avg. daily gain (kg)	0.55	0.60	0.61	0.62	0.62	0.57	0.60	0.55	0.59
Avg. daily feed (kg)	1.62	1.80	1.68	1.90	1.71	1.84	1.78	1.91	1.82
Feed/gain	2.95	3.00	2.76	3.06	2.75	3.23	2.96	3.47	3.09
Dressing (%)	79.77	79.84	78.20	79.48	80.31	80.93	78.25	81.19	77.95
Carcass length (cm)	69.90	69.58	71.91	71.34	69.60	71.12	70.13	70.49	68.20
Backfat (cm)	2.34	2.27	2.40	2.33	2.38	2.37	2.57	2.35	2.50
L. dorsi area (cm^2)	28.2	29.5	29.3	27.9	29.0	28.6	27.8	28.0	26.5
Iodine number	58.1	59.3	61.0	59.0	60.8	57.6	52.7	53.6	54.3

methionine with no tallow added (daily gain: 0.85 vs. 0.80, 0.82 kg; feed/gain: 2.24 vs. 2.35, 2.47). It is interesting to note that addition of 0.2% methionine to 10% tallow-cassava-based diets did not improve gain or feed/gain of pigs compared with a similar diet without added methionine (0.74 vs. 0.85 kg; feed/gain 2.21 vs. 2.24).

Studies on the effects of fat and sugar supplementation in cassava-based diets showed that this combination was more effective in overcoming the growth depression. Montilla et al. (1975) supplemented 2% animal fat and 9% molasses to diets containing either 30% bitter or sweet cassava meal. They found that addition of fat and molasses to the 30% cassava-based diet did not improve rate of gain and feed efficiency of chicks, except in the diets with low cassava content. Palm oil (5%) and glucose (2%) addition to diets containing 50% cassava and 0.2% methionine further improved the performance of pigs compared with those on cassava-methionine diets without palm oil (Hew and Hutagalung 1972). Similar results were obtained with chicks by feeding 3.7% soybean oil and 4% molasses with the 50% cassava-based diet containing methionine, but not with cassava-based diet without added methionine (Enriquez and Ross 1967).

Ross and Enriquez (1969) reported that addition of both soybean oil and molasses to methionine-supplemented cassava leaf diet had no effect on gain and feed conversion of chicks. Supplementation of sucrose alone to the cassava-leaf diet of rats in an attempt to improve feed intake was not successful (Rogers and Milner 1963). On the other hand, molasses or palm oil added to the cassava-leaf diet improved rate of gain and feed efficiency of pigs. This improvement was accentuated by the addition of methionine (Lee and Hutagalung 1972; Hutagalung et al. 1973, 1974). Oke (1966) reported that addition of glucose to unprocessed cassava root meal caused the HCN to disappear.

Data on the carbohydrate composition and enzyme properties of cassava are rather limited. Lira and Fernandez (1962) reported that cassava flour has a high starch content that highly favours tryptic digestion. Johnson and Raymond (1965) indicated that cassava flour is mainly a polyglucose carbohydrate containing 20% amylose and 70% amylopectin. The amylolytic activity (amylase) of cassava root meal is about one-third of that in maize and about one-half of that in rice bran (Müller et al. 1974, 1975a). However, no data were given to substantiate this amylase activity. The detailed study of enzyme activity, and the carbohydrate and fatty acid composition of cassava roots and leaves in the fresh and dry condition are worthy of consideration for accurate assessment of their nutritive value.

Because cassava-based diets are low in fat, it has been suspected that essential fatty acids are limiting. Müller et al. (1975b) indicated that supplementation of essential fatty acids (by 2% peanut oil) to a 50% cassava-based diet did not affect rate of gain or feed efficiency (Table 5). Because fish meal, maize, and soybean were added to the cassava-based diets, it is plausible that these diets contained sufficient essential fatty acids prior to the addition of peanut oil.

Apart from being a principal source of energy, supplemented fats or oils also provide certain "additional dynamic actions" (ADNA), including increased growth, better palatability, essential fatty acids, better absorption or retention of other nutrients, and a significantly improved dust control (N.R.A. 1974, Table 2).

Improvements in rate of gain and feed efficiency of animals fed palm oil added to a cassava-based diet could be due to an improvement in palatability. Hutagalung (1972) postulated possible interaction between essential fatty acids present in the palm oil and the methionine of the diet. Furthermore, the addition of palm oil to cassava-based diet enables the animals to utilize methionine efficiently and to facilitate absorption and retention of essential fatty acids. Sugars (molasses/sucrose/glucose) in cassava-based diets probably reduce HCN levels by forming glyconohydrin, and as well improve palatability.

Protein and Amino Acids

Cassava root meal is low in crude protein and essential amino acids, with insignificant levels for methionine, cystine, and tryptophan (Table 1). Therefore, when it is used in large proportions, most of the protein in the diet must come from other protein sources. Similarly, when the maize fraction of the diet is replaced by cassava meal, the level of the protein source should be adjusted to balance the difference in the level of protein between maize and cassava. When soybean meal is used as the main protein supplement, growth

Table 5. Effect of supplementation of essential fatty acids, niacin, lysine, and methionine in cassava-based diets on the performance of broiler chickens (Müller et al. 1975b).

	Maize diet	Cassava-based diet (50% cassava meal)				
Fish meal (%)	6.0	10	10	10	5	5
Palm oil (%)	—	2	—	—	—	—
Peanut oil (%)	—	—	2	2	2	2
Niacin (mg/kg)	—	—	—	20	20	20
Lysine (%)	—	—	—	—	—	0.11
Methionine (%)	—	—	—	—	—	0.05
Performance at 10 weeks						
Live wt. (kg)	1.93	1.87	1.85	1.88	1.77	1.80
Feed/gain	2.65	2.78	2.81	2.76	2.88	2.78
Mortality (%)	11.0	10.1	14.1	11.1	5.10	2.00

depression is more likely to occur than in the case of a protein supplement of animal origin, such as fish meal. This is because methionine is the first limiting amino acid in soybean protein (Kroening et al. 1965; Berry et al. 1966).

Cassava leaves could become a potential source of protein for human and livestock (Rogers and Milner 1963; Terra 1964; Ross and Enriquez 1969; Eggum 1970; Lee and Hutagalung 1972; Adrian and Peyrot 1971; Hutagalung et al. 1973). Leaf-protein concentrate could be used as a protein supplement for monogastrics and the voluminous-fibrous residue could be utilized as roughage for ruminant animals (Nestel 1974, 1975; Müller et al. 1975a). The protein content of cassava leaves is 17–40%, depending mainly on age and time of harvest, variety, soil condition, and processing methods (Rogers and Milner 1963; Eggum 1970; Hutagalung et al. 1973) and their nutritive value is somewhat similar or even superior to alfalfa leaf meal (Bangham 1950). The protein of cassava leaves is deficient in sulfur-containing amino acids (methionine and cystine), marginal in tryptophan and isoleucine, but rich in lysine (Akinrele 1967; Hutagalung et al. 1973; Müller et al. 1975a). Digestibility of the protein in cassava leaves was shown to be high, especially with young leaves (Van Veen 1938; Luyken et al. 1961). Young leaves had a true digestibility of 80% for the protein but this decreased to 67% in older leaves (Luyken et al 1961). Methionine addition to older leaves increased net protein utilization (NPU). Eggum (1970) reported that digestibility of leaf protein in rats was from 70 to 80%; whereas, its biological value was 44–57%, depending on the methionine content. He stated further that only about 60% of its methionine was available and that the true availability of the other amino acids was inconsistent.

Hew and Hutagalung (1972) observed growth depression in pigs as the level of cassava root in the diet increased. In their study, animal protein was kept constant, while vegetable protein was increased with increasing level of cassava. On the other hand, when the level of animal protein (fish meal) was raised and the plant protein was held constant, the growth depression of pigs fed cassava-based diet was alleviated (Hew and Hutagalung 1972, 1976) (Table 6). Reports elsewhere have also shown that supplementation of high quality protein feedstuffs to cassava-root based diet could overcome growth depression (Maner and Gomez 1973; Khajarern and Khajarern 1976). Reduction of fish meal from 10 to 5% in the 50% cassava-based diets resulted in a significant reduction in growth rate and less efficient feed conversion of broiler chickens (Müller et al. 1975a).

Phuah and Hutagalung (1974) studied the effects of varying protein increment (19–17; 22–20; 25–23%) in combination with graded levels of cassava root meal (0, 20, 40%) on the performance and body composition of broiler chickens. Protein and cassava levels in the diet gave little or no improvement in rate of gain and feed efficiency. The nonsignificant response of chicks apparently was due to the fact that the diets were balanced in animal and plant proteins to supply the essential amino acids. However, increasing levels of dietary protein in the cassava-based diet resulted in increased carcass protein and decreased carcass fat (Table 7).

Supplementation of groundnut flour, skim

Table 6. Effect of fish meal supplementation to diets containing 18% soybean meal and varying levels of cassava on performance and carcass measurements of pigs (Hew and Hutagalung 1976).

	Cassava (%)				
	0	15	30	45	60
	Fish meal (%)				
	9	11	13	15	18
Avg. daily gain (kg)	0.62	0.58	0.58	0.60	0.63
Avg. daily feed (kg)	2.10	2.02	2.07	1.98	2.11
Feed/gain	3.40	3.45	3.60	3.32	3.38
Days to slaughter	113	109	109	112	114
Dressing (%)	78.33	79.18	80.40	79.85	78.63
Shrink (%)	3.22	4.59	4.35	4.17	4.02
Backfat (cm)	2.48	2.33	2.26	2.54	2.57
L. dorsi area (cm^2)[3]	32.28	33.50	36.59	31.93	32.83
L. dorsi area (cm^2)[4]	18.17[1]	17.44[1]	15.63[1,2]	13.90[2]	14.25[2]

[1,2]Means in the same row bearing different superscripts differ significantly ($p < 0.05$).
[3]*L. dorsi* area taken at 2nd lumbar position.
[4]*L. dorsi* area taken at 4th rib position.

Table 7. Effects of dietary cassava (C) at levels of 0, 20, and 40% and protein on performance and body composition of broiler chickens (Hutagalung et al. 1973; Phuah and Hutagalung 1974).

	19–17% protein			22–20% protein			25–23% protein		
	0% C	20% C	40% C	0% C	20% C	40% C	0% C	20% C	40% C
Av. daily gain (g)	18.0	17.5	16.8	18.6	12.6	16.1	18.1	17.6	16.7
Feed/gain	2.42	2.19	2.31	2.10	2.09	2.24	2.15	2.24	2.20
Whole carcass									
Moisture (%)	65.3	68.3	67.8	68.7	69.6	70.4	69.2	69.8	68.4
Fat (%)[1,2]	32.8	25.6	25.8	23.9	23.9	18.5	16.4	16.1	21.0
Protein (%)[1,2]	52.1	57.4	57.5	59.4	60.7	61.0	64.3	67.1	63.2

[1]Significant ($p < 0.01$) effect of cassava and protein.
[2]Significant ($p < 0.01$) cassava × protein interaction.

milk powder, or a mixture of the two to the cassava-based diets, to provide 15% extra protein, resulted in a significant increase in the growth rate of rats compared with those on cassava-maize diets (Tasker 1962). Barbosa et al. (1957) substituted wheat flour by a combination of cassava and peanut-oil meal in swine diets and found that rate of gain and feed efficiency were superior in the cassava-peanut-oil-meal diet.

Eggum (1970) compared the combination of dried fish (cod) and cassava leaves in rats and found a marked improvement in the biological value of leaf protein.

Hew and Hutagalung (1976) stated that the choice of cassava root meal with a low cyanogenic glucoside content and the use of high quality proteins to correct nutrient deficiencies, such as sulfur-containing amino acids and vitamins, make the replacement of grains by cassava possible. The inclusion of a higher concentration of fish meal as animal protein rather than a combination of plant protein and synthetic amino acids compared favourably in terms of rate of gain, feed efficiency, and the cost of feed per unit of gain (Table 6). The use of a higher quantity of fish meal may have improved the protein quality or the amino acid make up of the feed and hence supported better growth. Also, fish meal is a rich source of vitamin B_{12} that may contribute to the detoxification process of HCN. In the case of a cassava-fish meal combination, methionine supplementation may not be required. However, where fish meal is limited and expensive, methionine supplementation of a combination of cassava and plant protein would be more economical.

Amino Acids

The role of methionine addition to cassava-based diets has been presented by Adegbola (1977). Therefore, this discussion is confined only to amino acids other than methionine. It has been generally agreed that supplementation of sulfur-containing amino acids in cassava-based diets serves two functions. Besides satisfying the overall essential amino acid requirement of the animals, methionine in particular is actively involved in cyanide detoxification. Sulfur-containing amino acids contribute the sulfhydryl (–SH) groups that react with cyanide to form harmless thiocyanate. The sulfhydryl group is also supplied by 3-mercaptopyruvic acid, which may arise from cystine by transamination or deamination (Meister 1953).

Literature on supplementation of synthetic amino acids other than methionine to cassava-based diets is rather limited, particularly for large animals. One would expect a scarcity of nutritional studies on these essential amino acids. Commercially, lysine, methionine, and occasionally cystine are the only amino acids available at reasonable cost. Other amino acids such as tryptophan and threonine are produced on a laboratory scale, and for large scale application they are very costly. Hence, most of the work on amino acid supplementation to cassava-based diets has been done on small animals.

Earlier work on amino acid supplementation in chickens (Enriquez and Ross 1967) indicated that the adverse effects of a high cassava (50%) diet were overcome by supplementation with 0.15% methionine. Similarly, Olson et al. (1969b) obtained satisfactory results with supplementation of 0.2–0.8% methionine or 0.4–0.8% cystine in cassava (45%) diets. The role of cystine to replace methionine, ranging from 40–70% has been documented (Becker et al. 1955; Baker et al. 1969; Mitchell et al. 1968).

Work in Malaysia and Singapore has also demonstrated the ability of sulfur-containing amino acids to alleviate the depressing effects of high cassava rations given to pigs (Hutagalung 1972; Hew and Hutagalung 1972; Müller et al. 1972; Hutagalung et al. 1973) and poultry (Kassim and Jalaludin 1972; Leong and Jalaludin 1972; Oh and Jalaludin 1972; Chou and Müller 1972; Hutagalung et al. 1974; Syed et al. 1975; Yeong and Syed 1976a,b).

Olson et al. (1969a,b) studied the effects of leucine or methionine (or both) supplementation to rations containing 45% cassava meal in chicks. Addition of 0.1% methionine, but not 0.1% leucine, to the cassava-based diets increased weight gain and feed efficiency. Supplementation with both leucine and methionine resulted in significantly heavier birds and better feed conversion compared with unsupplemented diets and those receiving only leucine.

Incorporation of both lysine (0.11%) and methionine (0.05%) into 50% cassava-based diets containing 2% peanut oil and 5% fish meal markedly improved rate of gain and feed conversion of broiler chickens during the early period but not at 10 weeks of age (Müller et al. 1975b) (Table 5). It appears that the addition of lysine and methionine was necessary for the chicks to reach optimum growth; whereas, at 10 weeks of age these higher levels were not required.

Lysine and methionine supplementation to cassava-leaf based diets increased the protein efficiency of rats (Pechnik and Guimares 1962). Drying, prolonged cooking, and redrying of the leaves had no significant effect on the growth of rats even when supplemented with lysine, methionine, and threonine. In a subsequent experiment (Pechnik and Guimares 1963) lysine, histidine, and methionine addition, singly or in combination, to sweet cassava-leaf based diets gave various growth responses in young rats. Methionine alone gave the best growth response; whereas, the addition of lysine and histidine resulted in decreased feed efficiency and body weight gain. No explanation was given for this growth depression, but it could be due to an amino acid imbalance in the protein of the leaf.

The effectiveness of adding amino acids, especially those belonging to the sulfur-containing group, to alleviate growth depression depends primarily on the level and source of protein and energy in the cassava-based diets. However, one can question the safety of adding synthetic amino acids to the diet. Eggum (1970) indicated the possibility of an adverse effect from an overdose of single amino acids. In an extensive review by Harper et al. (1970), it was stated that excessive intake of individual amino acids, particularly in young animals fed a low protein diet, can result in adverse effects ranging from moderate growth and food intake depression to clear-cut toxic reactions. Amino acid imbalance and more general dietary disproportion, result in depressed food intake and growth. They further stated that methionine is the most toxic of the amino acids, and that in amounts exceeding 2% of the diet it causes severe growth depression and histopathological changes. Excessive intake of lysine, arginine, leucine, isoleucine, and valine appears to be mutually antagonistic. This antagonism appears to be due to the specific structure and metabolic relationships of the individual amino acids. The adverse effects are generally alleviated if the protein content of the diet is increased or the nutritional quality of the protein is improved. Therefore, when supplementation of synthetic amino acids to cassava-based diets is required the amino acid balance and the protein and energy contents of the diet should be carefully considered.

Nonprotein Nitrogen

It is known that nonprotein nitrogen (NPN), mainly urea, in ruminant animals can satisfactorily replace up to 25% of the total dietary protein (Reid 1953). However, there is evidence that the growth of animals on such diets is slightly depressed in comparison with those on conventional protein. Addition of urea beyond 1% of the ration often reduces palatability, but this can be counteracted by molasses. With the shortage of conventional protein, grains, or forage concentrates, the use of urea with either cassava or molasses, or both, as protein and energy sources, has been frequently practiced, more so in ruminants than in monogastric animals.

Little work has been done on the use of cassava products, particularly leaves, as ruminant feeds. This is probably due to the difficulty of obtaining sufficient quantity of cassava materials for feeding experiments, notably for beef and dairy cattle. Chicco et al. (1971) and Schultz et al. (1970a,b) undertook extensive studies on the effect of feeding a combination of cassava and urea to cattle and sheep. Chicco et al. (1971) evaluated the effect of urea (1%) and molasses (5%) added to the cassava-based diet on the digestibility and rumen constituents of sheep. Significant improvement with the urea-molasses-cassava combination was observed for bacterial protein, blood urea, propionic acid, butyric acid, and for the digestibility of organic matter and cellulose. Schultz et al. (1970a) compared the effects of adding urea to either uncooked or cooked cassava with vegetable protein in cattle. Addition of urea to cooked cassava improved the quantity of microbial N and total volatile fatty acid (VFA) concentration, but not ruminal cellulose digestion, compared with uncooked cassava. In their following experiment (Schultz et al. 1970b), urea-cassava-molasses diets were compared with a vegetable protein control diet in young cattle. Rumen microbial protein content of the control diet was higher than that of the cassava-urea and molasses-urea combination; whereas, VFA concentrations in the rumen samples from rations containing urea were equal to or greater than the control diet. No apparent differences were noted for cellulose digestibility in the rumen. Somewhat similar studies on urea-cassava utilization in cattle were reported by Kay et al. (1972) and Karue et al. (1973). Karue et al. (1973) fed poor quality hay supplemented with concentrates containing cassava, molasses, and urea to Zebu steers. They found that an increase in caloric intake from the cassava concentrates resulted in reduction of metabolic body weight of the steers. Müller et al. (1975a) indicated that feeding cattle, either in a feedlot or on pasture, a concentrate diet containing 85% cassava root meal, 6% molasses, 8% urea, and 1% mineral supplement compared favourably with tropical grasses for optimum performance. However, no data were given in recommending such a combination, especially when the urea used was higher than is normally recommended.

Substitution of corn by 1.5% urea in a chopped sugarcane foliage-cassava diet produced similar weight gains of 8-month-old heifers (Pineda and Rubio 1972). Total or partial substitution of cotton seed meal by urea in the diet, when cassava was used as a supplement, produced similar weight gains. A marked increase in weight gains was obtained when cassava was used as a supplement in a molasses-urea mixture (Neves 1969).

There have been some attempts to use the wastes from the poultry industry as nitrogen sources for livestock. Ng and Hutagalung (1974) studied the effects of poultry excreta (5, 10, 15%) in combination with two levels of cassava (15, 30%) diet containing either low (17–19%) or high (20–22%) protein levels in broiler chicks. Supplementation of 15% poultry excreta to a 30% cassava-based diet produced no adverse effects on performance. Müller et al. (1975a) indicated that the addition of poultry excreta to cassava-based diets produced responses in broiler chickens similar to those from maize-soybean diets. With recycling technology, they have successfully and economically fattened steers in Singapore on a ration composed of 60% cassava meal and 38% poultry litter.

One should take into consideration when using animal wastes, that they are very variable. Their major disadvantage seems to be a reduction in palatability, but there is also the problem that drugs previously administered to the poultry might prove toxic to animals fed poultry wastes.

Minerals

Most of the work reported earlier on mineral-cassava relationships in domestic and laboratory animals has been concerned with mineral deficiency, particularly iodine (Ekpechi et al. 1966) and zinc (Maust et al. 1969, 1972), rather than their effect on economic criteria such as growth rate and feed conversion.

Recent investigations, however, have been directed to the effects of mineral-cassava combinations on mineral metabolism and the performance of animals (Ermans et al. 1973; Maner and Gomez 1973; Phuah 1973/74; Hutagalung and Tan 1976; Phuah and Hutagalung 1977). In view of the fact that minerals are relatively inexpensive resources and represent only a small part of the diet, there has been little incentive to carry out extensive studies on the effect of mineral supplementation of cassava-based diets on performance, especially for large animals. Moreover, interactions of minerals with each other, especially of the trace elements, present problems of interpretation.

Calcium (Ca) and Phosphorus (P)

The calcium and phosphorus contents of cassava roots used in Malaysia (Table 1) are relatively high (Ca 0.35%; P 0.40%) (Hutagalung et al. 1973); whereas, reports from Africa (Oke 1966) show lower values (Ca 0.13%; P 0.15%). However, contents of other minerals are low, principally copper, iron, and zinc (Raymond et al. 1941; Oke 1966; Maust et al. 1972; Hutagalung et al. 1973). Particular attention should be given to the oxalic content of the cassava root, which is reported to range from 0.1 to 0.32% (Raymond et al. 1941; Oke 1966), because this affects the absorption of minerals. Variations in the mineral content of cassava root meal could be due to variations in total ash content, which are affected by the rate of contamination by soil and foreign materials during harvesting and drying.

Zinc (Zn)

Hutagalung (1972) demonstrated that pigs fed diets containing a high level of cassava root (60–75%) developed distinctive disorders such as diarrhea, skin lesions on the mucosa of the mouth, stomach, and hind quarters, localized swelling and hind leg weakness, and watery meat. Some of these conditions were also observed in chickens (Phuah 1973/74). Low copper (Cu) and Zn contents of the tissues of chicks fed cassava root diets tend to indicate that cassava could upset the balance and availability of minerals (Hutagalung et al. 1973).

Utilization of a large quantity of cassava meal in livestock has resulted in poor gains and parakeratosis, but this condition is corrected by adding extra Zn to the diet (Maust et al. 1969, 1972; Hutagalung et al. 1973; Phuah 1973/74). An explanation for the Zn-cassava relationship is not apparent, especially when the Zn level in the diets was calculated to meet the recommended requirement (NRC 1973). Generally, the incorporation of a large quantity of cassava into the diets necessitated the addition of a greater amount of protein, such as soybean meal, to satisfy protein requirements. When additional soybean is used the phytic acid level in the diet is proportionally raised, resulting in reduced absorbability of Zn from the intestine because more Zn is involved in the formation of insoluble Zn-phytate (Savage et al. 1964; Edwards 1966; Hutagalung et al. 1977). The relatively large quantity of calcium (Ca) in cassava and fish meal, and the presence of oxalic acid in the cassava root, might also reduce the availability of Zn. The presence of Ca in excess was reported to aggravate Zn depletion in the intestine by raising the intestinal pH (Oberleas et al. 1966), and the addition of Zn to the diet might replenish Zn bound to the insoluble Ca-Zn-phytate complex (Savage et al. 1964; Edwards 1966). Hutagalung et al. (1973) stated that an improvement from Zn addition could be attributable to Zn participation in carbohydrate metabolism in that Zn increased the glucose uptake by adipose tissues.

Iodine (I)

In the presence of marginal I and low protein intake, high levels of cassava in the diet may be a key factor in the development of goitre and cretinism (Ekpechi 1973; Ermans et al. 1973) and possibly the cause of reduced availability of zinc (Maust et al. 1972). Apart from Zn deficiency, animals fed diets containing a high concentration of cassava have been suspected to suffer I deficiency (Ekpechi 1973; Hutagalung et al. 1973; Maner and Gomez 1973). Supplementation of I can reduce the deleterious effect of cyanide toxicity, which is manifested as subnormal thyroid function or goitre (Ekpechi et al. 1966) and ataxic neuropathy (Osuntokun 1973). The goitrogenic action of cassava is well documented by Ermans et al. (1973). They stated that the main effect of prolonged consumption of cassava is a marked depletion of the thyroidal I stores, which appears to be severe in the absence of I supplementation. Consequently, animals fed diets containing a large proportion of cassava require a constant supply of I to maintain the thyroid function.

In contradiction to findings in rats (Maner and Gomez 1973; Ekpechi 1973), studies in Malaysia have shown that rate of gain and feed efficiency of broiler chicks were not significantly affected by an I level up to 50 mg/kg (Hutagalung et al. 1973; Phuah 1973/74). Similarly in pigs it was observed (Hutagalung and Tan 1976) that addition of I up to 100 mg/kg to cassava-based diets had no apparent effect on growth and feed efficiency, but addition of 500–1000 mg/kg I depressed growth and feed intake of pigs, rats, and poultry. No significant differences in the carcass composition of pigs resulted from supplementing I in cassava based diets. Iodine (I^{131}) uptake by the thyroid gland decreased with a higher increment of I, particularly at the 50 and 100 mg/kg supplementation levels. The nonsignificant effect of I supplementation could be attributed to the low HCN content of the cassava-based diets. Ekpechi et al. (1966) reported an increased uptake of I^{131} by the thyroid after cassava (50–100%) or I-deficient diets were fed to rats; uptake was normal after I addition. They suggested that the cassava diet was not only I-deficient but also contained a goitrogen. Iodine uptake is energy dependent and is inhibited by cyanide. In their investigation, Maner and Gomez (1973) suggested that because cyanide detoxification requires labile sulfur methionine could serve as a source of sulfur. The detoxification produces thiocyanate, which exerts a goitrogenic effect on the body resulting in thyroid hypertrophy, especially in the absence of adequate dietary I (Sihombing et al. 1974; Cromwell et al. 1975). The extent of supplementation also deserves particular attention because excessive intake of I can cause further problems, including cessation of egg production, delayed sexual maturity, altered reflexes, and diarrhea (Arrington et al. 1967; Wilson et al. 1967; Wilson and Harms 1972; Wilson and Rowland 1970; Phuah 1973/74).

Iron (Fe)

Iron supplementation in cassava-based diets should be undertaken only when there is a deficiency. This is because excessive Fe in the diet can cause nutritional disturbance of P by forming insoluble phosphate, which results in reduced P absorption (Harmon et al. 1968; Standish et al. 1969).

Cobalt (Co)

Cobalt is required for the biosynthesis of vitamin B_{12}; therefore, in a cassava-based diet, Co indirectly plays a part in the cyanide detoxification. The simple salts of Co readily combine with cyanides to form a stable, harmless ion, cobalt cyanide $Co(CN)_6$ (Knowles and Bain 1968).

Selenium (Se)

Selenium functions to ensure efficient utilization of vitamin E or to serve as a nonspecific antioxidant (Oldfield et al. 1963). However, because of its low requirement and its toxicity when used improperly, Se should be used as a feed additive only under careful supervision.

Other Minerals

Other trace minerals likely to be important in the formulation of cassava-based diets are copper (Cu), magnesium (Mg), and manganese (Mn). Under normal conditions, all these trace minerals are easily provided by supplementing the diets with the proper proportion of premixed trace minerals. In cases of deficiency of one or more elements, particular attention should be directed to the antagonistic effect of elements supplemented together. Zinc, particularly when added as an inorganic salt to cassava-based diets, in an attempt to alleviate parakeratosis symptoms, can depress Cu absorption and retention. This antagonism is most prominent when Cu is limiting, leading to acute Cu deficiency (Van Campen 1966; Phuah 1973/74). Starcher (1969) attributed the depressing effect of Zn on Cu absorption to competition for an active site in the duodenal mucosa protein, which serves to transport these elements during absorption.

Vitamins

Besides being deficient in protein, fat, and trace minerals, cassava roots are also low in vitamins. Vitamin A content is only a trace, thiamine 0.6 mg/kg, riboflavin 0.3 mg/kg, and niacin 0.6 mg/kg. De Brochard et al. (1957) reported the vitamin content of cassava root meal to be: vitamin A 550 IU/kg; vitamin D_3 0.01 IU/kg; thiamine 1.6 mg/kg; and riboflavin 0.8 mg/kg. In fresh roots, vitamin values given by different workers are variable; thiamine levels were found to be 0.4–0.6 mg/kg (Jones 1959; Chadha 1961; Müller et al. 1972), but riboflavin values were 0.75 mg/kg (Müller et al. 1972) or lower 0.3 mg/kg (Chadha 1961; Jones 1959). Ascorbic acid in fresh roots ranges from 5 to 360 mg/kg (Raymond et al. 1941; Chadha 1961; Müller et al. 1972), but this is destroyed during the drying process.

Fresh cassava leaves contain high levels of ascorbic acid (0.4–1.8 g/kg), appreciable amounts of the B-vitamins and carotene, but very low levels of vitamin E (Raymond et al. 1941; Oke 1966).

The vitamin values of the cassava root are nutritionally insignificant compared with those of maize. Therefore, to substitute maize with cassava meal in the formulation of the diet, vitamin values must be adjusted to meet the requirements. Vitamin A is particularly critical because yellow maize in a normal diet contributes adequate amounts of vitamin A in its precursor form (carotene and cryptoxanthine). The vitamin A content of cassava root meal is particularly low and this vitamin is readily destroyed by exposure to air and light, especially during the drying process when it is exposed to high temperatures.

Of the B-vitamins, niacin (nicotinic acid) and vitamin B_{12} (cyanocobalamin) deserve particular attention. Niacin in cereal grains and their by-products is unavailable to monogastric animals as it is present in a bound form (Scott et al. 1969). The presence of a sufficient quantity of tryptophan in the diet can reduce the need for niacin, due to the ability of animals to synthesize niacin from tryptophan. Because tryptophan and other essential amino acids are deficient in cassava root meal, supplementation of niacin in the cassava-based diets is inevitable. However, the addition of 20 mg/kg niacin to 50% cassava-based diets has no apparent effect on the rate of gain and feed efficiency (Müller et al. 1975b). The fish meal content of the diet ranged from 5 to 10%; therefore, it is possible that the tryptophan content of the diet was sufficient to meet the tryptophan and niacin requirements (Table 5).

Because biotin synthesis depends on the availability of sulfur and sulfur-containing amino acids, biotin deficiency is likely to occur in cassava-based diets low in methionine. Biotin addition (0, 50, 100 μg/kg) to either 65% broken rice-35% cassava diet or 57% cassava-based diet did not exert any improvement in the performance of chicks (Müller et al. 1975b). On the other hand, when biotin was supplemented to either 68% cassava-16% protein diet or 55% cassava-22% protein diet, it markedly improved body weight and feed efficiency of broilers, particularly with the low protein (16%)-55% cassava diet (Table 8). Unfortunately, these investigations did not state the composition of the diets, i.e. the type of ingredients used, level or source of protein and energy, kind of vitamins and minerals supplemented, which could have influenced the utilization of biotin.

Data on supplementation of other B-vitamins to cassava-based diets are very limited. Low plasma levels of riboflavin were reported in patients subsisting mainly on a cassava diet (Osuntokun 1972, 1973). Vogt and Penner (1963) reported that supplementation of an admixture of niacin, calcium pantothenate, and choline chloride to a 20–30% cassava-based diet did not improve gain or feed conversion of broiler chicks. Carvalho et al. (1969) observed an incidence of perosis in broiler chicks when a large proportion of wheat bran was substituted by cassava meal in the diet. This deficiency symptom was corrected by choline supplementation to the diet.

Vitamin B_{12} has been reported to be an important detoxifying agent in cyanide toxicity (Smith 1961). It was shown that mice exhibiting complete respiratory arrest and coma due to cyanide poisoning recovered rapidly after an injection of vitamin B_{12} (Mushett et al.

Table 8. Effect of biotin supplementation to low and high protein (P) cassava diets for broilers (Müller et al. 1975b).

Periods (weeks)	Added biotin (μg/kg)	Body wt. (kg)		Feed/gain	
		16% P	22% P	16% P	22% P
4th	0	0.44	0.60	2.18	1.64
	50	0.48	0.62	2.01	1.63
	100	0.50	0.60	1.89	1.67
6th	0	0.70	0.87	2.53	2.18
	50	0.64	0.96	2.33	2.04
	100	0.78	0.91	2.29	2.12

1952). The antidotal action of B_{12} results from the immobilization of the cyanide ion as harmless cyanocobalamin (B_{12}) (Smith et al. 1963). Likewise, cyanide poisoning has been shown to be aggravated by vitamin B_{12} deficiency (Wokes and Pickard 1955; Oke 1973).

The biological significance of the interrelationship between vitamin B_{12}, cyanide, and thiocyanate is not yet fully understood. It is believed that cyanide participates in normal metabolic processes (Boxer and Rickards 1952), and it is known to combine with various forms of B_{12} to form cyanocobalamin (Montgomery 1969). Chronic administration of cyanide to animals depletes liver B_{12} (Braekkan et al. 1957). An increase in urinary excretion of thiocyanate in vitamin B_{12}-deficient people can be counteracted by administration of large doses of the vitamin (Wokes et al. 1955).

Two hypotheses have been advanced to explain the role of vitamin B_{12}. Firstly, the cyanide utilization hypothesis assumes that rhodanese and hydroxocobalamin compete for cyanide, some of which converts hydroxocobalamin to its cyano-form, the latter splitting again thus regenerating hydroxocobalamin while the cyanide carbon enters one-carbon metabolism to be directly oxidized to carbon dioxide (Boxer and Rickards 1952). The weakness in this hypothesis is that it cannot account for the quantitative aspect of the observed facts. Secondly, the sulfur transfer hypothesis, based on the abundance of thiocyanate relative to cyanide in body tissues. In the presence of the large excess of thiocyanate, hydroxocobalamin may take up thiocyanate to form thiocyanacobalamin, which reverts to cyanocobalamin, liberating sulfur to an active intermediate X to form SX. The cyanocobalamin then completes the cycle by regenerating hydroxycobalamin, while the cyanide thus liberated is converted to thiocyanate by rhodanese (Oke 1973; Oh 1976).

Another problem with feeding large quantities of cassava meal to animals, particularly cassava chips, is the production of pale, soft, and exudative (PSE) meat. Addition of vitamin E in the form of DL-α-tocopheryl acetate above the recommended requirement can improve the meat quality (personal communication with researchers, feed manufacturers, farmers and butchers in Malaysia). The role of vitamin E in the prevention of muscular dystrophy is well documented, but its function in myoglobin synthesis is unknown. Meat colour is determined by the myoglobin content of the meat. There may be some factors in cassava meal that affect the absorption or metabolism of vitamin E in animals; however, little work has been done along this line. Investigation of the vitamin E-cassava relationship, when cassava is to be utilized as the main source of energy in the animal industry, is worthy of consideration.

Nonnutritive Feed Additives

Nonnutritive feed additives are included in feeds to ensure that the dietary nutrients are ingested, digested, protected from destruction, absorbed, and transported to the body cells, and frequently to alter the metabolism of the animals in an attempt to produce better growth or more desirable finished products. These include pigments (carotenoid sources), antibiotics and antifungals, flavouring agents, antioxidants, enzymes, hormones, pellet binders, coccidiostats and worming drugs, and tranquilizing agents.

Very little information is available on the effects of adding nonnutritive feed additives to cassava-based diets for livestock.

Pigments

Poultry farmers and feed manufacturers have been concerned that if their broilers and pullets were fed cassava-meal based diets, consumers would be reluctant to purchase them, because they would appear to lack in vigour or might produce pale skins, shanks, beaks, and egg yolks. They have usually added grass or legume (alfalfa) meals to corn-based diets to provide pigments (xanthophylls) for the skin and the egg yolks.

Two synthetic carotenoids have been tested widely as supplements for broiler and egg yolk pigmentation (Scott et al. 1969; Guenther et al. 1973; Hinton et al. 1974). These are marketed under various names, but essentially they are cantaxanthin and the ethylester of β-apo-8'carotenoic acid (BACE). Cantaxanthin, a red pigment, when added at 2–10 g/tonne of feed, supplements the natural xanthophylls for broilers; whereas, BACE at 2–8 g/tonne of feed, supplements the natural pigments of the laying mash to produce egg yolks of good colour. It would therefore be beneficial for a poultry farmer to know what effects xanthophyll supplementation to a cassava-based diet would have on subsequent yolk colour, and how much of the pigments are deposited in the fat and skin of broilers.

The effect of feeding cassava-based diets on the pigmentation of the skin, shanks, and fat of broilers (Yeong and Syed 1976a) and egg yolks (Hutagalung 1972; Syed et al. 1975; Yeong and Syed 1976b) has been demonstrated. The lack of pigmentation is attributed to the replacement of yellow maize (rich in xanthophyll) with cassava root meal. However, the defect in cassava rations can easily be corrected by the addition of synthetic carotenoids (Hutagalung et al. 1973; Syed et al. 1975; Yeong and Syed 1976a,b), or even by cassava leaves (Hutagalung and Chang 1977a). Agudu (1972) compared cassava and Madras thorn (*Pithecellobium dulce*) leaf meals, a synthetic xanthophyll material, and two sources of yellow corn as sources of egg yolk pigments in pullets. Xanthophyll assays showed that cassava leaf meal had a higher total and pigmenting xanthophyll content than Madras thorn leaf meal. Increased leaf meal in the diets resulted in increased yolk score, which was not proportional to the level of leaf meal in the diets. The commercial xanthophyll material had an unusually low xanthophyll content and consequently had no significant effect on yolk colour when supplemented at twice the recommended level to a white or yellow corn diet.

In pigs and other livestock, colour pigment is not normally included in the formulation of rations. However, many consumers feel that white fat on pork and beef has more eye appeal than a yellow fat; therefore, the addition of pigments in this case would be uneconomical. The colour of the feed containing large amounts of cassava is poor and less attractive, more so to the farmers than to the animals; in this case, some nonpoisonous colour agent or dye could be introduced.

Antibiotics and Fungicides

Cassava root meal has been implicated in problems of aflatoxicity, because it appears to be an excellent growth medium for aspergilli, especially *Aspergillus flavus*. Samples of cassava flour/starch/meal in Thailand, Hongkong, Brazil, India, and Uganda (Boshell 1968; Shank et al. 1972; Natarajan et al. 1973; Serck-Hanssen 1970) have been shown to contain mycotoxins (aflatoxins). Prolonged storage of high moisture cassava, the amount of free sugars available, and contamination with soil appear to induce the growth of *A. flavus*; whereas, in cassava with a low moisture content, the presence of aflatoxins is practically insignificant.

Schmidt (1966) analyzed 50 cassava food products of different origin and found a high level of bacteria and fungi, including *A. flavus*, *A. fumigatus*, *A. chevalieri*, *A. terreus*, and *Penicillium rubrum* which cause mycoses. He indicated that the chips were highly contaminated by soil containing these microorganisms.

In experiments with mouldy corn, Hew (1975) demonstrated that the presence of aflatoxin in the cassava and maize caused growth depression and less efficient feed conversion of pigs and rats. Oral administration of antibiotics and fungicids did not alleviate the adverse effect upon the chickens of the mycotoxin present in the feedstuffs. Hew (1975) added antibiotic two-fold higher than recommended to a cassava based pig diet suspected to be contaminated by aflatoxin. A slight improvement in the performance of the pigs was observed.

Although feeding diets based on high levels of cassava have been reported to cause diarrhea, there is no report to indicate the requirement of an antibacterial feed additive as a corrective measure. Also, there have been no reports to demonstrate whether this condition can be corrected by drugs. In West Germany, cassava meal has been removed from turkey rations because it caused profuse watery diarrhea and was disastrous to the turkey industry (Fraser 1973). Because such a drastic measure has been taken, one can assume that the deleterious effect of cassava meal on turkeys could not be corrected by pharmaceutical means. With other livestock like pigs and chicken, the diarrhea did not appear to be very serious, probably due to their genetic potential to cope with cassava, which is evidently incompatible with the intestine of the turkey (Zausch et al. 1968).

Of the bacteria and fungi, *A. fumigatus* is the most pathogenic fungus and is the mould most frequently encountered in aspergillosis in chickens. The occurrence of bacteria and fungi would probably justify the addition of antibiotics and fungicids to cassava-root based diet.

Flavouring Agents

The ability of pigs and chickens to differentiate by showing preference for sucrose solution and rejection of saccharine solution has been demonstrated (Jacobs and Scott 1957). Kare (1965) also showed that chickens possess a sense of taste but a very limited ability to smell. However, experiments on supplementation of flavouring agent in a well-balanced diet did not appear to produce any significant increase in feed consumption (Kare 1965). Phuah et al. (1974) studied the effects of supplementing flavouring agents to cassava-based diets of broiler chickens. Addition of either an artificial flavouring agent or molasses did not improve the rate of growth or feed conversion of the broilers.

Whether chickens avoid certain feedstuffs on the basis of taste, lack of eye appeal, or because of adverse effects upon metabolism or "sense of well being" is unknown.

In pigs, the supplementation of normal rations with a flavouring agent (e.g. pig nectar) has been practiced by most feed manufacturers, especially in their starter and grower rations. In the case of cassava-based diets, the inclusion of a sweetener like glucose and molasses has been shown to increase appetite (Hew and Hutagalung 1972; Hutagalung et al. 1973) but without necessary improvement in growth and feed efficiency. As mentioned earlier, glucose and the glucose portion of molasses may play an active part in reducing the HCN content of the cassava by formation of glyconohydrin in addition to increasing the palatability of the cassava-based diet (Hew and Hutagalung 1972).

Enrichment of Cassava by Microbial Fermentation

The concept of fermenting cassava for human consumption is not a recent innovation. For many decades, various forms of fermented cassava such as peuyeum and gari have constituted a part of the staple diet of the people in Asia and Africa (Hesseltine 1965; Gray 1970; Pederson 1971). However, the idea of employing microorganisms to convert cassava into microbial protein on a large scale has been investigated only rather extensively in the last two decades.

The cassava project entitled Microbiological Enrichment initiated at the University of Malaya in 1973, sponsored by IDRC, has successfully produced a fermented cassava containing 10% true or digestible protein. Nutritional and safety evaluation trials on poultry and pigs have been undertaken and the preliminary results have been encouraging (Hutagalung and Tan 1977; Varghese et al. 1977). A similar cassava-enrichment project at the University of Guelph, also sponsored by IDRC since 1972, has revealed a process for producing microbial protein from cassava in a high-temperature low pH fermentation. High protein value biomass (36.9% protein) was obtained and the nutritive value of the product has been evaluated in rats (Reade and Gregory 1975; Gregory et al. 1976; Khor et al. 1976) and is being assessed in pigs. It is hoped that from these two cassava-enrichment projects, a product high in protein, in terms of quantity and quality, and nutritionally safe will be available on a larger scale to cope with the protein shortage for animal feeds.

Conclusions

The following conclusions can be drawn on the role of feed additives in cassava-based diets:

(1) Supplementation with feed additives is necessary to nutritionally balance the cassava-based diet and to improve its feeding value. These may include: (*a*) incorporation of fats or oils to improve palatability and to overcome the powdery characteristic, loose texture, and voluminous nature of cassava products and to facilitate nutrient absorption and retention in

the digestive tract; (*b*) supplementation with good quality protein feedstuffs or synthetic amino acids to balance protein and amino acids; (*c*) supplementation of nonprotein nitrogen to cassava-based diets, which appears more promising for ruminants than for nonruminants; (*d*) taking care to maintain the mineral balance of cassava-based diets, especially excesses of calcium, phosphorus, and oxalic acid, which can reduce the availability of zinc, copper, and iodine; (*e*) adjustments for certain vitamins (vitamin B_{12}, niacin, riboflavin, and biotin) that appear to be relevant in the cassava-based diet; (*f*) enrichment of cassava-based diets with natural or synthetic xanthophylls as required for pigmentation of skin, shanks, fats, and egg yolks of broilers and layers; (*g*) addition of antibiotics, fungicids, and antioxidants to cassava-based diets, which appears necessary to prevent contamination by microorganisms, rancidity, and deterioration of nutrients; (*h*) paying particular attention to standard specifications of cassava products, particularly their moisture, ash, and crude fibre contents, as these factors markedly reduce the nutritive value of cassava; (*i*) replacement of conventional feedstuffs (cereals) by cassava, which is economically feasible when the cost of the fortified cassava-based diet is lower than that of the conventional diet.

(2) Enrichment through microbial fermentation to increase the protein value of cassava has shown promising results, but the safety and economics of the microbially enriched cassava products should be of primary consideration prior to its use as animal feed.

Suggestions for Further Studies

The following points appear worthy of consideration:

(1) There seem to be great inconsistencies in the data on chemical composition of cassava products, particularly the "true protein" (nonextractable nitrogen) content, apart from the amino acid composition. Hence, there is a need to develop a simple and rapid procedure for the determination in the cassava products of the protein that is biologically available to animals, applicable for simple laboratory facilities in the developing countries. Consequently, a compilation of the data on chemical constituents of various cassava products should be undertaken.

(2) Apart from the cyanogenic glucosides of cassava, the possibility of enzyme-inhibiting factors in cassava should be investigated.

(3) Although in the previous workshop on chronic cassava toxicity (Zitnak 1973) the urgent need to develop simplified and reproducible analytical procedures for hydrocyanic acid (cyanogenic glucosides) has been stressed, such procedures are not yet available. These are of paramount importance so that investigators (nutritionists) can rapidly and accurately determine the cyanogenic glucosides content of cassava products prior to their use as animal feeds.

(4) The long-term effect of continuous feeding of cassava products on the whole life cycle of animals should be studied in depth.

(5) A study of the combined effects of cassava leaves and roots with various supplemented feed additives, to obtain their optimum combination in the diet as sources of protein and energy, should be initiated.

(6) Based on the suggestive evidence that ruminants have a greater tolerance to hydrocyanic acid than nonruminants, it appears necessary to undertake a basic study on the effect of feeding cassava products containing high concentrations of HCN on the metabolism of cyanides in the rumen and to compare the detoxifying ability of the ruminants with that of nonruminants.