THE UTILIZATION OF CASSAVA (TAPIOCA) IN LIVESTOCK FEEDING

R.I. Hutagalung, Phuah Chui Hing and Hew Voon Fong*

SUMMARY

Experiments have been carried out using cassava root meal and cassava leaf meal for partial to complete substitution of maize in chick and pig diets. Despite inclusion of supplementary methionine and extra energy sources, the cassava meals have given slower or reduced growth in comparison with isocaloric and equal protein standard diets. There appear to be as yet unexplained factors which are not fully overcome by amino acid, mineral or other additions. Nevertheless, cassava root meal can usefully be fed to broilers and finishing pigs. Cassava leaf meal has poor digestibility and despite its favourable 'proximate analysis', comparable to that of alfalfa, it cannot be regarded as a substitute. Further work on anti-nutritional factors in cassava meals is indicated.

RESUME

Des essais ont permis d'utiliser la farine de racines du manioc et la farine de feuilles du manioc pour la substitution partielle, puis totale du maîs dans l'alimentation des poussins et des porcs. Bien qu'on ait renforcé les farines du manioc de méthionine et d'autres sources d'énergie, elles ont ralenti ou contrarié la croissance comparativement aux régimes isocaloriques de teneur égale en protéine. Il existe probablement des facteurs encore indéterminés qui restent à surmonter par l'utilisation d'acides aminés, d'additions minérales et autres. Toutefois, la farine du manioc peut étre utilé pour l'entretien des poulets et des porcs en embouche. La farine des feuilles du manioc se digère difficilement et bien que son "analyse immédiate" soit favorable comparativement à celle de la luzerne, one ne peut pas en faire un substitut. Il y a lieu de poursuivre les travaux sur les facteurs anti-nutritionnels des farines du manioc.

RESUMEN

Se han conducido experimentos usando alimentos hechos de raîces y de hojas de yuca, para substituir — parcial hasta totalmente — la dieta de maîz de ollos y puercos. A pesar de la inclusión de metionina suplementaria y fuentes extras de energîa, los alimentos de yuca han reducido el crecimiento en comparación con dietas isocalóricas con iguales estandares proteînicos. Parece haber factores no explicados que no han sido superados con la adición de aminoácidos y minerales, entre otras cosas. No obstante, los alimentos de yuca podrîan ser utiles para alimentar pollos azaderos y cerdos para ceba. Los alimentos de hojas de yuca tienen digestibilidad pobre, y a pesar de sus favorables "análisis proximos", comparables a los de la alfalfa, no pueden ser considerados como substituto. Es indicado realizar mas trabajos sobre factores antinutricionales de los alimentos de yuca.

*University of Malaya, Kuala Lumpur, Malaysia.

INTRODUCTION

Cassava (manioc, tapioca, yuca, *Manihot esculenta* (Crantz) is cultivated in many tropical regions for food and provides a major source of dietary carbohydrate for about 400 million people.[7] Because the root is low in protein, minerals and vitamins and also because of recent findings that cyanogenic glucosides are associated with many chronic diseases, including tropical ataxic neuropathy[4] and goitre[11], there has been anxiety over the use of cassava for food and feed in some areas. Nevertheless there is an increasing demand for the use of cassava, both to provide industrial starch and for animal feed. This is reflected in the world production of cassava which rose to 92.2 million tons in 1970[33].

At present, Malaysia depends heavily on imported feeds, amounting to approximately 70 million Malaysian dollars-worth per year for her livestock industry[53]. With the recent world shortage of cereal grains resulting in high costs of imported feedstuffs, the expansion of the Malaysian livestock industry has been critically affected. A local supply of feedstuffs should therefore be explored in order to make the animal industry remain viable and profitable.

Cassava has many agronomic advantages over other staple food crops, including its relative ease of propagation, high energy-yielding potential, disease and pest resistance and its ability to tolerate drought and poor soils. Furthermore, it offers no storage problems as it can be harvested as required. These advantages made this crop a valuable famine reserve for subsistence farmers in tropical regions.

The yield of fresh cassava roots in Malaysia has been reported within the range of 20-40 tons/ha, although yields of more than 50 tons/ha have been recorded also under good conditions[6].

The yield of cassava leaves has been estimated at 5-10 tons dry matter per hectare annually, depending on the soil and climatic conditions[59].

Many feeding trials with cassava roots have been conducted with poultry, pigs and laboratory animals[4,17,24,58]; and it would be impractical to mention all these reports in this paper as most of these publications have been reviewed. Most of the investigators suggest that cassava root is a satisfactory replacement for maize in chicks[13,38,39], and pigs[3,16,25,32,42], without there being any evidence of acute cyanide toxicity. Performance using cassava root meal as an energy feed, with suitable protein sources, has been improved to the same level as that obtained from a maize-soybean control by supplementing the cassava with methionine and increasing the energy content of the diet.

Information on feeding cassava leaves to monogastric animals is rather limited, but in general the reports indicate that the use of cassava leaf meal at levels in excess of 10-20 percent in the diet will depress gain and feed efficiency of rats[1,46,56], chicks[46] and pigs[23]. However, Lee and Hutagalung indicated that performance of pigs fed diets containing 20 percent cassava leaf could be greatly improved by increasing the methionine level and with the use of an additional energy source.

METHODS AND MATERIALS

Preparation of materials

Cassava materials used in these studies were a composite of several 'sweet" cultivars (e.g. Medan, Pulut, Jurai, Sakai), locally known as tapioca or 'ubi kayu' and were obtained from the University of Malaya Farm, the Federal Experimental Station and the surrounding farmers.

Fresh roots were harvested, cleaned, partially peeled in a rotary peeler, ground in a cutter grinder, then centrifuged to remove part of the liquid, and finally dried in a tunnel drier for 1-2 hours at approximately 90° C. The dried product, hereafter referred to as cassava root meal, was further ground in a hammer mill, and the resulting meals were stored in tightly sealed plastic containers before being analyzed or incorporated into the experimental diets.

Chemical analyses

Cassava leaf and root samples were subjected to proximate analysis according to the standard methods[3]. The amino-acid composition was determined by ion-exchange chromatography[31] on an amino acid analyzer after acid hydrolysis. Since acid hydrolysis tends to destroy tryptophan and cystine, these were determined separately. The methods of Spies and Chambers[50] and Miller[30] were used to estimate tryptophan. Cystine was determined as cysteic acid after oxidation with performic acid and acid hydrolysis according to the method of Schram *et al.*[47]. Mineral values were determined by using either a dry ashing or acid digestion procedure[43] on an atomic absorption spectrophotometer, with the exception of phosphorus which was analyzed by the A.O.A.C. procedure[3]. The combustible (gross) energy analysis of samples was carried out by an automatic ballistic bomb calorimeter.

The chemical composition of the cassava samples is summarized in Table 1. The proximate composition of cassava leaf is somewhat comparable to alfalfa leaf, being rather high in protein (25%), crude fibre

(15.9%) and about sufficient in calcium (1.4%) and iron (450 ppm) contents. Cassava root meal is low in practically all nutrients including protein (2.3%), fibre (2.7%), ash (1.6%) and fat (1.2%), but it is high in carbohydrates (81.2%). Mineral content is also low, particularly in copper and zinc which could not be detected during analysis. The vitamin composition of cassava leaf and root was not determined.

The amino acid profile of cassava leaf (Table 1) shows that the leaf is deficient in methionine, tryptophan and cystine, but quite sufficient in other essential amino acids, especially lysine. Similar low methionine content have been also reported by other workers[45,56]. With reference to the amino acid pattern, cassava leaf protein is more or less similar to that of alfalfa meal, which suggests that this leaf could be utilized as a good protein source to substitute other proteins in livestock diets. Cassava root is clearly deficient in all amino acids, being very low in methionine, tryptophan and cystine, which is expected from its low protein content. Olson *et al.*[39] reported a similar amino acid pattern for cassava root.

FEEDING EXPERIMENTS

Chick feeding tests

Experiment 1:

One-day old crossbred chicks were used to determine the digestibility and metabolizable energy of cassava leaf and roots. All chicks were reared to 2 weeks of age on the reference diet. They were then assigned to groups of 10 chicks each on the basis of body weight, equalizing both mean weight and weight distribution among the groups. Each experimental diet was fed to triplicated lots of chicks 2-4 weeks of age. The metabolizable energy (M.E.) content of the cassava samples was determined by the methods recommended by Hill *et al.*[18] using reference diet E-9. Since certain ingredients used in their reference diet were not easily obtainable and rather expensive to use for a large number of test materials, a semi-practical diet was formulated using ingredients found in commercial poultry diets in order to develop a more suitable local reference diet. The M.E. value of pineapple bran with this diet was found to be comparable to that of reference diet E–9[20]. Cassava leaf and root meals were incorporated at 20% and 40% respectively of both reference diets either at the expense of glucose or maize. The composition of basal diets is presented in Table 2, with the chromic oxide addition at a level of 0.3% to serve as an index marker. Chromic oxide analyses were made on both feed and excreta samples according to the procedure outlined by Czarnocki *et al*[8]. The M.E. values are the average of data obtained from the triplicate lots, expressed on a dry matter basis. M.E. values were corrected for nitrogen retention using a value of 8.22 kcal per gram of nitrogen retained. Digestibilities of dry matter, ether extract, energy and protein of the diets were also determined. All chicks were fed the experimental diets for 14 days for M.E. and digestibility determination, but the performance data was extended to 35 days.

The results of gross and M.E. values for cassava root and leaf are shown in Table 3. The average M.E. content of cassava leaf was calculated to be 1590 kcal/kg on a dry matter basis. This low M.E. result is somewhat similar to that of alfalfa meal[48]. It appears that the high fibre content of other constituents of cassava leaves hindered digestibility of the diet and lowered the M.E. value. Digestibility results given in Table 4 support this finding in which chicks fed cassava leaf diet had lower digestion coefficients for dry matter, protein and energy than those fed the basal diets, indicating that young chicks have lower tolerance level for cassava leaf. Earlier work with chicks[46] and pigs[23] has shown that cassava leaf meal depressed performance. Since all our diets were formulated to contain equal protein and energy levels, and were adjusted to meet or exceed the minimum methionine requirement[34,48], it is possible that the high crude fibre content of the leaf may limit the nutrient density and voluntary feed intake.

The M.E. value for cassava root (3230 kcal/kg) compares favourably to that of maize[18,44,49], but it is lower than that reported by Olson *et al.*[38] and Maust *et al.*[27,28], for cassava meal, being 3440 kcal/kg and 4310 kcal/kg respectively. The lower M.E. value of the cassava root meal in this study could have been due to the difference in the processing method of the meal, the higher crude fibre content resulting from incomplete peeling, the cultivars of cassava used and possibly also due to the difference in the strains of chicks employed.

As shown in Table 4, the chicks fed dietary cassava leaf had lower digestion coefficients for dry matter, protein, fat and energy than those fed the basal diets. Apparent digestion of dry matter, protein, fat and energy was not consistently influenced by dietary cassava root.

An explanation for the low dry matter, protein, fat and energy digestibilities in chicks fed the cassava leaf diet is not readily apparent. It is possible that growth-suppressing factors are present in cassava leaves.

The average daily gain and feed/gain data of chicks fed experimental diets for 5 weeks are summarized in Table 5. The chicks fed cassava leaf had less average daily gain and required more feed per unit of gain than the chicks fed the basal diets, while gain and feed conversion of those fed cassava root diet were not consistently affected.

Experiment 2:

Two hundred and ten day-old chicks (Red Cornish x White Plymouth Rock) were used to study the influence of feeding graded levels of cassava leaf and root and their combination on the performance, body composition and on the mineral composition of tissues. The chicks were reared on the basal diet to 2 weeks of age. They were then distributed at random into 7 treatment groups of 10 chicks each on the basis of body weight, equalizing both mean weight and weight distribution among the groups. Each experimental diet was fed to triplicate pens of chicks from 2 to 10 weeks of age. The protein level of the dietary treatment was maintained isonitrogenous by the adjustment of the soybean and maize portion of the diets, while fish meal portion was kept constant.

Based on the performance and M.E. value of the cassava for chicks as determined in Experiment 1, vegetable oil (palm oil) was incorporated in increments to maintain the energy level isocaloric. The composition of the diets is shown in Table 6. The chicks were weighed and feed consumption was recorded at weekly intervals, throughout the 8 week experimental period. Four birds from each treatment were sacrificed after fasting for 12 hours. The whole carcasses of three birds were frozen, cut into sections with a saw, ground in a meat grinder and then samples taken for moisture, protein and fat analyses. The final moisture was obtained by drying the ground samples in a vacuum oven at 105°C for 16 hours. Samples for protein and fat analyses were weighed immediately after the samples were ground and were first dried in a vacuum oven for over 24 hours at 57°C and were then ground in a Wiley mill. Liver samples from the other birds were collected, frozen, dried and were then analyzed for moisture, protein and fat. Both dried samples of whole carcasses and livers were analyzed for mineral elements with the methods previously described. The average daily gain and feed efficiency and body composition data from this experiment are summarized in Table 7. The effect of increasing levels of leaf alone or in combination with graded levels of root caused a growth depression and poorer feed conversion as compared with those of the control diet. Gain and feed conversion of chicks fed root diets however were not significantly different from those of the basal group, although there was a reduction in gain of chicks fed diets containing 40% root. An explanation for the decline in gain and poor feed conversion of chicks from feeding leaf alone or in combination with root is not readily apparent. Since our diets were fortified with adequate methionine and energy supplements, it appears that either a reduction in nutrient density or incomplete elimination of growth depressing factors of cassava leaf diet are possible causes of the adverse effects of cassava leaf meal on growth performance and feed utilization.

Carcass composition of broilers fed cassava diets

Although much work has been done in feeding cassava leaf and root to chickens, there is little information available on the influence of cassava diets on carcass composition at time of marketing. It is becoming increasingly important to consider not only weight gain and feed efficiency of meat animals, but also their carcass composition resulting from feeding cassava products. With the recent findings on the incidence of tropical ataxic neuropathy and goitre in humans having high cassava intakes, public awareness of the possible health hazards from consuming meat animals fed high levels of cassava products is also increasing. This increases the need for an investigation of carcass characteristics and composition.

The average whole carcass and liver composition data are presented in Table 7. In general, cassava leaf and root diets did not exert any consistent effect on whole carcass and liver composition; however, there was a tendency for the birds fed diets containing a combination of leaf and root to have slightly less moisture and more fat in the whole carcass than for birds fed the basal diet. This difference is probably not due to the effect of cassava leaf and root but it may be related to the difference in the dry matter and fat contents of diets containing leaf and root meals compared with those of the basal diet. The observed increase in fat content with a concomitant decrease in moisture with increasing either fat or energy level supports the observations of several researchers[9,10,22,54].

A summary of the results of mineral contents of chicks fed cassava leaf and root diets is presented in Table 8. No consistent differences in the mineral content of the whole carcass and liver were observed between the cassava and the basal diets, although there was a slight reduction in the copper and zinc content of carcasses of chicks fed the diets containing leaf and root.

Experiment 3:

The objective of this experiment was to assess the performance response and the body composition of broiler chicks to protein increments in diets containing graded levels of cassava root when the energy value was maintained relatively constant for all diets. The combination of protein and cassava levels in the diet giving satisfactory performance then served as the basal diet for the subsequent experiments (Experiment 4, 5 and 6) in which the combination of supplemented minerals were studied. Commercial broiler chicks were reared from 1 day to 2 weeks of age as a group using standard brooding practices. One hundred and sixty two chicks were allocated at random to three replications of a 3 x 3 factorial arrangement of 9 dietary treatments to compare the effects of crude protein levels of 19, 22 and 25% at dietary cassava levels of 0, 20 and 40% from 2 to 6 weeks of age. All diets were calculated to contain a constant level of energy (3.00 kcal/g M.E.). Thereafter, the same chicks were changed to cassava diets containing 17, 20 and 23% protein formulated with a single M.E. value of 3.10 kcal/g. and these were fed to 10 weeks of age. Composition of the starter and grower diets is presented in Table 9A and 9B, respectively. At 10 weeks of age, the birds were individually weighed and fasted for 12 hours prior to sacrifice for carcass analyses. Two randomly selected birds from each replicate were ground and then pooled for analysis. Carcasses were analyzed for moisture, ether extract and protein in accordance with the previously described methods.

The results of this experiment are given in Table 10. No significant differences in performance were noted within the protein levels of the cassava diets, although there was a slight improvement in gain and feed/gain at higher dietary protein levels without cassava supplementation. This supports the conclusions of Spring and Wilkinson[51] and Summers *et al.*[54] who showed no increased gain in weight of 8 week broilers when the protein of the diet was raised. Summed over all protein levels, chicks fed diets containing 40 percent cassava gained weight slightly slower and were less efficient than those fed diets containing 0 and 20 percent cassava, although the difference was not significant.

The carcass composition data (Table 10) showed some evidence of interdependence between dietary factors for carcass fat and protein content but not for carcass moisture content. As dietary protein increased there was a reduction in carcass fat and an increase in carcass protein.

Up to 20 percent increases in the cassava level of the diet significantly increased protein content and decreased fat content but at 40 percent level of cassava meal the fat and protein were inconsistently affected. These results of dietary protein level effects on carcass protein and fat content supports those of Donaldson *et al.*[9] and Summers *et al.*[54].

Experiments 4, 5 and 6:

Three experiments were carried out to study the effects of varying levels of copper, iodine, iron and zinc added to cassava diets on the growth performance and body composition of chicks.

Preliminary observations showed that pigs fed diets containing high levels of cassava leaf (40-50%) and root (60-75%) developed clear health disorders such as diarrhoea, skin lesions in the stomach and hind quarters, localized swelling and weakness of the hind legs. Diarrhoea also occurred in chicks. In view of the low copper and zinc contents of carcass of chicks fed cassava leaf and root diets (found in Experiment 2), it appeared that some factors in the cassava diet may upset the availability of minerals. Maust *et al.*[27,28,29] have already indicated that the disorders developed in animals fed high levels of cassava diet are due to zinc deficiency (parakeratosis).

Ekpechi *et al.*[12] and Osuntokun[4] have also reported the incidence of skin lesions and goitre in human patients in Nigeria and have suggested that this may be associated with the long term high consumption of fermented cassava. Ekpechi[11] and Maner and Gomez[26] working independently have studied the effects of iodine supplementation in cassava diets and found that rats fed iodine-supplemented cassava diet gained more weight and utilized feed more efficiently than those fed cassava diets without added iodine.

In the view of the close nutritional interrelationships among copper, iodine, iron and zinc and the difficulty in identifying the factors involved in the resulting symptoms, we carried out three factorial experiments. Experiment 4 was a 3 x 3 factorial experiment to study the effects of three levels of zinc (0, 25, 50 ppm) and three levels of iron)0, 25, 50 ppm). Experiment 5 tested three levels of zinc (0, 25, 50 ppm) and three of iodine (0, 25, 50 ppm). Experiment 6 tested three levels of zinc (0, 25, 50 ppm) and three of copper (0, 25, 50 ppm). All these supplementations were made in diets containing 40 percent cassava root. Chicks were alloted at random to 3 replications of 9 treatments with 6 chicks for each replicate in all experiments. The compositions of basal diets is presented in Table 11. Each experiment was carried out for 8 weeks. At the end of the experiments, 4 birds from each replicate were randomly selected, fasted, sacrificed and analyzed as previously described.

The performance and body composition data of chicks in Experiments 4, 5 and 6 are summarized in Tables 12, 13 and 14 respectively. There are few significant differences. Nevertheless they contain some clear indications of real effects.

The effects of mineral supplementation in cassava diets on the performance and body composition can be summarized as follows:

1. Zinc supplementation regardless of its combination with copper or iodine resulted in improved weight gains and efficiency of feed utilization. Increments of iodine tended to cause an adverse effect on weight gains and feed efficiency. Performance of chicks was not consistently affected by incorporation of copper and iron.
2. Supplementation of zinc in combination with copper, iodine or iron had little overall effect on carcass moisture, nor on protein levels.
3. Regardless of zinc combination with iron, iodine or copper, liver copper levels were markedly reduced as the level of zinc increased. Dietary additions of zinc and iron significantly increased liver iron and zinc content. Within zinc levels, iodine additions gradually increased liver zinc levels. Copper addition

in increments increased liver copper levels. Dietary addition of zinc and copper significantly increased liver zinc level, being less apparent with copper supplementation experiments.

Pig feeding experiments

Hew and Hutagalung[16] showed in pigs that weight gains and efficiency of feed utilization declined as increasing amounts of cassava root meal were incorporated into the diets. However, supplementation of high cassava diets with methionine, palm oil and glucose or molasses improved the performance of the pigs.

Although much work has been done in feeding cassava root meal to pigs, there is little information available on the influence of cassava root on carcass characteristics at time of marketing[32]. It is becoming increasingly important at this stage to consider not only weight gain and feed efficiency of pigs but also their carcass characteristics from feeding cassava.

Sixty crossbred weanling pigs of Landrace and Large White weighing approximately 20 kg were randomly allotted to five dietary treatments, each treatment being replicated three times. Cassava root was incorporated in place of maize at 0, 15, 30, 45 and 60 percent into conventional maize-soybean-fish meal diets. This experiment was undertaken to study the effects of levels of cassava root meal on performance and carcass characteristics of pigs. The composition of the basal diets is presented in Table 15. All diets were supplemented with vitamins and minerals to meet the estimated requirements for growing and finishing pigs[35]. Although the cassava diets used in this experiment were deficient in methionine and lysine and also required fat and molasses supplementation in increments to satisfy the energy requirements, as well as increasing the palatability of cassava diets, these ingredients were deliberately omitted in order to compare effects of cassava substitution on the carcass characteristics of pigs. All pigs were fed 18 percent crude protein diets from 20 to approximately 45 kg weight, after which the pigs were shifted to the 15 percent protein diets on an individual basis and were retained on these diets until the termination of the experiment. Sex was balanced among treatments.

Individual pigs were removed from the test when they reached a weight of approximately 70 kg. which is the traditional market weight in this region. All pigs were slaughtered and processed in the commercial meat packer unit for determination of carcass characteristics. Feed, but not water, was withdrawn about 20 hr before slaughter. Carcass weight (24 hr chill), dressing percentage, length of carcass, averaged back-fat thickness and cross sectional area of the *longissimus dorsi* were obtained on carcass of all pigs.

During the first three weeks of the experiment, pigs fed diets containing the higher levels of cassava root (45 and 60 percent) developed diarrhoea and in a few cases they also developed skin lesions, and localized oedema. Treatments with drugs and antibiotics were ineffective in controlling these disorders in any of the pigs. Doubling the vitamin and mineral supplementation in all diets alleviated the skin disorder, but did not arrest the diarrhoea. Surprisingly, the diarrhoea gradually disappeared several weeks after the pigs had been on the cassava diets. An explanation for the cause and the subsequent recovery of pigs from this disorder was not apparent.

A summary of the gain, feed/gain and carcass data is presented in Table 16. The average daily gain decreased with an increase in dietary cassava level from 15 to 60 percent. Pigs fed diets containing 60 percent cassava reached the market weight approximately 36 days later than those fed the basal diet.

As is expected in pigs fed according to their live weight, differences in efficiency of feed conversion paralleled those in the rate of gain, with the highest levels of cassava giving efficiencies poorer than the diets without cassava supplementation. As is evident from the carcass data and the statistical analysis, neither of the cassava level feeding sequences exert a significant influence on carcass weight, dressing (killing-out) percentage and the carcass length, although the carcass weight and dressing percentage tended to decrease as the level of cassava in the diet increased from 15 to 60 percent. Carcass backfat and cross-sectional area of the *l. dorsi* were significantly affected by dietary cassava level. Carcasses from pigs fed the highest cassava diet had thicker backfat and smaller *l. dorsi* areas than those from pigs fed the low cassava diet and the basal diet.

Experiment 8:

Thirty-six pigs averaging 24 kg body weight, were allotted to three dietary treatments with twelve individual replicates. The treatments were (1) a basal maize-soybean meal diet; (2) a diet containing 15 percent cassava leaf meal and (3) a diet containing 40 percent cassava root. The objective of this experiment was to compare the performance of pigs fed the basal diet and diets containing either cassava root or leaf. All the diets were fed to pigs weighing up to approximately 44 kg and were supplemented with vitamins and minerals and contained 18 percent protein, after which a 16 percent protein diet was fed until the end of the experiment. The composition of the diets is presented in Table 17. Synthetic L-lysine was added in all diets, while DL-methionine was supplemented only in the cassava leaf and root diets. In balancing the diets, attempts were made to have approximately the same protein (isonitrogenous) and energy (isocaloric) levels.

Because of the difficulties experienced in obtaining adequate quantities of cassava materials the experiment was able to be conducted for only 11 weeks.

The summary of the performance data is given in Table 18. There were no statistically significant differences for daily gains and efficiency of food utilization, although there was a trend in pigs fed dietary cassava leaf or root to have lesser gains and consume more feed per unit gained than those fed the basal diet.

DISCUSSION

Cassava leaf meal, as prepared for use in this study, was generally rich in protein and high in crude fibre content, slightly sufficient in calcium and iron levels, but low in metabolizable energy level. Terra[56] reported that cassava leaves are rich in B-complex, ascorbic acid and carotene vitamins, containing respectively 10, 190 I.U. carotene, 0.21 mg thiamine, 0.33 mg riboflavin, 1.85 mg niacin and 224 mg ascorbic acid per 100 g on a fresh weight basis (33.8% dry matter). Leaves are deficient in sulphur-containing amino acids, but quite sufficient in most other essential amino acids, particularly lysine. Our amino acid data supports those of Rogers and Milner[45] and Terra[56]. Overall, cassava leaf meal is slightly superior to alfalfa meal in nutrient content* and compares favourably with soybean meal in amino acid composition. Cassava root meal is low in practically all nutrients, with the exception of carbohydrate. However, data of Oke[37] show that it contains reasonable amounts of ascorbic acid (35 mg/100 g), thiamine (0.06 mg/100 g), riboflavin (0.03 mg/100 g) and niacin (0.6 mg/100 g). The levels of these are affected by the method of sample preparation.

High levels of cassava leaf supplementation in the diet (Experiment 1) however, continued to depress growth and efficiency of feed conversion, even when methionine and energy contents are supplemented, thus it appears that either the levels of crude fibre or other growth depressing factors present in the cassava leaves, reduce or antagonise nutrient uptake of the animals. This finding for chicks and pigs supports work on rats[1,56].

Results of Experiment 2 support previous work with chicks and pigs in adding methionine, lysine, fat and molasses to the cassava root diet which improves feed efficiency[13]. Although chicks fed diets containing cassava leaf and root had no substantial differences in the moisture, fat, protein and mineral content of carcasses and livers, we have not ascertained whether there may be differences in the chemical composition of animals fed cassava rich diets and this warrants further investigation.

Mineral supplementation experiments indicate that zinc addition, regardless of its combination with copper, iodine or iron will improve rate of gain and feed efficiency. Maust *et al.*[27,28,29] obtained similar results. An explanation for the relationship of zinc and cassava is not apparent but it has been suggested that zinc may enhance glucose uptake by adipose tissue, and conversely that zinc deficiency in animals is characterized by lack of normal adipose tissue[57].

In contrast with previous findings in rats[11,26] iodine was not effective in improving gain and feed efficiency of chicks. However, we used lower levels of cassava and iodine in our diets. Maner and Gomez[26] suggested that supplementation with methionine and iodine in cassava diets might reduce toxic effects of cyanide.

Performance of pigs over the weight range of 20–70 kg (Experiment 7) showed that increased cassava content in the diet decreases daily weight gain compared with standard diets, especially in the range 30 – 60 percent cassava. This supports findings in rats[21], chicks[13,39,55,60], and other recent work with pigs[16,27].

It is improbable that methionine was the limiting factor in affecting the performance of pigs on cassava diets as has been suggested by many investigators because methionine was unlikely to be deficient in our feeds in view of the adequate content of fish meal.

Cassava had no significant influence on carcass weight, dressing percentage and carcass length of pigs slaughtered at the standard 70 kg weight. However, there was a significant increase in backfat thickness and smaller loin eye (*l. dorsi*) area with increasing cassava content of diet. This may simply reflect the fact that pigs fed cassava were generally older at slaughter weight than pigs fed basal diets.

Long term experiments involving pigs fed on cassava products are required to assess further their carcass desirability.

CONCLUSIONS

Crudely processed cassava root meal can most suitably be fed to broilers or finishing pigs because of its higher fibre and lower energy content than maize. Special attention will have to be given to limiting factors, including essential amino acids, minerals and vitamins.

Because of the powdery nature of cassava meal attention should be given to formulation so that the

*If no account is taken of possible anti-nutritional factors. Ed nutrient densities of cassava diets are made similar to those of other conventional diets.

Although cassava root has a potential for very high calorie production, its low protein content is disadvantageous. It is therefore necessary to find methods either for improving its own quality, notably in protein, or to find complementary high protein materials with which to enrich cassava meal[2,36]. One such product might be produced by the microbial fermentation of cassava itself.

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TABLE 1

Proximate analysis and amino acid composition of cassava root and leaf

Item	Cassava leaf	Cassava root
Proximate analysis*		
Dry matter	90.00	89.00
Ash	5.50	1.60
Crude fiber	15.90	2.70
Ether extract	6.30	1.20
N-free extract	37.30	81.20
Protein (Nx6.25)	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**		
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	1.89	0.01

* Expressed as percent or unit of 'as fed' sample
** Expressed as percent of air dry sample

TABLE 2

Composition of diets (Experiment 1)

Ingredients, %	Diets Basal A*	Basal B
Maize, yellow	-	53.20
Glucose	43.10	-
Soybean meal	17.50	28.60
Ground wheat	9.00	-
Alfalfa meal	-	2.00
Dried yeast	2.50	2.50
Crude casein	10.50	-
Dried whey	2.00	-
Meat and bone meal	-	2.85
Fish meal	5.00	3.30
Dried fish solubles	1.00	-
Gelatin	2.50	-
Stabilized fat	2.50	3.00
Limestone	2.00	0.70
Dicalcium phosphate	1.00	1.40
Salt	0.50	0.50
Mineral mixture	0.40	0.30
Vitamin mixture	0.50	0.25
Vitamin mixture	0.50	0.25
DL-Methionine	-	0.20
L-Lysine	-	0.20
Chromic oxide mixture	1.00	1.00
Total	100.00	100.00

* Reference diet (E-9), Hill *et al.*[18]

TABLE 3

Energy values of cassava leaf and root for chicks (Experiment 1)

Item	Gross energy (kcal/g)[1]	Matabolizable energy (kcal/g)[1]
Glucose	4.85	3.62[2]
Maize	4.57	3.30
Cassava leaf[3]	5.30	1.59
Cassava root[4]	4.20	3.23

1 Expressed on a dry matter basis
2 Values are the averages of triplicate lots fed each experimental diet
3 Cassava leaf was substituted for either glucose(Basal A) or maize (Basal B) on 'as fed' basis at 20% level
4 Cassava root was substituted for either glucose(Basal A) or maize (Basal B) on 'as fed' basis at 40% level

TABLE 4

Digestibility of dry matter, protein, fat and energy of basal and cassava diets (Experiment 1)

Items *Diets-	Basal A	Basal B	Cassava root	Cassava leaf
No. of chicks	30	30	30	30
Dry matter, %	80.6[a]	78.3[a]	77.5[a]	68.7[b]
Crude protein,%	76.6[c]	75.8[c]	74.7[c]	66.8[d]
Crude fat, %	60.4[e]	61.5[e]	60.3[e]	51.7[f]
Gross energy, %	73.4[g]	77.9[g]	76.4[g]	53.8[h]

* Means in the same row without a common superscript are significantly different ($P < 0.05$)

TABLE 5

Performance of chicks fed basal and cassava diets for 5 weeks (Experiment 1)

Items	Basal A	Basal B	Cassava root	Cassava leaf
No. animals	30	30	30	30
Length of trials, days.	35	35	35	35
Protein level,%	23	23	23	23
5-week gain, g	334[a]	413[a]	354[a]	280[b]
Avg.daily gain,g	9.55[a]	11.80[a]	10.11[a]	7.80[b]
Feed/gain	2.48[a]	2.28[a]	2.62[a]	3.61[b]

a,b Values with the same superscript are not significantly different ($P < 0.05$)

TABLE 6

Composition of diets (Experiment 2)

Ingredients, %	Basal	Leaf 10	Leaf 20	Root 20	Root 40	Leaf root 10-20	Leaf-root 15-30
Maize	62.55	50.60	36.45	31.90	-	20.80	-
Soybean meal	25.50	22.65	20.20	30.25	35.40	27.10	28.25
Fish meal	4.25	4.25	4.25	4.25	4.25	4.25	4.25
Yeast	2.50	2.59	2.50	2.50	2.50	2.50	2.50
C. leaf meal	-	10.00	20.00	-	-	10.00	15.00
C. root meal	-	-	-	20.00	40.00	20.00	30.00
Molasses	-	2.50	5.00	3.00	6.50	4.00	6.00
Vegetable oil	1.75	4.00	8.00	4.50	7.75	7.75	10.40
Limestone	0.75	0.75	0.75	0.75	0.75	0.75	0.75
Dical.phosphate	1.50	1.50	1.50	1.50	1.50	1.50	1.50
Salt	0.50	0.50	0.50	0.50	0.50	0.50	0.50
Mineral mixture	0.30	0.30	0.30	0.30	0.30	0.30	0.30
Vitamin mixture	0.25	0.25	0.25	0.25	0.25	0.25	0.25
DL-Methionine	0.05	0.20	0.20	0.20	0.20	0.20	0.25
L-Lysine	0.10	0.10	0.10	0.10	0.10	0.10	0.10
Total	100.00	100.00	100.00	100.00	100.00	100.00	100.00

TABLE 7

Performance and body composition of chicks fed dietary cassava leaf and root (Experiment 2)

Items	Basal	Leaf 10	Leaf 20	Root 20	Root 40	Leaf-root 10-20	Leaf-root 15-30
No. animals	30	30	30	30	30	30	30
Length trials, days	56	56	56	56	56	56	56
Avg.daily gain,g	18.2	15.7	15.2	18.4	16.0	15.8	15.7
Feed/gain	3.12	3.36	3.81	3.14	3.24	3.64	3.81
Carcass*							
moisture	74.3	73.4	73.6	12.3	73.5	70.3	71.8
fat, % dry-wt.	34.8	35.8	35.8	37.0	35.2	37.9	36.1
protein %dry-wt.	51.6	52.0	51.4	51.9	52.5	51.0	52.3
Liver*							
moisture,%	75.1	74.0	74.0	73.9	73.2	72.7	73.8
fat, % dry-wt.	14.2	14.8	14.5	14.5	13.3	14.5	14.8
Protein,%dry-wt.	69.9	70.8	71.3	70.7	71.6	70.6	70.1

* Carcass and liver data based on 4 and 3 birds per treatment respectively.

TABLE 8

Effects of dietary cassava leaf and root on mineral contents of chick tissues (Experiment 2)

	Basal	Leaf 10	Leaf 20	Root 20	Root 40	Leaf-root 10-20	Leaf-root 15-30
Whole carcass							
Calcium,%	8.0	7.2	8.0	7.1	6.6	6.7	7.3
Phosphorus,%	3.4	3.4	3.4	3.3	3.7	3.6	3.3
Copper, ppm	23	22	21	19	13	15	16
Iron, ppm	160	550	500	550	460	550	460
Magnesium,%	0.46	0.46	0.46	0.46	0.54	0.48	0.48
Zinc, ppm	87	78	81	7.	81	58	64
Liver*							
Calcium,%	0.72	0.70	0.73	0.73	0.76	0.73	0.74
Phosphorus, %	1.05	1.03	1.04	1.04	1.16	1.10	1.28
Copper, ppm	29	25	22	21	26	25	29
Iron, ppm	621	630	607	608	617	637	648
Magnesium, %	0.90	0.82	0.83	0.80	0.86	0.89	0.90
Zinc, ppm	137	125	166	123	165	155	107

* Expressed on a dry matter basis

TABLE 9A

Composition of starter diets (Experiment 3)

Dietary variables									
Protein, %		19			22			25	
Cassava, %	0	20	40	0	20	40	0	20	40
Cassava root	-	20.00	40.00	-	20.00	40.00	-	20.00	40.00
Maize	66.20	43.30	18.55	57.80	37.00	13.00	52.25	29.00	6.55
Soybean meal	15.50	15.50	23.50	23.90	15.55	21.35	20.40	22.55	20.60
Fish meal	12.35	15.25	12.00	12.35	21.50	20.70	21.40	22.50	27.00
Palm oil	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00
Trical.phosphate	1.75	1.75	1.75	1.75	1.75	1.75	1.75	1.75	1.75
Salt	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50
Mineral mixture	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30
Vitamin premix	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10
DL-Methionine	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20
L-Lysine	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10
Total	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00

TABLE 9B

Composition of grower diets (Experiment 3)

	Dietary variables								
Protein, %	17			20			23		
Cassava, %	0	20	40	0	20	40	0	20	40
Ingredients,%									
Cassava root	-	20.00	40.00	-	20.00	40.00	-	20.00	40.00
Maize	69.00	45.00	23.00	61.50	38.20	15.00	54.50	31.00	7.70
Soybean meal	16.00	17.00	18.00	20.50	22.80	24.00	23.50	26.00	28.30
Fish meal	8.00	10.00	12.00	11.00	12.00	14.00	15.00	16.00	17.00
Palm oil	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00
Trical.phosphate	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
Salt	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50
Mineral mixture	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30
Vitamin premix	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10
DL-Methionine	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20
L-Lysine	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10
Chromic oxide	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30
Total	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00

TABLE 10

Effects of dietary cassava and protein levels on performance and body composition of chicks for 8 weeks (Experiment 3)

	Dietary variables								
Protein %	19 - 17			22 - 20			25 - 23		
Cassava %	0	20	40	0	20	40	0	20	40
Avg.daily gain	18.0	17.5	16.8	18.6	16.6	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	8.5	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 x protein interaction

TABLE 11

Composition of basal diets (Experiment 4, 5 and 6)

Ingredients, %	Diets: Starter	Grower
Cassava root meal	40.00	40.00
Maize, yellow	16.25	22.25
Soybean meal	20.60	17.80
Fish meal	16.20	12.00
Palm oil	4.00	5.00
Tricalcium phosphate	1.75	1.45
Salt	0.50	0.50
Mineral mixture	0.30	0.30
Vitamin premix	0.10	0.10
DL-Methionine	0.20	0.20
L-Lysine	0.10	0.10
Chromic oxide	-	0.30
Total	100.00	100.00

TABLE 12

Effects of graded levels of zinc and iron in cassava diets on performance and body composition of chicks for 8 weeks (Experiment 4)

Dietary variables									
Zinc,ppm	0			25			50		
Iron,ppm	0	25	50	0	25	50	0	25	50
Avg.daily gain(g)	17.2	16.7	17.5	15.7	15.7	18.4	16.7	16.2	14.8
Feed/gain	3.27	3.16	3.33	3.25	3.17	3.07	3.08	3.02	3.02
Carcass data									
Moisture,%	65.8	64.4	62.7	64.4	63.4	63.7	62.1	65.8	64.4
Fat,%	33.3	36.1	38.9	33.1	35.9	31.0	37.2	37.8	33.5
Protein,%[1,5]	58.7	54.4	52.3	56.3	52.0	54.6	53.5	57.6	55.1
Copper,ppm	13.0	9.0	9.2	9.2	11.6	8.4	9.2	8.5	9.8
Iron,ppm[3,5]	240	256	273	253	276	313	233	274	314
Zinc,ppm[2,4]	163	168	168	193	168	186	238	173	173
Liver									
Copper,ppm[2,5]	34	33	37	24	28	26	19	17	17
Iron,ppm[2,4]	519	543	592	520	558	610	618	663	728
Zinc,ppm[5,6]	170	167	173	184	189	188	192	194	200

1 Significant effect of iron ($P<0.05$), but not zinc
2 Significant ($P<0.01$) interaction of zinc and iron
3 Significant ($P<0.05$) effect of zinc and iron
4 Significant ($P<0.01$) effect of zinc and iron
5 Significant ($P<0.05$) interaction of zinc and iron
6 Significant effect of zinc ($P<0.01$), but not iron

TABLE 13

Effects of graded levels of zinc and iodine in cassava diets on performance and body composition of chicks for 8 weeks (Experiment 5)

	Dietary variables								
Zinc,ppm	0			25			50		
Iodine	0	25	50	0	25	50	0	25	50
Avg.daily gain[1,2]	15.5	16.3	13.6	15.2	15.4	15.5	17.3	15.5	14.2
Feed/gain[1,2]	3.12	3.12	3.53	3.30	3.27	3.15	3.12	3.13	3.41
Carcass data									
Moisture,%	63.9	67.1	64.2	63.2	64.4	63.6	61.7	64.9	63.7
Fat, %[2,3]	31.2	28.7	31.4	37.5	34.6	20.6	33.3	33.6	34.0
Protein,%[2,3]	54.0	59.3	52.9	51.5	55.4	57.3	51.2	54.6	55.3
Copper,ppm[1,2]	11.2	11.1	9.1	8.6	8.0	7.9	10.4	8.5	13.1
Iron,ppm[2,5]	249	253	237	241	259	270	249	233	224
Zinc,ppm[3,4]	160	189	177	179	199	198	158	169	204
Liver									
Copper,ppm[2,3]	31	32	34	23	26	25	20	22	19
Iron,ppm[4,5]	547	488	523	531	548	533	547	575	578
Zinc,ppm[6]	167	169	169	179	183	184	187	193	200

1 Significant effect of iodine ($P<0.05$), but not zinc
2 Significant ($P<0.05$) zinc x iodine interaction
3 Significant ($P<0.05$) effect of zinc and iodine
4 Significant ($P<0.01$) zinc x iodine interaction
5 Significant effect of zinc ($P<0.05$), but not iodine
6 Significant effect of iodine ($P<0.05$) and zinc (P 0.01)

TABLE 14

Effects of graded levels of zinc and copper in cassava diets on performance and body composition of chicks for 8 weeks (Experiment 6)

	Dietary variables								
Zinc,ppm	0			25			5o		
Copper,ppm	0	25	50	0	25	50	0	25	50
Av.daily gain,g	17.3	16.4	18.7	17.7	18.2	17.7	19.9	17.6	19.9
Feed/gain	3.24	2.96	3.06	2.78	2.87	2.89	2.85	2.80	2.82
Carcass data									
Moisture,%	65.7	66.6	66.6	67.4	65.9	67.2	67.4	67.5	66.7
Fat, %	29.2	21.6	27.7	21.6	27.8	22.9	23.6	27.5	28.6
Protein,%[1]	55.9	58.1	54.7	62.3	61.2	59.9	60.5	56.9	59.9
Copper,ppm[5]	11.8	14.8	17.7	10.4	13.6	17.9	13.1	15.9	18.5
Iron,ppm[1,3]	310	228	247	258	318	306	321	313	295
Zinc,ppm[3,4]	194	212	225	229	229	188	232	212	165
Liver									
Copper,ppm[2,3]	31	74	126	23	56	73	22	52	69
Iron,ppm[3,5]	586	548	582	517	585	558	559	701	551
Zinc,ppm[3,6]	167	159	155	171	169	174	185	204	205

1 Significant effect of zinc ($P<0.05$), but not copper
2 Significant ($P<0.01$) effect of zinc and copper
3 Significant ($P<0.01$) zinc and copper interaction
4 Significant effect of copper ($P<0.05$), but not zinc
5 Significant effect of copper ($P<0.01$), but not zinc
6 Significant effect of zinc ($P<0.01$), but not copper

TABLE 15

Composition of diets (Experiment 7)

Ingredients,%	Basal	Cassava 15	Cassava 30	Cassava 45	Cassava 60
			Diets		
Maize	70.50	53.00	35.50	18.00	1.00
Soybean meal	20.30	22.30	24.30	26.30	26.00
Cassava root meal	-	15.00	30.00	45.00	60.00
Fish meal	6.00	6.50	7.00	7.50	9.80
Limestone	0.80	0.80	0.80	0.80	0.80
Dicalcium phosphate	1.50	1.50	1.50	1.50	1.50
Salt	0.50	0.50	0.50	0.50	0.50
Mineral mixture	0.30	0.30	0.30	0.30	0.30
Vitamin mixture	0.10	0.10	0.10	0.10	0.10

TABLE 16

Effects of dietary cassava root on performance and carcass characteristics of swine (Experiment 7)

Item	Basal	Cassava 15	Cassava 30	Cassava 45	Cassava 60
			Diets		
No.animals	12	12	12	12	12
Length of trials,days[a]	134	139	156	165	170
Performance data					
Avg.daily gain,kg[b]	0.55	0.52	0.48	0.43	0.42
Feed/gain[b]	3.52	3.57	3.68	3.82	3.90
Weight at slaughter,kg	69.8	70.0	70.4	70.2	69.9
Carcass data					
Weight,kg	55.0	55.5	54.8	52.6	52.7
Dressing,%	78.8	79.3	77.9	75.0	75.4
Length, cm	73.1	74.4	74.7	73.6	72.5
Backfat,cm[b]	3.24	3.30	3.47	3.69	3.78
Area of loin,cm^2[b]	31.7	32.2	27.9	24.3	23.5

a Days required to reach an averaged slaughter weight of 70 kg from the weanling stage.

b Significant (P<0.01) effect of cassava level

TABLE 17

Composition of diets (Experiment 8)

	Diets		
	Basal	Cassava leaf	Cassava root
Maize	69.20	53.60	14.10
Soybean meal	27.50	21.40	35.90
Cassava meal	-	15.00	-
Cassava root meal	-	-	40.00
Molasses	-	3.50	3.50
Palm oil	-	3.00	3.00
Limestone	0.80	0.80	0.80
Dical.phosphate	1.50	1.50	1.50
Salt	0.50	0.50	0.50
Mineral mixture	0.30	0.30	0.30
Vitamin mixture	0.10	0.10	0.10
DL-Methionine	-	0.20	0.20
L-Lysine	0.10	0.10	0.10
Total	100.00	100.00	100.00

TABLE 18

Effect of dietary cassava leaf and root on the performance of pigs (Experiment 8)

	Diets		
	Basal	Cassava leaf	Cassava root
No. animals	12	12	12
Length of trials,days	84	84	84
Protein level,%	18-16	18-16	18-16
Avg.daily gain,g	0.55	0.50	0.52
Feed/gain	3.72	3.88	3.93