CHAPTER 27

The Use of Cassava Products in Animal Feeding*

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Introduction

Improved feeding technology and the introduction of high yielding varieties of cassava have open the possibility to increase its participation in commercial production of animal feeds. Although yields of cassava roots may be as high as 60 t of fresh roots per hectare, under conditions of commercial cultivation it is possible to obtain production levels of 25 to 40 t of fresh roots (9.5 to 15 t of dry roots) and around 5 to 10 t of fresh foliage (1 to 2 t of dry foliage) per hectare. This productivity levels are almost impossible to obtain in tropical environments with other agricultural crops of direct application in animal feeding.

The main value offered by cassava root as a feedstuff is its capacity to provide starch which is a valuable source of useful energy for monogastric and ruminant animals. On the other hand, cassava foliage provides a high level of protein which can be used for ruminants and to a limited extent (as a dried product) in monogastric feeding. Table 27-1[4] illustrates the main nutrients present in fresh and dried samples of cassava products.

Most of the early studies with cassava products were based on the use of fresh roots in swine and cattle feeding as a day-to-day practice. Due to the high moisture level of fresh roots and foliage, its use in poultry and swine diets was not recommended.

The silage processing contributed to improve the management practices since the roots and foliage could be chopped and preserved for long periods before they were supplied to animals.

In later stages, natural drying (sun drying) or artificial drying (gas, diesel, coal, or steam) was introduced as a practice for commercial production of cassava root meal (CRM)[5] or cassava foliage meal, which opened the opportunities for large scale feeding programs, including poultry, swine, and aquaculture production.

Some feed management limitations (dustiness, palatability) with high levels of CRM were overcome with the introduction of new pelleting or extruding techniques. Through the inclusion of pelletized diets for poultry and swine, high levels of CRM and cassava foliage meal were included, and the performance results were comparable to those with conventional cereal diets.

The following revision shows some of the most relevant results with the inclusion of different products derived from cassava roots and foliage (fresh, ensiled, natural drying, artificial drying, and pelletized diets). The first part is directed to traditional feeding practices with fresh and ensiled products for swine and ruminants. The second part also presents traditional information with dried products for poultry, swine, and ruminants. The third part provides more recent developments, especially related to the introduction of fullfat soybean (FFSB) as a strategic complement to dried cassava diets in poultry and swine feeding.

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4. To facilitate readability, all of the 70 tables referred to in this chapter can be found at the end of this document before the References section.

5. For an explanation of this and other abbreviations and acronyms, see *Appendix 1: Acronyms, Abbreviations, and Technical Terminology*, this volume.

Fresh and Ensiled Cassava Roots and Foliage for Swine and Ruminants

The usual feeding practice in most traditional experiences with fresh cassava has been the daily supply of the whole chopped roots supplemented with a dry mixture of protein and micro ingredients (vitamins, minerals, and feed additives). As anticipated, this practice is mainly suitable for small-or medium-size swine and cattle enterprises where cassava production is usually a complement to the animal operations and where hand labor is not an important limitation.

For larger and more technified operations, the heavy hand labor requirements, the perishability of the product, and the troublesome management of the daily feeding program limit the extensive use of fresh products. The use of dried mixtures in automatic feeding systems is the general trend in these cases, where cassava roots and/or foliage should be dried and, preferably, pelletized, to be included in commercial diets.

Although the information with fresh and ensiled roots for swine and cattle feeding is quite lengthy, a summarized report of the most relevant studies is included, with special emphasis on the experimental work conducted at the Centro Internacional de Agricultura Tropical (CIAT), the Colombian Institute of Agriculture (ICA), and the Latin American and Caribbean Consortium to Support Cassava Research and Development (CLAYUCA).

Performance Results with Fresh Cassava Roots in Swine Feeding

Programs based on fresh cassava are suitable for feeding growing-finishing pigs and breeding sows. Due to the high moisture and low energy of roots, the animals have to be supplied with ample amounts of chopped cassava roots and a limited amount of a dry protein supplement (Figures 27-1, 27-22, and 27-3). Nevertheless, in most cases the animal is not able to consume the total energy requirements even though the product is offered at free choice. The maximum consumption of fresh roots obtained in most studies is around 3 kg for growing pigs, 4 kg for finishing pigs, and 6 kg for lactating gilts, which is less than the expected consumption of 3.5–4, 5–6, and 8–10 kg, respectively. Based on these limitations, the performance is partially affected although in most cases the cost:benefit criteria is positive for the small producer.

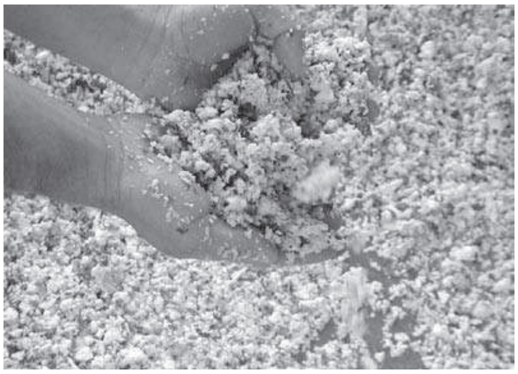

Figure 27-1. Fresh cassava chips.

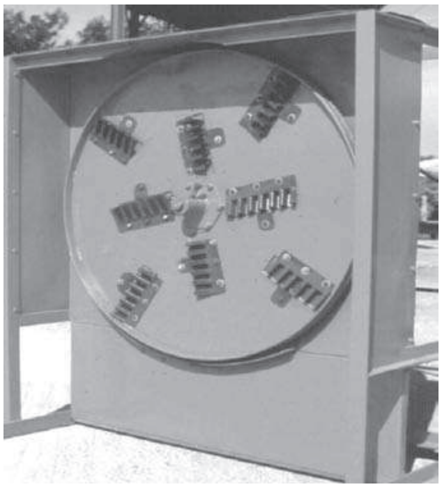

Figure 27-2. Cassava chipper.

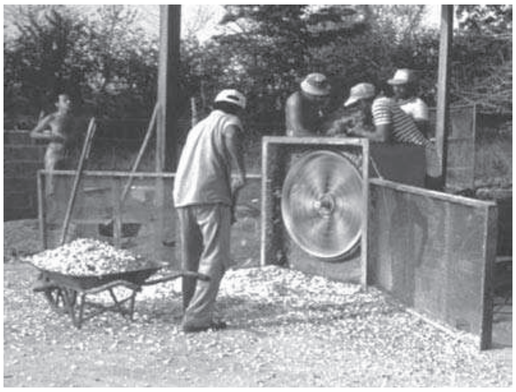

Figure 27-3. Chipping fresh cassava.

In the day-to-day feeding management program, cassava can either be supplied in a mixture together with the nutritional supplement or separately. Nevertheless, free choice supply of the supplement often results in over-consumption of protein, minerals, and vitamins, which generally raises the price and makes the feeding program inefficient.

The most recommended programs to fulfill the pigs' nutritional requirements and at minimal production costs are based on nutritional supplement supply in a daily controlled scheme, according to age and weight of the animals.

Fresh cassava from sweet varieties can be supplied either at free choice to pigs or in controlled amounts to avoid waste, although consumption should not be restricted. Each day, the corresponding amount of fresh roots must be offered to the animals (Figure 27-4).

Figure 27-4. Pig feeders for fresh cassava.

When pigs weight less than 50 kg, they consume smaller amounts of fresh cassava (2.5–3.5 kg/day), but afterwards, during the final fattening stages, consumption should increase up to 4.0–4.5 kg/day. Since these quantities still do not provide the pig with the required dry matter (DM) or energy level to obtain maximum performance, the animal tries to compensate this deficit with a higher consumption of the nutritional supplement (in the case that it is offered at free choice).

In the following tables, results of different trials with growing-finishing pigs and breeding females are analyzed.

Fresh cassava roots for growing-finishing pigs

Tables 27-2 to 27-7 illustrate different feeding approaches which have been tested as viable alternatives to maximize the consumption of fresh roots and to avoid the over consumption of protein supplement without affecting the performance of animals.

The information obtained from the performance results confirms most of the observations already mentioned and illustrates some new approaches to be considered for a more efficient use of fresh roots.

In general, performance results are a little lower than those obtained with commercial corn-soybean meal (SBM) diets. The main reason is associated with a lower consumption of DM when cassava roots are fed fresh, due to the incapacity of the pig to consume larger levels of the fresh product. The high humidity, and probably the effect of low levels of hydrocyanic acid (HCN) still present in sweet varieties of cassava roots, may also have some influence in this situation.

When the protein supplement is provided in a free choice arrangement, the animals will consume larger amounts as compensation to the reduced consumption of cassava roots. Therefore, an over-consumption of protein (approximately an extra 20%) will occur, which results in the higher cost of the total diet (Tables 27-3 and 27-5).

The over-consumption of protein supplement is observed regardless of the ingredients used in the formulation, but the inclusion of intermediate levels of meat meal and blood meal seem to stimulate a further increase in the daily consumption (Table 27-5).

As a mechanism to avoid the over-consumption of the protein supplement, it should be offered every day in controlled amounts related with the body weight of the pig. Although the protein consumption is controlled, the total consumption of DM is still deficient due to the lower cassava intake, which partially affects the animal's performance (Table 27-3).

In Table 27-4 it can be observed that the addition of sugarcane molasses or raw sugar to the cassava roots resulted in a small increase in consumption of roots and DM, and a lower consumption of the protein supplement, which improves the energy:protein ratio as well as the performance of the pigs.

Lowering the protein content of the supplements also helps in reducing protein consumption in pigs, although the consumption of fresh roots is also reduced. The total DM intake from cassava roots are reduced, while the supplement consumption and weight gains are improved by providing lower protein percentages, which also results in a better feed conversion (Table 27-6).

When bitter varieties (i.e., CMC-84) of fresh cassava roots are used, a decrease in its consumption is observed with a parallel increase in the consumption of protein supplement when it is offered *ad libitum* (Table 27-7). However, when the protein supplement is controlled to the required daily level, both the cassava and the protein supplement consumption are reduced, creating a larger deficit in the daily energy intake and a drastic reduction in animal performance.

Fresh cassava roots for gestating and lactating gilts

A small number of studies with fresh cassava roots have been conducted during gestation and lactation. While gestating females need small amounts of energy to fulfill their requirements, lactating females require two to four more intakes of energy as well as protein. Therefore, the reduced consumption of cassava roots should not be an important limiting factor in gestation, in contrast to the high demand during lactation.

Table 27-8 summarizes the feed treatments and the performance results of gestating gilts kept on pasture or in confinement. Both cassava roots and the 40% protein supplement were offered in controlled amounts to supply the daily requirements. The feeding of gilts on pasture was adjusted so they received smaller amounts of cassava and protein supplementation since the pasture provided part of the requirements.

The daily feed intake of cassava and protein supplement corresponded to the predicted daily need of DM and protein during gestation. While cassava fed gilts gained more weight during gestation, the litters were smaller and lighter. Piglet weight and litter weight at birth were lower in case of the cassava treatments, especially in the confined gilts.

On the other hand, the performance of sows and litters during lactation was not affected by the inclusion of cassava roots and protein supplement in a balanced proportion (Table 27-9). The mixture of cassava roots and protein supplement was equivalent to a 16% protein diet on a DM basis, which is similar to the control group given a corn-SBM diet.

Daily consumption of DM in the cassava group was smaller (3.40 kg) than in the control group (4.32 kg). In spite of the reduced consumption of DM, total litter weight at weaning was not affected, even with the smaller litter size of the cassava fed sows. The sows from the control group gained a little more weight during lactation since their DM consumption was higher.

Performance Results with Ensiled Cassava Roots in Swine Feeding

A large proportion of the information obtained with fresh cassava in animal feeding also applies to the preserved product obtained through the silage process (Figures 27-5, 27-6, and 27-7).

The principal nutritional differences are due to the starch fermentation and the reduction in moisture

Figure 27-5. Ensiled cassava chips.

Figure 27-6. Cassava roots silage in small polyethylene bags.

Figure 27-7. Cassava silage in big bags.

during the silage production process. Again, monogastric animals, like swine and poultry, generally are not able to consume the total amount of DM from the ensiled roots to satisfy the energy requirements during the higher demanding phases. Their performance is slightly affected in terms of weight gains, although feed efficiency and production costs will probably compensate for the slower weight gain. Growing-finishing pigs, gilts, and sows are suitable to be included in feeding programs based on cassava silage, once the performance limitations are considered.

As was already mentioned with the fresh cassava feeding practices, the ensiled product also has to be offered in a day to day scheme. Protein supplementation can be offered at free choice or in daily controlled amounts. However, the most recommended feeding practice consists in *ad libitum* supply of ensiled chopped roots plus a controlled quantity of protein supplement which has to be periodically calculated to fix the precise amount to be offered.

Ensiled cassava roots for growing-finishing pigs

The following information on the performance of pigs included in different feeding demonstrations with ensiled cassava, considers the use of ensiled cassava roots in a free choice supply and the controlled supply of protein supplement.

Table 27-10 refers to growing-finishing pigs which were fed three possible cassava-based feeding schemes: fresh roots, ensiled roots, and ensiled roots plus foliage. In all cases, the cassava products were supplemented with a fixed amount of protein supplement (38% protein) to satisfy the daily requirements.

From the performance results it may be concluded that the silage process of cassava roots is a valid alternative to be considered as a mechanism to preserve their nutritional value. The high perishability of the fresh roots may be overcome through the inexpensive practice of anaerobic silage production, which also facilitates the feeding management practices for the small- and medium-size producer.

Table 27-10 shows a very similar response in weight gains and feed efficiency when fresh roots are compared with ensiled roots on a DM basis. However, the inclusion of cassava foliage to the ensiled product negatively affected the consumption of the silage, which is reflected in lower weight gains and poorer feed conversion ratios. The lower consumption of the combined roots and foliage silage may be related to the lower palatability of leaves and stems even at minimum levels (10%).

The information presented in Table 27-11 illustrates the possibilities to include different ingredients as protein supplements to cassava silage in growing-finishing pigs. Excluding the high cottonseed meal supplement, where the consumption was reduced, these alternatives compare favorably with pigs fed commercial balanced diets.

The addition of 2% common salt (Table 27-12) to the cassava root silage showed a beneficial effect on feed conversion rate, without affecting the weight performance of pigs. The same experimental work demonstrated that silage stored for long periods (more than 6 months) does not affect production performance of pigs. The ensiled product progressively decreases in moisture content which resulted in better feed conversion ratios.

Ensiled cassava roots for lactating sows

In a similar experimental comparison as the one described for fresh cassava roots, ensiled cassava roots were also included in diets for lactating sows. Protein supplemented cassava silage diets were compared with corn-SBM diets, either fed as mixed or separated products (Table 27-13).

Performance of sows and litters was not affected by the use of cassava silage as total replacement of the cereal grains normally used in the dry lactation feeds. Even though the amount of cassava silage was more than twice the amount of dry feeds consumed by the sows, a small shortage of DM and energy is still observed in their total daily consumption. However the performance of sows and their litters was not affected up to weaning time. Litter size, individual weights, as well as total litter weight were comparable among treatments, which demonstrate the feasibility for the inclusion of cassava root silage as the main component for lactating sows (Table 27-13).

Performance Results with Fresh Cassava Roots in Ruminant Feeding

Fresh cassava roots for dairy cattle

Tables 27-14 and 27-15 show the effect on the performance of heifers and milking cows when the feeding treatments were mainly based on fresh cassava roots and protein supplements.

Heifers fed with cassava roots and protein supplement (Figure 27-8), in addition to green forage (sugarcane tops), showed a slightly superior daily weight gain than heifers receiving a commercial concentrate based on conventional sources and the same green forage (Table 27-14).

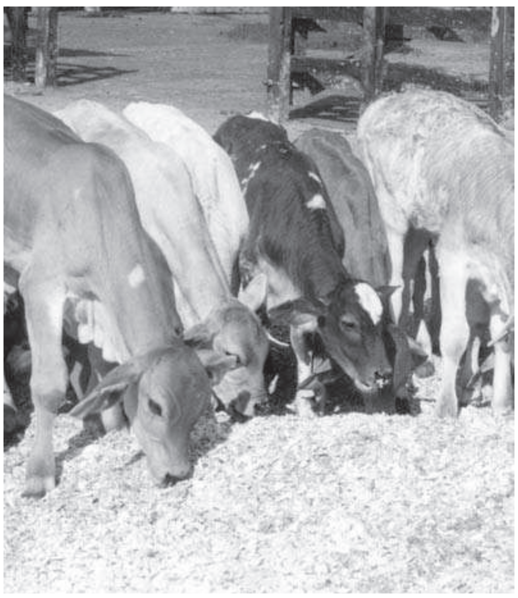

Figure 27-8. Calves consuming fresh cassava.

Confined milking cows also showed a slightly superior production of milk associated with the consumption of cassava roots and protein supplement in addition to star grass hay (Table 27-15).

Fresh cassava roots for beef cattle

The results of a feedlot study are shown in Table 27-16 in which growing-finishing steers were supplemented with a fixed level of fresh grass (elephant grass) plus different dry supplements vs. the cassava group which was fed a similar quantity of fresh grass plus fresh cassava roots and a protein supplement with a high level of urea. One part of the protein supplement was mixed with 10 parts of cassava roots as a complement to the fresh grass in this last group.

The performance results demonstrated excellent growing rates and feed efficiency in the cassava fed group. The inclusion of a high level of urea in the cassava group provides an important advantage by replacing a high percentage of other costly protein sources.

Performance Results with Fresh Cassava Foliage in Ruminant Feeding

The use of fresh cassava foliage is almost limited to ruminant feeding, considering its high moisture (70%–72%) and fiber (4%–6%) levels. Due to its high quantity and quality of protein, the fresh product resembles conventional legumes and is suitable as a forage supplement for ruminants (Figure 27-9).

The best quality foliage should contain a larger proportion of green leaves, petioles, or tender parts from branches, and a minimum of stems or woody

Figure 27-9. Chopped cassava fresh foliage.

parts of the plant. The age of the plant is also an important factor in defining the nutritional quality: when cuts are made from the early stage forage (i.e., less than 3 months) and thereafter harvested at frequent intervals (i.e., every 2–3 months), an excellent product can be obtained in terms of nutrient quality and quantity.

Special care should be taken with fresh forage due to the higher level of HCN in leaves and petioles. The chopping or cutting procedure plus a wilting process during at least 6 hours is very effective in reducing the HCN concentration to safe levels in cattle feeding.

Tables 27-17 and 27-18 illustrate three examples with dairy and beef cattle where cassava foliage is included in a large proportion of the feeding program. In all cases there was an improvement in animal performance associated with the inclusion of cassava foliage. In one of the trials, cassava foliage was offered as a total replacement of alfalfa forage with superior performance results (Table 27-17).

Dry Cassava Root and Foliage Meal for Poultry, Swine, and Ruminants

The information concerning the use of dried cassava products for animal feeding is quite ample in all productive species, mainly swine, poultry, and ruminants. The dried products can be handled more easily and with higher accuracy than programs based on fresh or ensiled cassava (Figures 27-10 to 27-15).

The roots and foliage are dehydrated in order to increase the total nutrient concentration and to facilitate the preservation of the finished feed. In addition, dehydration by heat eliminates most of the cyanogenic components which produce toxic and deleterious effects on animal performance.

Figure 27-10. Solar drying of cassava root chips.

Figure 27-11. Drying trays for cassava root chips.

Figure 27-12. Industrial drying of cassava root chips.

Figure 27-13. Dried cassava chips.

CRM is essentially a carbohydrate product with a high concentration of starch (60%–65%). The metabolizable energy content of good quality meal for poultry and swine is around 3.20 and 3.40 Mcal/kg, respectively, while the total digestible nutrient (TDN) content is around 86%. Its main nutritional limitation is due to the low protein level, so that protein supplementation is required, with special emphasis on the first limiting aminoacid: methionine.

Figure 27-14. Cassava root flour.

Figure 27-15. Dried cassava foliage flour.

The quality of the roots being dehydrated to produce CRM has a natural, direct influence on the final quality of the product. Roots with fibrous impurities (stems, leaves, peels, waste material) or those contaminated with sand or soil affect the nutritional quality and reduce the energy concentration.

Although there is not an official method to grade the quality of CRM, Table 27-19 shows an approach, based on the proposal of Muller et al. (1972), and complemented by the authors of this chapter. This initiative refers principally to the parameters of primary importance for determining the energetic value (main contribution of the roots), and giving a secondary value to the elements of less importance on the root (protein, aminoacids). Based on the above classification, it is possible to recommend the use of CRM, according to more precise nutritional criteria, and better adapted to the different animal production stages, as follows:

Grade 1: broilers, piglets, and aquaculture
Grades 1 and 2: layers, growing-finishing pigs, and calves
Grades 1, 2 and 3: pullets, gestating, and lactating pigs
Grades 1, 2, 3, and 4: dairy, beef, goats, and horses.

Conversely, cassava foliage meal is characterized by its high fiber and protein levels. Depending on the leaves:stems ratio and the age of the plant, crude fiber may range between 18% and 30%, while the protein content may vary from 16% to 28%. Under practical conditions, the green plant top or its third superior aerial part, should be considered as the recommended material to be processed.

The plant top is a mixture of leaves, petioles, and primary and secondary stems. The proportion in which these elements participate in the final product will determine the nutritional quality of the foliage meal. Table 27-20 illustrates the differences in separate samples of the foliage components.

Different alternatives may be considered when foliage tops are harvested for feeding purposes: a single cut may be obtained simultaneously with the root at harvesting time, or the top cuts may be obtained periodically (every 2–3 months) without root harvesting. Moreover, the cassava crop can be completely oriented for just foliage production.

It is also important to note that foliage meal from early regrowth (less than 3 months) will provide better nutritional characteristics (more than 18% protein and less than 20% fiber) in contrast with late regrowths (less than 18% protein and more than 20% fiber) as is illustrated in Table 27-21.

Performance Results with Dried Cassava Roots in Poultry Feeding

The results of some selected experiences will be presented in the following tables, where CRM is included in medium to high levels of the diet for broilers and layers. Most of the early demonstrations were conducted with ground diets and free choice consumption. In the more recent experiences, pelletized diets were introduced as an important mechanism to improve the performance of broilers and to reduce the dusty conditions in diets with high cassava meal content.

The economic considerations when CRM replaces corn or other cereal grains in commercial operations should consider the lower energy and protein values of the cassava root. These limitations normally indicate that CRM should have a cost not higher than 70% to 80% of the price of corn.

Dried CRM for broilers

Table 27-22 illustrates an early, but conclusive study to measure the effect of diets where cassava meal gradually replaced corn as the energy source for broiler diets, without the adjustment of energy level. The results show a slight decrease in performance mainly associated with higher levels of cassava meal due to the reduction in metabolizable energy.

The inclusion of vegetable oil in diets with high cassava meal compensates the lower energy and provides an improvement in performance of broilers, as is illustrated in Table 27-23, where the diets contained different levels of cassava meal but similar protein and metabolizable energy concentrations. In addition, vegetable oil provides an increment in linoleic acid, which is an essential fatty acid for poultry. Total replacement of corn by cassava meal did not affect body weight or feed conversion of broilers.

Pelletized diets provided an additional benefit to high cassava meal diets at the different levels of cassava meal inclusion for broiler diets (Table 27-24).

Dried CRM for layers

The inclusion of dried cassava roots in layer feeding has also been experimented in different comparisons where corn is gradually replaced. In several of the earlier studies there was not a precise adjustment in some of the nutrients, mainly metabolizable energy, methionine, and linoleic acid (Table 27-25), which lowers the production performance.

Egg production and feed conversion ratio are affected in most cases when cassava meal replaces corn without adjustments in the diet, especially at high levels of substitution. Egg yolk pigmentation is also affected with high levels of CRM due to the absence of xantophyl pigments in roots, in contrast with its high concentration in cassava leaves.

Once the nutrient adjustments are introduced in diets with high levels of CRM, improvement on production parameters are generally obtained. The essential aminoacid methionine and the energy concentration are important factors in egg production and egg size, while linoleic acid is mainly involved in egg size. Tables 27-26 and 27-27 illustrate the effect of high levels of CRM when the diets are correctly balanced in energy and methionine. The results obtained in egg production, egg size, and feed conversion ratio are generally comparable with corn-SBM diets. The use of FFSB (8% linoleic acid) shows a favorable effect in the size, pigmentation, and weight of eggs (Table 27-27).

Performance Results with Dried Cassava Roots in Swine Feeding

Several experiments have been conducted with swine in order to demonstrate the effect of different levels of CRM in conventional feeding programs for piglets, growing, finishing, gestating, and lactating pigs. Partial to total substitution of cereal grains, inclusion of different protein supplements, and comparisons between sweet and bitter varieties of cassava have been analyzed in a large number of feeding trials.

As already mentioned in poultry feeding, with high levels of cassava meal the dustiness of the diet may become one of the main limitations for an efficient use of the mixed diet. The addition of sugarcane molasses, animal fat, or vegetable oil helps in the prevention of the dusty presentation and to avoid feed waste. Whenever it becomes possible, pellet processing is the best practice when high levels of cassava meal have to be included.

Similarly to poultry feeding, the cost of cassava meal compared to corn or other cereal grains is the key factor in deciding the economics of its use. The lower energy and protein concentration in CRM generally bears to an adjustment in the price of cassava meal, which, in general, should be equivalent to around 70%–80% of the price of corn.

Dried CRM for growing-finishing pigs

Feeding practices with dried cassava roots have been extensively studied during the growing-finishing stage of pigs. Some of the most representative feeding studies have been selected in the following tables, which summarize the performance results under different environmental and management conditions.

Table 27-28 compares sweet (less than 80 ppm HCN) and bitter (150–200 ppm HCN) varieties of CRM as the main source of energy in diets for growing pigs. Although the sun drying process partially reduced the HCN content, there is still a negative effect in consumption and weight gains of the pigs. However, this effect is very marginal compared to the effect observed when the roots are fresh, since all HCN remains in the tissue of the unprocessed product.

In most studies the inclusion of low HCN cassava root varieties can replace cereal grains without detrimental effects in growing-finishing pigs, even though in some trials no adjustments were made in the energy levels of high cassava diets (Table 27-29). Yields of lean meat cuts were not affected and no clear differences were noticed on fat percentages, fat quality, or saturation index (iodine number), although all animals showed a larger proportion of body fat proper to the crossbred pigs available at the experimental time.

The addition of cane molasses, raw sugarcane, or animal fat to diets based on CRM as the only energy source, did not contribute to the improvement of feed consumption or performance in growing pigs, as shown in Table 27-30. Animal fat addition decreased feed consumption and improved the feed conversion ratio, due to the increment in energy density of the diet. Unexpectedly, methionine supplementation did not improve the performance of growing pigs in this study. Nevertheless, in other experiments the beneficial effect of methionine supplementation to diets containing high levels of cassava has been observed.

Table 27-31 illustrates the positive response to methionine, compared to other sulfur sources in an effort to explore the effect of sulfur in cassava based diets with high levels of HCN.

Dried CRM for gestating and lactating sows

The continued use of high levels of CRM has also been tried during gestation and lactation in order to evaluate its effects on the mothers and on their offspring. Tables 27-32 and 27-33 summarize the results observed in performance of Yorkshire and Duroc x Yorkshire females during gestation and lactation, as well as in piglets during the lactating period.

In Tables 27-32 and 27-33 a corn-based diet was compared with diets where the corn was completely replaced by CRM. The 16% protein diets were offered in controlled quantities during gestation and at free choice during lactation. In general, there are no detrimental effects in performance due to cassava usage, although the first trial (Table 27-32) shows a smaller litter size with no differences in the individual weight of piglets. Conversely, Table 27-33 shows no differences in litter size, individual piglet weight, or total litter weight. The weight differential between breeding time and weaning time of females was not affected when CRM totally replaced corn.

Dried CRM for piglets

Creep feed for lactating piglets with increasing levels of cassava meal has been offered from 10 days up to weaning time. The first trial results during a lactation period of 30 days are summarized in Table 27-34. No differences were observed in performance of piglets with levels up to 20% of CRM in the diet. Weight gains, feed consumption, and feed conversion were equivalent to piglets receiving diets with corn. In a second feeding trial (Table 27-35), creep feed diets with 0%, 20% and 40% cassava meal were compared in order to measure consumption of lactating piglets when fed at free choice up to weaning time at 56 days. There was a positive effect in feed consumption associated with higher levels of cassava meal. Palatability of the diet and performance of piglets were clearly improved with increasing amounts of CRM, even though dustiness was greater in these diets.

Performance Results with Dried Cassava Roots in Ruminant Feeding

CRM diets have been used at different stages of ruminant nutrition. A selection of experimental diets and production performance obtained in calves, milking cows, and growing-finishing steers are included in the following tables.

Dried CRM for calves

Tables 27-36 describes different feeding treatments with variable levels of CRM for early feeding of calves. At low levels of cassava meal, performance was maintained close to those of the corn or sorghum-based diets but levels higher than 25% usually produced a slight decrease in consumption and growth rate of calves. In this experiment calves were raised with cow milk until the sixth week, and from this moment until the fourth month the dry diet was provided at free choice plus forages (alfalfa hay or ensiled sorghum) at free choice.

Dried CRM for dairy cows

The results from two experiments with dairy cows are described in the following tables. Table 27-37 presents results in milking cows where dried diets were supplied in addition to sorghum silage. The inclusion of CRM in substitution of 50% of the sorghum in the dried feed did not affect milk production. Similar results were observed when cassava meal replaced oats as the main energy source of the dried supplement (Table 27-38).

Dried CRM for growing-finishing steers

Steers under intensive grazing or under total confinement have also been included in experiments where CRM has been used as a component of the dried feed supplements.

Table 27-39 shows the results with growing-finishing steers under intensive grazing (4.8 head/ha) conditions, supplemented with controlled quantities of dry feed based on CRM, cane molasses, urea, and blood meal. Animals with higher levels of cassava consumption showed a slight increase in daily weight gain.

Table 27-40 shows the results with feedlot steers consuming a controlled amount of sorghum silage plus a free choice of dry supplement based on cassava meal or sorghum. Daily feed consumption of the supplement decreased with increasing levels of cassava meal. Conversely, sorghum silage consumption was increased to fulfill the energy deficit. Nevertheless, there was a negative effect on daily weight gains associated with lower supplement consumption as a result of increasing levels of CRM in the diet.

Performance Results with Dried Cassava Foliage in Poultry Feeding

In general, dried cassava foliage does not have a significant potential for poultry feeding due to its low energy level and poor palatability. As it happens with other forage products, fiber is a limiting factor which dilutes the concentration of the essential nutrients, mainly energy and protein. Although the protein level in good quality dried cassava foliage is high (18%–26%), the high fiber and low energy concentration limits its use to levels not higher than 10%. The aminoacid profile is characterized by the high lysine content (7.2 g/100 grams of crude protein) and the low methionine level (1.7 g/100 grams of crude protein).

An important factor in cassava foliage, relevant to poultry feeding, is its high content in xanthophyll pigments (500-600 mg/kg), which improves the pigmentation of skin in broilers and egg yolk in layers when used at levels between 5% and 8% of the diet.

The best quality forage meal contains a larger proportion of leaves and young stems which can be easily obtained from plants less than 3 months of age. The nutritional quality decreases as the plant gets older and the leaf:stem ratio changes to a lower proportion of young leaves.

Though HCN levels in dehydrated foliage are generally over 200 ppm, the low foliage percentage recommended for poultry and pigs usually does not present a danger of toxicity; however, in some cases, a HCN content can affect the palatability of the diet, and, eventually, cause toxicity problems.

It is suggested than no more than 6% of forage meal is included in broiler diets and no more than 10% in layer diets. The addition of methionine and fat to these diets is a recommended practice in order to overcome the deficit in these nutrients. At this low level of usage, the cyanide content in dried forage does not constitute a limiting factor.

Dried cassava foliage meal for broilers

Low (less than 6%) levels of cassava foliage meal may be used, mainly as a natural skin pigmenter, with a very light negative effect on feed consumption and weight gain. When the inclusion of the foliage is higher than 6%, the growth rate and feed consumption are negatively affected. When a high level (more than 15%) of cassava foliage is compared with alfalfa meal, the performance results are negatively affected in both treatments, but a larger effect is observed for cassava foliage (Table 27-41).

Table 27-42 also shows the results of diets with high levels (20%) of cassava foliage and the effect of methionine supplementation, since this aminoacid becomes limiting in this type of diets. The growth rate is negatively affected with high foliage content. However, up to 0.3% methionine addition improves the growth performance, although it does not reach the levels obtained by broilers consuming high energy diets.

Dried cassava foliage meal for layers

Little information is available in performance of layers fed cassava foliage diets, except in relation to its pigmenting effect on egg yolk. Table 27-43 shows the effect of low levels (2.5% and 5.0%) of cassava foliage meal when added to white corn diets in comparison with yellow corn diets. There is a linear response to higher levels of cassava foliage, although the pigmenting effect of yellow corn is still superior at this low level of foliage meal. In recent evaluations, cassava foliage meal at levels around 8% show a pigmenting effect similar to yellow corn, without affecting the performance of layers.

Performance Results with Dried Cassava Foliage in Swine Feeding

Once again, since pigs are monogastric animals, the inclusion of cassava foliage does not have an important role in commercial feeding programs, especially for high energy demanding growing-fattening pigs. Gestating and lactating females provide a larger space for the inclusion of a higher percentage of cassava foliage, considering the need for crude fiber during these stages.

The high fiber content, low energy, and poor palatability of dried cassava foliage are the main limiting factors for its inclusion in swine diets.

As a general recommendation it is suggested that no more than 8% of cassava foliage meal may be included in the diets of growing-finishing pigs, no more than 15% in gestating females, and no more than 10% in lactating females. At this low level of usage, the cyanide content in dried foliage (200–500 ppm) does not constitute a potential danger of cyanide poisoning in pigs. Methionine and fat supplementation is a recommended practice whenever cassava foliage is included.

Dried cassava foliage meal for growing-finishing pigs

Some of the early studies (Tables 27-44 and 27-45) showed the effect of including more than 10% of dried cassava foliage in growing-finishing feeding programs. In every case there was a reduction in feed consumption and growth rate of pigs, even though the non-cassava foliage diets still did not have the needed energy concentration for modern genetic pig breeds. In the high demanding energy diets of modern lines, metabolizable energy and methionine supplementation are key factors to partially counteract the poor production performance with high cassava forage diets. These nutrient adjustments may be obtained if the dried cassava foliage is included at levels not larger than 6%–8%.

Recent Developments with Dried Cassava Roots and Foliage Meal for Poultry and Swine

Although cassava meal can be combined with several ingredients in order to obtain balanced diets, the FFSB has become a strategic product considering its nutritional benefits which somehow complements some of the cassava limitations (Figures 27-16 and 27-17). FFSB refer to the heat processed soybeans, through extrusion or toasting processes (Figures 27-18 and 27-19), which will guarantee the needed temperature to eliminate the antinutritional factors (trypsin inhibitors, hemaglutinins, and lipoxygenase) present in raw soybeans.

The inclusion of cassava meal and FFSB as the main ingredients in diets for poultry and swine, simplifies the feeding programs in most of their productive stages, where there is a high need for metabolizable energy, essential aminoacids, lecithin,

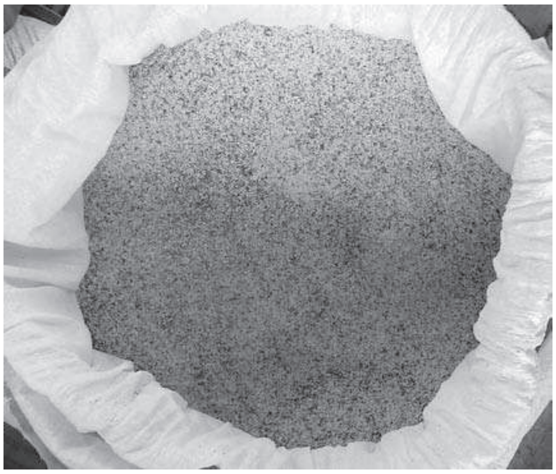

Figure 27-16. Cassava root flour.

Figure 27-17. Fullfat soybeans.

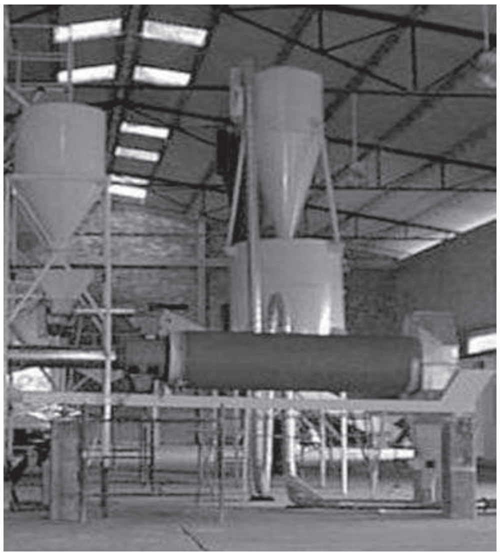

Figure 27-18. Soybean toaster.

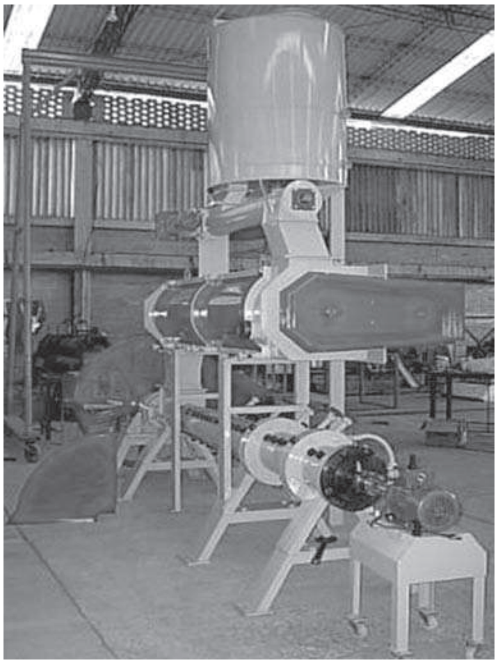

Figure 27-19. Soybean extruder.

and fatty acids. Cassava is rich in starches and energy, but poor in essential aminoacids and fatty acids. On the other hand, FFSB are poor in starches, but rich in essential protein, lecithin, and essential fatty acids.

As Table 27-46 indicates, the low concentration of some essential nutrients observed in CRM can be satisfactorily compensated by their high concentrations in FFSB.

In consideration to the previous observations, the following sections of this chapter will present various animal feeding programs for broilers, layers, and pigs, based on different combinations of CRM and FFSB (extruded or toasted FFSB).

Performance Results with CRM and FFSB in Broiler Feeding

Since the balanced feed for broilers is generally prepared in the form of a pelletized or crombelized product, the recommendations for the levels of CRM that can be used may go as high as the total substitution of cereal grains in diets for starting and finishing broilers. The dusty feature of diets with high levels of cassava meal is totally overcome during the pelletization process, without the need of agglutinants or special additives. The high oil content of these diets, due to the inclusion of FFSB, is also an important factor to improve the pellet quality. Moreover, this type of diets allows the incorporation of maximum levels of CRM (45%–50%) as well as the needed quantity of cassava foliage meal (5%–6%) in order to guarantee the proper pigmentation of broiler skins.

When the starting point is the mixture of CRM, cassava foliage meal, FFSB, and SBM, it is possible to formulate perfectly balanced diets for broilers, following the most recent National Research Council (NRC, 1998) nutritional requirements, in which these three ingredients can represent more than 95% of the total feed, as illustrated in Table 27-47. Table 27-48 provides more detailed information about the nutritional composition of the above mixtures.

Performance results based on diets with low and medium levels of cassava meal in broilers

Even though the results obtained with the total replacement of cereal grains by cassava meal in pelletized diets have demonstrated that this criterion may become a viable practice in commercial feeding programs for broilers, it is possible that in many occasions, it is more convenient to use a partial substitution of the traditional cereal grains. This last modality is even a must when the diets are prepared in meal or flour presentation, considering the dusty characteristics of the CRM. Nevertheless, pelletization or extrusion is always a very useful practice whenever CRM or other dusty products are used in a considerable percentage of the diet.

Tables 27-49 and 27-50 illustrate the composition of the diets with intermediate levels of cassava meal plus FFSB, in which the objective was the substitution of about 40%–50% of the corn or sorghum used in pelletized diets for the starting (0–21 days) and finishing (21–42 days) phases.

Based on previous laboratory trials conducted with a small number of animals, the above diets were then tested with a larger number of chickens on commercial farms in two locations: diets from Table 27-49 were tested under mild environmental conditions in the Cauca Valley of Colombia (24 °C, 78% humidity, 1050 masl) and diets from Table 27-50 were tested under a warmer environment (32 °C, 86% humidity, 40 masl) near the north coast of Colombia (Cereté, Córdoba). A total of 15,350 birds were used in the first trial and 72,400 birds were used in the second trial. In both cases, the cassava diets were compared with corn-SBM commercial diets with similar nutrient composition.

The results obtained with respect to the performance of broilers are shown in Tables 27-51 and 27-52. In general, it can be concluded that broilers consuming diets with a substitution of 50% of corn or sorghum by CRM had the same (or better) performance than those that consumed the conventional diets with cereal grains. In terms of weight increase, feed conversion ratio, and carcass yield, there were no significant differences. Adverse effects, above the normal figures, were not observed in terms of mortality or morbidity as a result of the inclusion of CRM as the main energy source plus FFSB as the main protein source. Differences in humidity of the litter used in the different poultry houses were not appreciable either.

Performance results based on diets with maximum levels of cassava root and cassava foliage meal in broilers

Experimental work conducted at CIAT compared a commercial pelletized broiler diet based on corn and SBM with pelletized diets totally based on cassava root and cassava foliage meal supplemented with FFSB. The comparison between solar dehydration and artificial dehydration of cassava roots was also included in the same study. A detailed description of the experimental diets as well as its nutritional composition for the starting (0–21 days) and finishing (21–42 days) phases is presented in Tables 27-53 and 27-54.

Performance results demonstrated the feasibility of preparing broiler feeding programs totally based on CRM as the main energy source and limited levels of cassava foliage meal as a partial protein source, as long as FFSB is included to provide the deficit of energy, fatty acids, and protein.

Table 27-55 shows the overall performance of broilers until 42 days when the trial was finished. All groups consuming cassava products and FFSB obtained similar or better weight gains and feed conversion ratios when compared to the control group fed with corn and SBM. The consumption of the balanced feed was not affected by the inclusion of high levels of cassava meal during the starting and finishing production phases.

In the treatments that included CRM, the effect of artificial drying was superior to the sun drying procedure. Both steam and gas drying equipments were equally effective for the drying process. The high temperature obtained during the artificial drying facilitates the gelatinization of starches and the control of pathogenic germs. These two factors have probably an important influence on the superior performance of these groups when compared with the sun dried cassava group.

Although the diets with a high percentage of cassava meal and FFSB contain high potassium levels in their final composition, it was not observed to have an adverse effect on the chicken manure and humid litters. Humidity of the manure was analyzed at weekly intervals and no significant differences were observed. Additionally, the measure of the moisture content of the litter did not indicate differences among groups.

Through external measurements of the skin and by checking the chicken carcasses after sacrifice, pigmentation of legs, skin, and internal fat were analyzed. The groups with diets based on just cassava roots showed a poor pigmentation, while the group with cassava roots and foliage showed a pigmentation grade similar to that of the control group fed with diets based on yellow corn. The visual appreciation on a scale from 1 (pale) to 5 (optimum pigmentation), gave both the control and the group fed with cassava roots plus foliage meal a grade of 4, while the other groups without cassava foliage obtained a grade of 2 on the pigmentation scale.

Performance Results with CRM and FFSB in Layer Feeding

Feeding programs for layers generally involve the use of diets in meal presentation, which becomes an important limitation for the inclusion of high levels of CRM due to the dustiness of the final product. This situation is no longer a problem when low or medium levels of CRM are included. Unless the possibility of using pelletized or crombelized diets is considered, it is difficult to incorporate levels higher than 25% of cassava root flour.

In relation to cassava foliage meal, it is also recommended that its use in diets should not exceed levels of 6% in order to minimize the negative effects on palatability or high HCN presence in the feed. When high quality foliage meal is included at levels between 5% and 6%, a satisfactory pigmentation of egg yolks is obtained, due to the presence of natural xanthophylls.

Table 27-56 illustrates an example of diets for replacement layer chickens and laying hens based on maximum levels of CRM combined with FFSB and 6% foliage meal, in which these ingredients can represent up to 85% of the total feed. The corresponding nutritional components are shown in Table 27-57. Tables 27-58 and 27-59 show similar examples in which CRM has been restricted to levels not higher than 25% of the chicken and layer diets.

Performance results based on diets with medium levels of cassava meal for laying hens

Field experiments have been conducted in one of the main poultry regions of Colombia (Cauca Valley). In all feeding trials the diets were prepared in meal or flour form and the level of replacement of corn was not more than 50%.

Tables 27-60, 27-62, 27-64, and 27-66 show the composition of the diets used in several experiments conducted in commercial layer farms, during different laying periods. CRM was included at levels from 10% to 20% of the total diet. FFSB, either extruded or toasted, was used in all cases at levels not higher than 20%.

Results in productivity of layers fed the experimental diets already described are presented in Tables 27-61, 27-63, 27-65, and 27-67.

No important differences were observed in the production parameters of all experiments. Laying percentage and feed conversion was similar in diets with no CRM compared to diets with 10%, 15%, and 20% CRM. A slight reduction in egg laying percentage and feed conversion was observed in brown layers fed with 10% or 20% CRM (Table 27-67).

Performance Results with CRM and FFSB in Swine Feeding

Nutritional considerations already analyzed in poultry feeding based on cassava and FFSB have a close similarity with other monogastric animals, mainly swine. CRM and cassava foliage meal can partially or totally replace the conventional cereal grains in commercial diets. FFSB also provide key nutrients which will complement the nutritional weaknesses of cassava.

When cassava root flour is included at levels above 20%, the pelletization or extrudization processes are always recommended, especially for starting piglet diets. In growing-finishing pigs and breeding animals, pelletization is also recommended, although the addition of molasses, fat, or FFSB can alleviate the dustiness of high cassava meal diets. As in broiler and layer feeding, it is possible to formulate balanced diets for the different production stages in pigs, based in the mixture of cassava roots and cassava foliage meal, FFSB, and SBM, in which these ingredients can represent more than 95% of the total feed, as illustrated in Table 27-68.

In recent studies, the inclusion of high levels of CRM has been successfully proven in finishing diets where FFSB has been also included. The total replacement of cereal grains by CRM is possible once the nutritional adjustments are introduced (Tables 27-69 and 27-70).

Table 27-1. Main nutrients in cassava roots and foliage.

Nutrients	Fresh products		Dry products	
	Roots	Foliage	Roots	Foliage
Moisture, %	64–66	70–72	12–14	12–14
Starch, %	28.0	4.1	73.0	14.0
ME, Mcal/kg[a]	1.20	0.34	3.0–3.1	1.38
Protein, %	1.10	6.5	2.80	21.0
Fiber, %	1.20	4.7	3.2	18.4
Fat, %	0.47	1.8	1.2	5.9
Ash, %	1.12	1.7	2.9	5.6
Methionine, %	0.01	0.07	0.03	0.28
Cystine, %	0.008	0.04	0.02	0.16
Lisine, %	0.02	0.37	0.06	1.6
Triptophane, %	—	0.05	—	0.2
Threonin, %	0.01	0.27	0.03	1.17
Calcium, %	0.10	0.52	0.30	1.7
Phosphorus, %	0.15	0.09	0.40	0.26
Potasium, %	0.25	0.34	0.65	1.2

a. Megacalories of metabolizable energy (ME) per kilogram of product.

SOURCE: Buitrago (1990).

Table 27-2. The effect of using fresh cassava roots and protein supplements in free choice supply to Duroc x Landrace growing pigs (15–50 kg)[a] on their performance.

	Diet 1	Diet 2	Diet 3	Diet 4
Protein supplement (Ingredients %)				
Cottonseed meal	16.0	23.0	23.0	—
Sesame meal	18.0	25.0	—	25.0
Peanut meal	14.0	—	25.0	23.0
Fish meal	36.0	36.0	36.0	36.0
Meat meal	14.2	14.2	14.2	14.2
Lysine	0.2	0.2	0.2	0.2
Vitamin premix	0.6	0.6	0.6	0.6
Nutritional composition				
Digestible energy, Mcal/kg	2.85	2.83	2.88	2.77
Protein, %	54.2	53.9	56.0	52.9
Methionine, %	1.20	1.27	1.07	1.23
Lysine, %	3.19	3.18	3.28	3.15
Performance of pigs				
Daily weight gain, kg	0.59	0.57	0.64	0.53
Daily feed consumption:				
Fresh cassava, kg	3.24	3.24	3.15	2.98
Protein supplement, kg	0.50	0.45	0.52	0.51
Feed conversion ratio (DM)	2.66	2.63	2.44	2.79

a. Chopped fresh cassava roots and protein supplement offered in different feeders for free-choice consumption.

SOURCE: Contreras (1973).

Table 27-3. The effect of using fresh cassava roots and protein supplements in free choice vs. controlled supply for Duroc growing-finishing pigs (18–100 kg)[a] on their performance.

Parameter	Free choice fresh roots + protein supplement[b]		Corn-SBM diet[c]
	Controlled supplement	Free choice supplement	
Soybean meal, %	61.50	61.50	10.59
Cottonseed meal, %	20.50	20.50	3.53
Minerals and vitamins, %	18.00	18.00	4.55
Corn, %	—	—	81.33
Daily consumption			
Fresh roots, kg	3.89	4.05	—
Protein supplement, kg	0.73	1.17	—
DM consumption, kg	2.07	2.52	2.60
Protein consumption, kg	0.372	0.564	0.459
Performance of pigs			
Daily weight gain, kg	0.79	0.83	0.84
Feed conversion ratio (DM)	2.90	3.36	3.43

a. Chopped fresh cassava and protein supplement offered in different feeders for free-choice or controlled consumption.
b. Protein supplement with 43% protein.
c. Commercial concentrate with 16% protein.

SOURCE: Buitrago (1964).

Table 27-4. Fresh roots and protein supplement added with molasses or sugarcane for Yorkshire growing-finishing pigs (20–90 kg).

Parameter	Feeding regime[a]		
	Only roots	Roots + molasses	Roots + sugar
Daily consumption (kg)			
Fresh cassava roots	2.99	3.27	3.11
Protein supplement (40% protein)[b]	1.02	0.92	0.85
Total DM	2.03	2.27	2.17
Total protein	0.54	0.51	0.46
Pig performance			
Daily weight gain, kg	0.69	0.72	0.74
Feed conversion rate (DM)	2.97	3.16	2.93

a. Molasses and sugarcane were used in a proportion equivalent to 15% of the total diet.
b. Protein supplement based on soybean meal (80.0%), corn (8.5%), and minerals and vitamins (11.5%). Free choice supply in feeders separated from the cassava treatments.

SOURCE: CIAT (1975).

Table 27-5. Fresh roots and protein supplements prepared with different protein sources for Duroc x Landrace growing-finishing pigs (19–90 kg)[a].

	Diet 1	Diet 2	Diet 3	Diet 4	Diet 5	Diet 6
Protein supplement (Ingredients, %)						
Soybean meal	78.10	—	—	—	—	—
Cottonseed meal	—	—	78.10	—	30.00	30.00
Meat meal	—	70.50	—	44.30	21.30	—
Blood meal				20.00	20.00	—
Fish meal	—	—	—	—	—	36.70
Corn	11.20	26.80	11.20	33.00	25.00	29.60
Vitamins and minerals	10.70	2.70	10.70	2.70	10.70	10.70
Protein level (%)	43.0	39.4	37.7	48.5	44.7	40.2
Daily consumption (kg)						
Fresh roots	4.00	3.40	3.13	3.88	4.00	4.08
Protein supplement	0.80	0.78	0.79	0.94	0.90	0.79
Total protein	0.34	0.31	0.30	0.44	0.40	0.32
Pig performance						
Daily weight gain, kg	0.72	0.68	0.59	0.72	0.72	0.68
Feed conversion rate	3.25	3.07	3.38	3.32	3.38	3.47

a. Both cassava roots and protein supplements were supplied at free choice in separated feeders.

SOURCE: Maner et al. (1978).

Table 27-6. Fresh roots and protein supplements with different protein levels for Yorkshire growing-finishing pigs (19–90 kg).

	Diet 1	Diet 2	Diet 3
Protein supplement (Ingredients, %)			
Soybean meal	26.73	53.15	79.56
Corn	67.27	37.85	8.44
Minerals and vitamins	6.0	9.0	12.0
Protein level (%)	20.0	30.0	40.0
Daily consumption (kg)			
Fresh roots	1.79	2.74	3.37
Protein supplement	1.39	1.00	0.75
Total DM	1.92	1.94	1.97
Total protein	0.34	0.40	0.39
Pig performance			
Daily weight gain, kg	0.71	0.67	0.65
Feed conversion rate	2.71	2.90	3.02

SOURCE: CIAT (1974).

Table 27-7. Performance of Yorkshire pigs fed with sweet vs. bitter cassava roots plus a protein supplement[a] with different protein levels.

	Sweet roots		Bitter roots[b]	
	Free choice supplement	Controlled supplement	Free choice supplement	Controlled supplement
Daily consumption (kg)				
Fresh roots	2.99	3.40	0.98	0.93
Protein supplement	0.81	0.82	1.21	0.22
Total DM	1.78	1.80	1.43	0.52
Pig performance				
Daily weight gain (kg)	0.66	0.77	0.56	—
Feed conversion ratio	2.99	2.61	2.86	—

a. 40% protein supplement in all treatments.
b. CMC-84 variety with 200 ppm cyanhydric acid.
SOURCE: CIAT (1973).

Table 27-8. Fresh cassava roots and protein supplementation in Duroc x Landrace gestating gilts.

	Feed treatment		
	Control pasture[a]	Cassava + supplement pasture[b]	Cassava + supplement confined[c]
Ingredients (%)			
Soybean meal	18.0	64.08	66.75
Cottonseed meal	—	20.53	20.53
Corn	74.8	—	—
Minerals and vitamins	7.20	15.39	12.72
Protein level (%)	16.0	40.0	40.0
Performance of gilts			
Weight gain in gestation, kg	19.90	24.90	37.70
Piglets/litter, No.	10.4	10.0	7.7
Piglet weight, kg	1.28	1.12	1.18
Litter weight, kg	13.31	11.20	9.08

a. Daily consumption/gilt: 1 kg of a corn-soybean meal diet.
b. Daily consumption/gilt: 1.7 kg of cassava roots and 0.4 kg of protein supplement.
c. Daily consumption/gilt: 3.1 kg of cassava roots and 0.62 kg of protein supplement.
SOURCE: Maner et al. (1978).

Table 27-9. Fresh cassava roots and protein supplementation as compared to a corn-soybean meal ration in Duroc x Landrace lactating sows.

	Corn-SBM[a]	Fresh roots + protein supplement[b]
Ingredients (%)		
Soybean meal	15.00	87.10
Corn	81.35	—
Minerals and vitamins	3.65	12.90
Protein level (%)	16.0	40.0
Daily consumption (kg)		
Corn-soybean meal diet	4.82	—
Fresh cassava	—	6.50
Protein supplement	—	1.21
Total DM intake	4.32	3.40
Performance of sows		
Weight at farrowing, kg	179.30	158.30
Weight at weaning, kg	190.30	165.80
Performance of litter at birth		
Piglets, No.	10.8	9.3
Individual weight, kg	1.18	1.36
Litter weight, kg	12.74	12.65
Performance of litter at weaning (35 days)[c]		
No. piglets	9.0	7.6
Individual weight, kg	6.03	7.63
Litter weight, kg	54.27	58.00

a. Control group with free choice consumption; SBM = soybean meal.
b. Cassava roots and protein supplement in a mixture to provide the equivalent to a 16% protein diet. Free choice consumption.
c. Piglets received the same creep feed at free choice.

SOURCE: Maner et al. (1978).

Table 27-10. The effect of using fresh cassava roots compared with ensiled cassava roots and foliage for Yorkshire x Landrace growing-finishing pigs (18–98 kg).

	Ensiled roots[a]	Ensiled roots+ foliage[b]	Fresh roots
Supplement ingredients (%)			
Corn	10.9	10.9	10.9
Cottonseed meal	78.1	78.1	78.1
Vitamins and minerals	11.0	11.0	11.0
Daily consumption (kg)			
Ensiled cassava roots (and foliage)	3.84	3.05	—
Fresh cassava roots	—	—	4.04
Protein supplement (38%)	1.01	1.01	1.01
Total protein	0.38	0.38	0.38
Pig performance			
Daily weight gain (kg)	0.77	0.64	0.75
Feed conversion ratio (DM)	2.92	3.17	3.09

a. Only chopped roots.
b. Chopped roots, leaves and stems.

SOURCE: Buitrago et al. (1978).

Table 27-11. The effect of feeding ensiled cassava roots with different protein supplements to Yorkshire growing-finishing pigs (16–90 kg) on their performance.

	Ensiled roots plus protein supplement				Corn-SBM[a] diet
	Diet 1	Diet 2	Diet 3	Diet 4	Diet 5
Supplement ingredients (%)					
Soybean meal	44.0	—	88.0	—	8.5
Cottonseed meal	44.0	48.5	—	97.0	8.5
Fish meal	—	48.5	—	—	—
Sorghum	—	—	—	78.0	
Minerals and vitamins	12.0	3.0	12.0	3.0	5.0
Protein level (%)	41.0	47.0	44.0	52.0	15.5
Daily consumption (kg)					
Cassava root silage	2.85	3.01	3.10	2.98	—
Protein supplement	0.86	0.67	0.73	0.60	—
Control diet	—	—	—	—	2.06
Performance of pigs					
Daily weight gain (kg)	0.59	0.55	0.59	0.50	0.56
Feed:weight ratio (DM)	3.27	3.31	3.24	3.50	3.31

a. SBM = soybean meal.

SOURCE: Buitrago et al. (1978).

Table 27-12. The effect of feeding ensiled cassava roots with different storage time and added salt to Yorkshire growing-finishing pigs (22–95 kg) on their performance.

Age of silage	Salt addition	Silage consumption	Supplement consumption[a]	ADG[b]	FCR[c]
> 6 months	—	3.30	0.78	0.63	3.34
	2%	2.87	0.78	0.62	3.10
< 6 months	—	3.45	0.78	0.63	3.46
	2%	3.20	0.78	0.63	3.27

a. 40% protein supplement with the following composition: 44% soybean meal, 44% cottonseed meal, 12% minerals and vitamins.
b. ADG = Average daily weight gain.
c. FCR = Feed conversion ratio.

SOURCE: Buitrago et al. (1978).

Table 27-13. Ensiled cassava roots (ECR) and protein supplement for Yorkshire lactating sows.

	ECR + supplement	Corn + supplement	Mixed corn-SBM[a]
Feed ingredients (%)			
Corn	—	—	78.1
Soybean meal	78.0	56.0	16.4
Minerals and vitamins	22.0	44.0	5.5
Protein level (%)	40	28	16
Daily feed consumption of sows (kg)			
Cassava silage	9.35	—	—
Corn	—	4.27	—
Protein supplement	1.11	0.66	—
Complete diet (corn-SBM)	—	—	4.54
Performance of sows			
Weight at farrowing, kg	140.9	168.5	155.4
Weight at weaning (35 days), kg	151.2	182.3	179.7
Performance of litters at birth			
Piglets, No.	10.6	10.0	10.7
Individual weight, kg	1.09	1.16	1.12
Total litter weight, kg	11.50	11.60	12.04
Performance of litters at weaning (35 days)[b]			
Piglets, No.	8.22	7.00	8.11
Individual weight, kg	5.54	4.95	5.33
Total litter weight, kg	45.51	34.66	43.23

a. SBM= soybean meal.
b. Piglets consumed the same creep feed at free choice.

SOURCE: Buitrago et al. (1978).

Table 27-14. Fresh cassava roots and protein supplementation in Holstein growing heifers[a].

	Commercial concentrate	Fresh cassava roots + protein supplement
Ingredients for supplemental feeding (%)[b]		
Corn	59.00	—
Sugarcane molasses	10.0	12.0
Wheat bran	14.0	16.3
Cottonseed meal	13.0	61.0
Urea	1.5	3.7
Minerals and vitamins	2.5	7.0
Daily consumption (kg)		
Commercial concentrate	2.64	—
Protein supplement	—	1.08
Cassava roots (DM)[c]	—	1.56
Sugarcane tops (DM)[c]	4.82	4.17
Total DM intake (kg)	7.46	6.81
Performance of heifers		
Initial weight, kg	191.8	190.6
Final weight, kg	366.8	377.3
Daily weight gain, kg	0.78	0.83

a. Heifers on group confinement from 8 to 16 months.
b. Heifers in the control group received 3 kg of commercial concentrate per day.
Heifers in the cassava group received 4.5 kg of fresh cassava and 1.23 kg of protein supplement per day.
Besides the supplemental feed all heifers received fresh sugarcane tops *ad libitum*.
c. Daily consumption expressed as dry matter (DM).

SOURCE: Pineda and Rubio (1972).

Table 27-15. Fresh cassava roots and protein supplementation in white Fulani milking cows[a].

	Commercial concentrate	Fresh cassava roots + protein supplement
Ingredients for supplemental feeding (%)[b]		
Corn	50.0	—
Palm cake	40.0	50.0
Peanut cake	10.0	50.0
Nutrient content (%)		
DM	90.0	91.0
Protein	15.7	26.7
Fiber	5.3	6.6
Fat	4.9	9.7
Performance of heifers		
4% fat corrected milk (kg)	6.8	7.2

a. Confined cows during an 84-days lactation period.
b. Cows in the control group received 0.42 kg of concentrate per kg of milk produced. Cows in the cassava group received 0.75 kg of fresh cassava roots plus 0.20 kg of protein supplement per kg of milk produced. Besides the supplemental feed all cows received star grass hay.

SOURCE: Olaloku et al. (1971).

Table 27-16. Fresh cassava roots and protein supplementation in growing-finishing Gyr x Brown Swiss steers[a].

	Cassava + commercial concentrates	Protein supplement		
	Diet 1	Diet 2	Diet 3	Diet 4
Ingredients (%)				
Corn	—	34.0	—	—
Rice polishings	—	53.0	—	—
Cottonseed meal	75.0	10.0	16.3	15.3
Corn husks	—	—	81.4	—
Cottonseed husks	—	—	—	82.4
Urea	12.0	—	—	—
Minerals and vitamins	13.0	2.3	2.3	2.3
Nutrient content (%)				
Protein	64.65	13.95	9.58	9.09
TDN	45.0	63.0	50.0	48.0
Ca	4.1	0.93	0.74	0.82
P	1.02	0.98	0.93	0.94
Daily feed consumption (kg)[b]				
Elephant grass	9.8	9.8	9.8	9.8
Fresh cassava	15.8	—	—	—
Protein supplement	1.6	—	—	—
Commercial concentrate	—	8.9	5.6	9.6
Total DM intake	8.4	9.3	6.4	9.9
Performance of steers				
Initial weight, kg	252	252	252	252
Final weight, kg	402	432	346	359
Daily weight gain, kg	1.39	1.66	0.87	0.99
Carcass yield, %	56.7	54.0	46.0	50.4

a. 22–24 month old steers.
b. Cassava roots were supplied at free choice in a 10:1 ratio with the protein supplement. Commercial feeds were supplied at free choice.

SOURCE: Terleira et al. (1975).

Table 27-17. Fresh cassava foliage as a complement to grazing Holstein heifers[a].

Feeding program	Diet 1	Diet 2
Daily consumption (kg/day)		
Fresh cassava foliage	7.50	—
Fresh alfalfa	—	10.00
Cane molasses	0.50	0.50
Mineral salt	*Ad libitum*	*Ad libitum*
Performance of heifers		
Initial weight, kg	189.3	183.6
Final weight, kg	256.3	241.3
Daily weight gain, kg	0.68	0.59

a. Growing heifers on star pangola grazing lots.

SOURCE: Zapata et al. (1985).

Table 27-18. Fresh cassava foliage and elephant grass for crossbred Zebu finishing steers on group confinement[a].

Feeding program	Diet 1	Diet 2	Diet 3
Elephant grass, % of mixture[b]	100	75	50
Cassava foliage, % of mixture	—	25	50
Performance of steers			
Initial weight, kg	265.5	276.3	270.0
Final weight, kg	342.5	392.7	379.0
Daily weight gain, kg	0.31	0.46	0.44
Feed conversion rate	17.6	13.7	13.7

a. Growing steers on group confinement.
b. Fresh mixture offered for free choice consumption.

SOURCE: Moore (1976).

Table 27-19. Quality grading of cassava root meal based on energy concentration.

Grade	Raw fiber (%)	Ash (%)	Fiber + azsh (%)	Metabolizable energy (Mcal/kg)
1	< 2.8	< 2.0	< 4.8	3.30
2	< 3.6	< 2.5	< 6.1	3.15
3	< 4.5	< 3.2	< 7.7	2.92
4	< 5.2	< 4.0	< 9.2	2.60

SOURCE: Buitrago (1990).

Table 27-20. Nutritional composition of cassava foliage meal with different proportions of leaves, petioles, and stems[a].

Nutrients, %	Leaves	Leaves and petioles	Leaves, petioles, and stems
Protein	22.7	21.6	20.2
Ash	10.9	9.8	8.5
Fat	6.3	6.3	5.3
Fiber	11.0	11.6	15.2
Calcium	1.68	1.70	1.68
Phosphorus	0.29	0.24	0.28
Potassium	0.69	0.60	1.09

a. Products with 8%-10% humidity.

SOURCE: Van Poppel (2001).

Table 27-21. Nutritional composition of cassava foliage meal at different harvesting times.

Main nutrients	Cassava foliage meal[a]		
	2–3 months	5–6 months	More than 8 months
Protein, % of DM	22.0	18.0	16.0
Fiber, %	16.0	20.0	26.0
Ash, %	5.5	5.8	5.8
Fat, %	5.2	5.6	5.6
Calcium, %	1.6	1.7	1.7
Phosphorus, %	0.26	0.28	0.28
TDN[b],%	68.0	66.0	58.0
DE[b], Mcal/kg	2.94	2.65	2.40

a. Third superior top (including leaves, petioles, and young stems).
b. TDN = total digestible nutrient; DE = digestible energy.

SOURCE: Buitrago (1990).

Table 27-22. Different levels of cassava root meal in diets for broilers[a].

	Cassava content							
	0		15%		30%		45%	
	S[b]	F[b]	S	F	S	F	S	F
Ingredients (%)								
Cassava root meal	0	0	15.0	15.0	30.0	30.0	45.0	45.0
Corn	59.9	64.0	42.9	47.4	26.3	30.7	9.7	14.1
Soybean meal	30.7	27.6	31.0	28.2	32.0	29.0	33.0	30.0
Fish meal	6.0	4.0	7.3	5.0	7.9	5.8	8.5	6.5
DL-methionine	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.17
Minerals and vitamins	3.6	3.6	3.6	3.6	3.6	3.6	3.6	3.6
Nutritional content								
ME, Mcal/kg	2.94	2.96	2.86	2.89	2.78	2.79	2.70	2.72
Protein, %	22.1	20.0	22.1	20.0	22.1	20.0	22.1	20.0
Methionine + cystine, %	0.87	0.80	0.87	0.79	0.86	0.80	0.86	0.79
Lysine, %	1.26	1.10	1.33	1.26	1.39	1.22	1.44	1.28
Performance of broilers								
Final weight, kg		1.47		1.50		1.45		1.39
Feed consumption, kg		3.33		3.39		3.48		3.29
Feed conversion ratio[c]		2.45		2.42		2.56		2.56

a. 0–8 weeks broilers.
b. S: starting: 0–5 weeks.
c. F: finishing: 5–8 weeks.

SOURCE: Enríquez V et al. (1977).

Table 27-23. Different levels of cassava root meal in iso-energetic diets for broilers[a].

	Cassava meal level (%)					
	0	20	30	40	50	58
Ingredients (%)						
Cassava root meal	0	20.0	30.0	40.0	50.0	58.0
Corn	54.0	30.0	16.0	9.0	3.9	—
Rice polishings	10.0	9.0	8.6	8.1	0	—
Fish meal	6.0	6.0	6.0	6.0	10.0	11.0
Soybean meal	27.0	31.0	35.0	32.0	32.0	27.0
Vegetable oil	—	1.0	1.4	1.9	2.0	2.0
Minerals and vitamins	3.0	3.0	3.0	3.0	2.1	2.0
Broiler performance						
Final weight, kg	2.04	2.05	2.04	2.03	2.04	2.04
Feed conversion ratio	2.61	2.59	2.64	2.61	2.56	2.53
Mortality, %	9.2	3.0	3.0	4.0	10.2	5.0

a. 0–6 week broilers.

SOURCE: Chou et al. (1974).

Table 27-24. Different levels of cassava root meal in pelletized iso-energetic diets for broilers[a].

	Cassava meal level (%)					
	0	10	20	30	40	50
Ingredients (%)						
Cassava root meal	0	10.0	20.0	30.0	40.0	50.0
Wheat	53.9	48.9	38.9	28.8	18.3	6.1
Corn	16.2	10.5	9.5	9.0	9.0	10.0
Soybean meal	16.3	14.8	13.8	12.8	11.6	11.1
Fish meal	5.0	6.8	8.9	10.5	11.4	12.5
Meat meal	3.0	3.0	3.0	3.1	4.3	5.0
Vegetable oil	3.1	3.9	3.9	3.9	3.6	3.5
DL-methionine	0.11	0.12	0.15	0.18	0.20	0.23
Minerals and vitamins	2.4	2.0	1.9	1.7	1.6	1.4
Nutritional composition						
ME, Megajoules/kg	13.7	13.5	13.8	13.9	13.9	13.8
Protein, %	19.3	19.7	20.0	19.4	19.4	19.8
Broiler performance						
Final weight, kg	2.31	2.39	2.30	2.31	2.31	2.30
Feed consumption, kg	4.45	4.49	4.39	4.59	4.38	4.62
Feed conversion ratio	1.92	1.88	1.91	1.99	1.90	2.01

a. 0–7 week broilers.

SOURCE: Stevenson and Jackson (1983).

Table 27-25. Performance of Leghorn layers with increasing levels of cassava root meal[a].

	Diet 1	Diet 2	Diet 3	Diet 4
Ingredients (%)				
Cassava root meal	—	10.0	25.0	50.0
Corn	62.0	50.0	32.1	2.1
Soybean meal	9.20	11.20	14.1	19.1
Rice bran	5.0	5.0	5.0	5.0
Copra meal	7.5	7.5	7.5	7.5
Fish meal	5.0	5.0	5.0	5.0
Meat and bone meal	2.5	2.5	2.5	2.5
Leucaena meal	3.0	3.0	3.0	3.0
Vitamins and minerals	5.8	5.8	5.8	5.8
Performance of layers				
Egg production, %	63.9	62.8	58.7	62.8
Weight of eggs, g	58	57	57	57
Feed conversion ratio	2.01	2.10	2.22	2.12
Yolk pigmentation[b]	6.0	6.0	5.0	3.5

a. 20–48 week layers.
b. Roche pigmentation scale.

SOURCE: Enriquez and Ross (1972).

Table 27-26. Performance of Hisex layers with increasing levels of cassava root meal[a].

	Diet 1	Diet 2	Diet 3	Diet 4	Diet 5	Diet 6
Ingredients (%)						
Cassava root meal	—	10.0	20.0	30.0	40.0	50.0
Wheat	50.0	50.0	46.1	30.8	15.5	—
Corn	13.2	8.5	5.8	8.8	11.9	15.2
Barley	12.7	5.4	—	—	—	—
Fish meal	3.0	3.0	3.0	3.0	3.0	2.9
Soybean meal	7.9	9.9	11.9	14.2	16.5	18.8
Meat and bone meal	5.0	5.0	5.0	5.0	5.0	5.0
Animal fat	1.0	1.0	1.0	1.0	1.0	1.0
DL-methionine	0.05	0.06	0.07	0.08	0.09	0.09
Vitamins and minerals	7.2	7.1	7.1	7.0	7.0	6.9
Nutritional composition						
ME, Megajoules (MJ)/kg	11.0	11.0	11.0	11.0	11.5	11.1
Protein, %	15.9	15.7	15.9	15.8	15.9	16.0
Calcium, %	3.2	3.3	3.3	3.3	3.3	3.3
Phosphorus, %	0.64	0.63	0.63	0.60	0.58	0.57
Performance of layers						
No. eggs in 280 days	205	203	205	215	201	196
Weight of eggs, g	55	56	55	55	55	56
Daily feed consumption, g	119	119	111	113	112	109
kg of eggs/kg of feed	0.38	0.34	0.35	0.38	0.35	0.36

a. 27–67 week layers.

SOURCE: Stevenson (1984).

Table 27-27. Performance of Shaver layers with increasing levels of cassava root meal[a].

	Diet 1	Diet 2	Diet 3	Diet 4	Diet 5	Diet 6
Ingredients (%)						
Cassava root meal	—	25.0	50.0	—	25.0	50.0
Sorghum	65.2	38.7	12.1	57.3	28.3	—
Soybean meal	11.3	14.8	18.3	—	—	—
Fullfat soybeans	—	—	—	15.3	20.0	24.7
Fish meal	7.0	7.0	7.0	7.0	7.0	7.0
DL-methionine	0.13	0.16	0.18	0.14	0.17	0.19
L-lysine	0.17	0.10	0.04	0.15	0.08	--
Corn cobs	6.6	4.9	3.2	10.6	10.1	6.8
Vitamins and minerals	9.6	9.3	9.2	9.5	9.3	11.3
Nutritional composition						
ME, Mcal/kg	2.65	2.65	2.65	2.65	2.65	2.65
Protein, %	15.5	15.5	15.5	15.5	15.5	15.5
Methionine + cystine, %	0.66	0.66	0.66	0.66	0.66	0.66
Lysine, %	0.98	0.98	0.98	0.98	0.98	0.98
Linoleic acid, %	0.78	0.51	0.24	1.92	2.01	2.10
Performance of layers						
Egg production, %	72.3	77.9	78.0	72.6	72.0	74.5
Weight of eggs, g	69	67	67	70	71	69
Daily feed consumption, g	125	133	132	122	121	120
Yolk pigmentation[b]	5.1	4.9	4.7	6.4	6.5	6.3

a. 42–62 week layers.
b. Roche pigmentation scale.

SOURCE: Hennesey and Ayala (1986).

Table 27-28. Bitter vs. sweet varieties of cassava root meal for growing Yorkshire pigs[a].

	Bitter[b]	Sweet[c]
Ingredients (%)		
Cassava root meal	71.0	71.0
Soybean meal	25.0	25.0
Vitamins and minerals	4.0	4.0
Performance of pigs		
Daily weight gain, kg	0.56	0.62
Feed consumption, kg	1.35	1.77
Feed conversion ratio	2.43	2.86

a. 38–58 kg.
b. CMC-84 variety with 150-200 ppm HCN.
c. 80 ppm HCN.

SOURCE: Gómez and Buitrago (1982).

Table 27-29. Root meal of low-HCN cassava varieties in substitution of corn for growing crossbred pigs and their effect on carcass characteristics[a,b].

	Diet 1	Diet 2	Diet 3	Diet 4
Ingredients (%)				
Cassava root meal	—	20.0	40.0	58.5
Corn	60.0	40.0	20.0	—
Meat meal	5.0	5.5	6.0	6.5
Sesame meal	20.0	23.0	26.0	29.0
Rice polishings	9.0	5.5	2.0	—
Cane molasses	5.0	5.0	5.0	5.0
Vitamins and minerals	1.0	1.0	1.0	1.0
Performance of pigs				
Daily weight gain, kg	0.79	0.78	0.84	0.80
Feed conversion ratio	3.50	3.60	3.30	3.30
Carcass characteristics				
Carcass length, cm	74.0	72.1	73.0	74.0
Dorsal fat, cm	3.10	3.40	3.30	2.90
Iodine number	69.3	64.5	71.3	69.3

a. 40–82 growing-finishing pigs.
b. 40 ppm HCN in fresh roots.

SOURCE: Chicco et al. (1972).

Table 27-30. Effect of adding cane molasses, raw sugar, or animal fat to diets based on cassava root meal for Landrace x Yorkshire pigs[a].

	Diet 1	Diet 2	Diet 3	Diet 4	Diet 5
Ingredients (%)					
Cassava root meal	65.9	65.7	55.5	55.5	55.5
Soybean meal	29.4	29.4	29.8	29.8	29.8
Cane molasses	—	—	10.0	—	—
Raw sugar	—	—	—	10.0	—
Animal fat	—	—	—	—	10.0
DL-methionine	—	0.2	—	—	—
Vitamins and minerals	4.7	4.7	4.7	4.7	4.7
Performance of pigs					
Daily weight gain, kg	0.71	0.68	0.69	0.68	0.63
Daily feed consumption, kg	1.94	1.88	1.89	1.84	1.59
Feed conversion ratio	2.73	2.76	2.74	2.70	2.53

a. 20–50 kg growing pigs. Isoproteic (16 %) diets.

SOURCE: Maner et al. (1978).

Table 27-31. Effect of adding methionine and other sulfur sources to diets based on cassava root meal for Landrace x Yorkshire pigs[a].

Feed treatment	Performance of pigs		
	Daily weight gain, kg	Daily feed consumption, kg	Feed conversion ratio
Control diet (CD)[b]	0.67	1.81	2.43
CD + 0.2% methionine	0.70	1.77	2.29
CD + 0.8% sodium thiosulphate	0.61	1.58	2.32
CD + 0.2% elemental sulfur	0.65	1.64	2.29

a. 20–50 kg growing pigs.
b. 16% protein control diet based on cassava root meal (70%), soybean meal (25%), and vitamin-mineral mixture (5%).

SOURCE: CIAT (1975).

Table 27-32. Cassava root meal vs. corn in diets for gestating and lactation sows[a].

	Diet 1	Diet 2
Ingredients (%)		
Cassava root meal	—	67.0
Corn	76.4	—
Soybean meal	18.8	28.2
Vitamins and minerals	4.8	4.8
Nutritional composition (%)		
Protein	16.0	16.0
Metionine + cystine	0.55	0.47
Lysine	0.77	0.92
Performance of sows		
Breeding weight, kg	127.6	118.5
Farrowing weight, kg	160.6	146.1
Weaning weight, kg	153.9	159.6
Performance of litters at farrowing		
Piglets, No.	10.0	8.4
Individual weight, kg	1.09	0.97
Litter weight, kg	10.9	8.15
Performance of litters at weaning		
No. of piglets	9.4	6.6
Individual weight, kg	15.87	15.70
Litter weight, kg	149.18	103.62

a. 56–day weaning time.

Table 27-33. Cassava root meal vs. corn in diets for lactating sows[a].

	Diet 1	Diet 2
Ingredients (%)		
Cassava root meal	—	59.1
Corn	81.5	—
Cane molasses	—	10.0
Soybean meal	15.0	27.4
Vitamins and minerals	3.5	3.5
Nutritional composition (%)		
Protein	16.0	16.0
Metionine + cystine	0.52	0.44
Lysine	0.71	0.89
Performance of sows		
Farrowing weight, kg	179.3	170.6
Weaning weight, kg	190.3	183.0
Performance of litters at farrowing		
Piglets, No.	10.8	10.1
Individual weight, kg	1.18	1.22
Litter weight, kg	12.74	12.32
Performance of litters at weaning		
Piglets, No.	9.01	7.90
Individual weight, kg	6.08	6.80
Litter weight, kg	54.0	53.7

a. 35-day weaning time.

SOURCE: Maner et al. (1978).

Table 27-34. Effect of partial substituting of corn by cassava root meal in lactating piglets[a].

	Diet 1	Diet 2	Diet 3
Ingredients (%)			
Cassava root meal	—	10.0	20.0
Corn	59.6	49.0	38.0
Soybean meal	27.7	28.3	28.9
Dehydrated milk whey	10.0	10.0	10.0
Vitamins and minerals	2.7	2.7	2.7
Nutritional composition			
Protein, %	18.5	18.1	17.8
Lysine, %	1.12	1.12	1.12
Calcium, %	0.78	0.78	0.78
Phosphorus, %	0.59	0.59	0.59
Performance of piglets			
Daily weight gain, kg	0.38	0.37	0.39
Daily feed consumption, kg	0.68	0.60	0.60
Feed conversion ratio	1.63	1.62	1.64

a. 7–18 kg piglets (30 days).

SOURCE: Ravindran et al. (1983).

Table 27-35. Feed consumption in lactating piglets associated with increasing levels of dry cassava root meal in their feed[a].

Age of piglets (days)	Total feed consumption per litter (kg)[b]		
	0% cassava meal	20% cassava meal	40% cassava meal
14 – 42	1.8	3.0	12.4
42 – 56	14.7	26.2	39.1
14 – 52 (total)	16.5	29.2	51.5

a. 1–56 day piglets.
b. Free choice cassava-sorghum-soybean diets with 20% protein.

SOURCE: Gómez et al. (1981).

Table 27-36. Effect of partial substitution of corn by cassava root meal in the feed of dairy calves[a].

	Energy source in dry feed[b]		
	50% sorghum	25% sorghum 25% cassava	50% cassava meal meal
Performance of calves (kg)			
Initial weight	35.15	34.10	34.26
Final weight	89.0	92.4	81.03
Daily weight gain	0.48	0.52	0.42
Total feed consumption in 112 days (kg)			
Dry feed	109.3	108.2	82.0
Alfalfa hay	28.4	28.6	29.1
Milk	132.7	135.3	126.9

a. 1 to 112-day Holstein calves. Only milk during the first 42 days and *ad libitum* dry feed plus alfalfa hay from 42 to 112 days.
b. Dry feed also supplemented with protein, mineral, and vitamin sources.

SOURCE: Peixoto (1973).

Table 27-37. Effect of partial substitution of sorghum by cassava root meal in dairy cows[a].

	Diet 1	Diet 2
Ingredients in dry diets (%)[b]		
Cassava root meal	—	27.0
Sorghum	54.0	27.0
Cottonseed meal	44.0	43.5
Urea	—	0.50
Salt	1.0	1.0
Minerals	1.0	1.0
Nutritional composition (%)		
NDT[c]	69.0	67.4
Protein	15.7	15.7
Daily milk production (kg)		
Non-corrected milk	12.0	12.4
4% fat corrected milk	11.4	11.3

a. 63–day lactation period.
b. Daily supply of 0.42 kg of dried feed per kg of milk produced plus *ad libitum* sorghum silage.
c. TDN = Total digestible nutrients.

SOURCE: Ribeiro et al. (1976).

Table 27-38. Effect of partial substitution of oats by cassava root meal in the feed of dairy cows[a].

	Energy source in dry feed[b]		
	Oats	Oats + cassava meal	Cassava meal
Ingredients (%)			
Cassava root meal	—	12.5	25.0
Oats	25.0	12.5	25.0
Peanut meal	20.0	25.0	25.0
Legumes hay	35.0	35.0	35.0
Wheat bran	20.0	20.0	20.0
Nutritional composition (%)			
TDN[c]	69.0	67.0	65.0
Protein	15.5	16.0	15.5
Daily milk production (kg)			
Non-corrected milk	6.97	7.20	7.84
4% fat corrected milk	7.81	7.91	7.84

a. 140–day lactation period.
b. Daily supply of 1 kg of dried feed per 3 kg of milk produced plus *ad libitum* Para grass hay.
c. TDN = total digestible nutrients.

SOURCE: Mathur et al. (1969).

Table 27-39. Growing-finishing crossbred Zebu steers under intensive grazing supplemented with two levels of cassava root meal[a].

	Dry supplement (kg/animal per day)	
Ingredientes (%)		
Cassava root meal	0.65	1.10
Cane molasses	4.5	4.5
Urea	0.23	0.25
Blood meal	0.22	0.22
Performance of steers (kg)		
Initial weight	336.0	336.0
Final weight	403.0	411.0
Daily weight gain	0.71	0.77

a. Steers on intensive grazing (4.8 head/ha) plus controlled dry supplement.

SOURCE: Lozada and Alderete (1979).

Table 27-40. Feedlot crossbred Zebu steers under total confinement with free choice consumption of sorghum-cassava meal supplement and controlled sorghum silage[a].

	Diet 1	Diet 2	Diet 3	Diet 4	Diet 5
Ingredients in dry supplement (%)					
Cassava root meal	—	20.5	41.0	61.5	82.0
Sorghum	88.5	66.4	44.3	22.2	—
Cottonseed meal	7.8	9.2	10.5	11.9	13.3
Urea	1.7	1.9	2.2	2.4	2.7
Vitamins and minerals	2.0	2.0	2.0	2.0	2.0
Performance of steers					
Initial weight, kg	302.7	306.2	317.2	305.8	315.4
Final weight, kg	424.4	425.1	427.2	412.4	404.3
Daily weight gain, kg	1.16	1.13	1.05	1.01	0.85
Dry supplement consumption, kg	10.2	9.3	8.6	8.1	6.9
Silage consumption, kg	3.1	5.0	5.5	5.2	5.2
Dry feed/weight gain	8.79	8.23	8.18	8.08	8.18

a. Free choice supplement and controlled sorghum silage (1.5 kg/100 kg body weight).

SOURCE: Delgado et al. (1975).

Table 27-41. Effect of including high levels of cassava foliage meal or alfalfa meal for Leghorn broilers[a].

	Diet 1	Diet 2	Diet 3	Diet 4
Ingredients (%)				
Cassava foliage meal	15.0	—	20.0	—
Alfalfa meal	—	15.0	—	20.0
Corn	53.6	53.6	51.9	51.9
Soybean meal	19.9	19.9	16.6	16.6
Tuna fish meal	5.0	5.0	5.0	5.0
Meat and bone meal	5.0	5.0	5.0	5.0
Vitamins and minerals	1.5	1.5	1.5	1.5
Performance of broilers				
Weight at 3 weeks, g	191	212	186	203
Daily feed consumption, g	21.8	21.5	22.5	21.6
Feed conversion ratio	2.40	2.13	2.54	2.24

a. 1–21 day old broilers.

SOURCE: Ross and Enriquez (1969).

Table 27-42. Effect of including a high level of cassava foliage meal and different levels of methionine in the feed of Leghorn broilers[a].

	Diet 1	Diet 2
Ingredients (%)		
Cassava foliage meal	—	20.0
Corn	66.5	51.9
Soybean meal	22.0	16.6
Tuna fish meal	5.0	5.0
Meat and bone meal	5.0	5.0
Vitamins and minerals	1.5	1.5
	Body weight at 21 days (grams)	
Methionine addition (%)		
0	208	114
0.2	220	185
0.3	—	211
0.4	—	205
0.5	—	202
	Feed conversion rate	
Methionine addition (%)		
0	2.10	2.73
0.2	1.99	2.32
0.3	—	2.18
0.4	—	2.35
0.5	—	2.18

a. 1–21 day old broilers.

SOURCE: Ross and Enriquez (1969).

Table 27-43. Effect of including low levels of cassava foliage meal on egg yolk pigmentation of Leghorn layers.

	Diet 1	Diet 2	Diet 3	Diet 4
Ingredients (%)				
Cassava foliage meal	—	2.5	5.0	—
White corn	68.5	66.0	63.5	—
Yellow corn	—	—	—	68.5
Wheat bran	2.5	19.9	16.6	16.6
Dextrose	0.5	0.5	0.5	0.5
Fish meal	2.5	2.5	2.5	2.5
Peanut meal	5.0	5.0	5.0	5.0
Soybean meal	13.0	13.0	13.0	13.0
Vitamins and minerals	8.0	8.0	8.0	8.0
Egg yolk pigmentation				
Grade on Roche scale	1.0	4.9	5.4	9.5

SOURCE: Agudu (1972).

Table 27-44. Effect of including high levels of dried cassava foliage meal in Landrace x Yorkshire growing pigs[a].

	Diet 1	Diet 2	Diet 3	Diet 4
Ingredients (%)				
Cassava foliage meal	—	10.0	20.0	20.0
Corn	74.40	66.85	59.85	59.65
Fish meal	8.0	7.0	7.0	7.0
Meat and bone meal	7.0	7.0	5.0	5.0
Soybean meal	7.95	6.50	5.50	5.50
DL-methionine	—	—	—	0.20
Vitamins and minerals	2.65	2.65	2.65	2.65
Performance of pigs				
Daily weight gain, kg	0.35	0.31	0.29	0.32
Daily feed consumption, kg	1.21	1.10	1.08	1.13
Feed conversion ratio	3.42	3.52	3.79	3.50

a. Growing pigs with initial weight of 13.6 kg, consuming isoproteic (18%) diets.

SOURCE: Choo and Hutagalung (1972).

Table 27-45. Effect of including high levels of dried cassava foliage meal in landrace x yorshire growing pigs[a].

	Diet 1	Diet 2	Diet 3	Diet 4	Diet 5
Ingredients (%)					
Cassava foliage meal	—	20.0	20.0	20.0	20.0
Corn	77.6	57.1	52.1	54.1	51.9
Soybean meal	14.8	10.3	10.3	10.3	10.3
Fish meal	2.5	2.5	2.5	2.5	2.5
Meat and bone meal	2.5	2.5	2.5	2.5	2.5
Molasses	—	5.0	10.0	5.0	10.0
Palm oil	—	—	—	3.0	—
DL-methionine	—	—	—	—	0.20
Vitamins and minerals	2.6	2.6	2.6	2.6	2.6
Performance of pigs					
Daily weight gain, kg	0.53	0.43	0.46	0.44	0.50
Daily feed consumption, kg	1.90	1.66	1.71	1.68	1.84
Feed conversion rate	3.60	3.90	3.74	3.80	3.68

a. Growing pigs with initial weight of 31 kg, consuming isoproteic (18%) diets.

SOURCE: Choo and Hutagalung (1972).

Table 27-46. Main nutritional differences between cassava root meal (CRM) and fullfat soybeans (FFSB).

Nutrients	Unit	CRM	FFSB
Protein	%	2.8	38.0
Fat	%	1.2	19
Starch	%	70	9
ME, poultry	Mcal/kg	3.1–3.2	3.6–3.8
ME, swine	Mcal/kg	3.2–3.4	3.7–3.8
Linoleic acid	%	0.2	8.9
Fiber	%	2.6	4.9
Ash	%	3.2	5.2
Methionine	%	0.03	0.51
Cystine	%	0.02	0.60
Lisine	%	0.05	2.31
Threonine	%	0.05	1.43
Thryptophane	%	0.02	0.52
Lecithin	%	0.1	2.1

SOURCE: Buitrago (1990).

Table 27-47. Broiler diets totally based on cassava root meal, cassava foliage meal, and fullfat soybeans.

Ingredients (%)	Starter (0-3 weeks)	Finisher (3-6 weeks)	Finisher (6-8 weeks)
Cassava root meal	41.05	44.70	50.50
Cassava foliage meal	—	6.0	6.0
Fullfat soybeans	44.50	44.74	40.80
Soybean meal	10.60	1.40	—
DL-methionine	0.25	0.16	0.10
L-lysine	—	—	—
Dicalcium phosphate	1.70	1.30	1.00
Calcium carbonate	1.20	1.00	0.90
Salt	0.30	0.30	0.30
Vitamins, minerals, additives	0.40	0.40	0.40

Table 27-48. Nutritional composition of broiler diets totally based on cassava root meal, cassava foliage meal, fullfat soybeans, and soybean meal.

Nutrients	Starter (0-3 weeks)	Finisher (3-6 weeks)	Finisher (6-8 weeks)
ME, Mcal/kg	3.20	3.20	3.20
Protein, %	23.0	20.0	18.0
Lisine, %	1.30	1.15	1.00
Methionine, %	0.55	0.43	0.34
Methionine + cystine	0.90	0.72	0.60
Threonine, %	0.85	0.78	0.69
Tryptophane, %	0.30	0.25	0.20
Fiber, %	4.3	5.0	4.8
Fat, %	8.8	8.9	8.3
Ash, %	7.2	6.6	6.1
Calcium, %	1.00	0.90	0.80
Available phosphorus, %	0.45	0.36	0.30
Linoleic acid, %	3.5	3.8	3.5

Table 27-49. Composition of broiler diets with intermediate levels of cassava meal and fullfat soybeans[a].

	Starting	Finishing
Ingredients (%)		
Corn	25.34	30.79
Cassava roots meal	25.0	25.0
Fullfat soybeans (toasted)	31.4	33.8
Soybean meal	12.1	4.8
Chicken viscera meal	3.00	3.00
Dicalcium phosphate	1.30	1.00
Calcium carbonate	1.00	0.90
DL-methionine	0.23	0.10
Salt	0.35	0.30
Vitamins and minerals	0.12	0.10
Anticoccidial	0.05	0.10
Fungicide	0.10	0.10
Nutritional composition		
ME, Mcal/kg	3.10	3.20
Protein, %	22.0	17.0
Methionine, %	0.56	0.40
Met + cystine, %	0.90	0.72
Lysine, %	1.24	1.10
Threonine, %	0.80	0.75
Linoleic acid, %	3.25	3.48
Calcium, %	0.90	0.82
Available phosphorus, %	0.42	0.39

a. Commercial Farm El Recreo–Carioca. Buga, Colombia.

SOURCE: Buitrago et al. (2002).

Table 27-50. Composition of broiler diets with intermediate levels of cassava meal and FFSB[a].

	Starting	Finishing
Ingredients (%)		
Cassava roots meal	20.0	25.0
FFSB (toasted)	32.0	34.0
Soybean meal	8.20	2.80
Fish meal	3.50	4.00
Palm oil	—	0.10
Dicalcium phosphate	0.90	0.70
Calcium carbonate	0.80	0.90
DL-methionine	0.27	0.22
Salt	0.25	0.25
Chline chloride	0.12	0.10
Vitamins and minerals	0.12	0.10
Anticoccidial	0.05	0.10
Fungicide	0.10	0.10
Nutritional composition		
ME, Mcal/kg	3.15	3.20
Protein, %	21.0	19.0
Methionine, %	0.58	0.51
Met + cystine, %	0.88	0.77
Lysine, %	1.23	1.10
Threonine, %	0.60	0.59
Linoleic acid, %	3.08	3.10
Calcium, %	0.90	0.91
Available phosphorus, %	0.43	0.42

a. Commercial Farms: Avités – Nutrilisto. Cereté, Colombia.

SOURCE: Buitrago et al. (2002).

Table 27-51. Results on the performance of broilers with intermediate levels of cassava root meal in the diet[a].

	Control (corn-SBM)[b]	Cassava-FFSB[c]
Number of birds at starting	7.680	7.673
Number of birds at finishing	7.415	7.108
Number of days	42	42
Mortality, %	3.2	5.7
Final weight, g	1.976	1.942
Feed consumption, g	3.754	3.781
Conversion efficiency	1.90	1.94
European conversion efficiency	239	218

a. El Recreo Farm. Buga, Cauca Valley, Colombia.
b. Control commercial diet based on corn and soybean meal.
c. Experimental diet based on cassava root meal and fullfat soybeans.

SOURCE: Buitrago et al. (2002).

Table 27-52. Results on the performance of broilers with intermediate levels of cassava root meal in the diet[a].

	Control (sorghum-SBM)[b]	Cassava-FFSB[c]
Number of birds at starting	48.441	24.000
Number of birds at finishing	46.199	22.392
Number of days	42	42
Mortality, %	4.6	6.7
Final weight, g	1.934	1.915
Feed consumption, g	3.559	3.152
Feed conversion ratio	1.84	1.69
European conversion efficiency	239	218

a. Avites Farm. Cereté, Córdoba, Colombia.
b. Control commercial diet based on sorghum and soybean meal.
c. Experimental diet based on cassava root meal and fullfat soybeans.

SOURCE: Buitrago et al. (2002).

Table 27-53. Composition of broiler diets with maximum levels of cassava meal and FFSB in the starting phase.

	Control	CRM + FFSB[a]			CRM + CFM +
	(corn-SBM)	Solar drying	Artificial drying		FFSB[d]
			A[b]	B[c]	
Ingredients (%)					
Corn	59.37	—	—	—	—
CRM	—	45.75	45.75	45.75	40.45
CFM	—	—	—	—	6.00
FFSB	12.8	30.0	30.0	30.0	30.0
Soybean meal	21.0	18.7	18.7	18.7	18.7
Palm oil	3.0	2.9	2.9	2.9	4.5
DL-methionine	0.16	0.29	0.29	0.29	0.29
L-lysine	0.07	—	—	—	—
Bone meal	1.70	1.90	1.90	1.90	1.90
Ca carbonate	1.50	—	—	—	—
Salt	0.30	0.30	0.30	0.30	0.30
Vitamin Premix	0.10	0.10	0.10	0.10	0.10
Nutritional composition					
ME, Mcal/kg	3.20	3.20	3.20	3.20	3.20
Protein, %	22.0	22.0	22.0	22.0	22.0
Methionine, %	0.59	0.59	0.59	0.59	0.59
Met + cystine, %	0.90	0.90	0.90	0.90	0.90
Lysine, %	1.26	1.26	1.26	1.26	1.27
Linoleic acid, %	2.62	3.42	3.42	3.42	3.56
Ca, %	0.91	0.91	0.91	0.91	0.91
Available P, %	0.42	0.42	0.42	0.42	0.42

a. Cassava root meal + fullfat soybeans.
b. Equipment with steam heating.
c. Equipment with propane gas heating.
d. Cassava root meal + cassava foliage meal + fullfat soybeans.

SOURCE: Gil et al. (2001).

Table 27-54. Composition of broiler diets with maximum levels of cassava meal and FFSB in the finishing phase.

	Control (corn-SBM)	CRM + FFSB[a]			CRM + CFM + FFSB[d]
		Solar drying	Artificial drying		
			A[b]	B[c]	
Ingredients (%)					
Corn	66.85	—	—	—	—
CRM	—	49.8	49.8	49.8	46.1
CFM	—	—	—	—	6.00
FFSB	6.1	41.6	41.6	41.6	45.1
Soybean meal	20.7	5.2	5.2	5.2	—
DL-methionine	0.13	0.23	0.23	0.23	0.23
Lysine	0.19	—	—	—	—
Bone meal	1.60	1.90	1.90	1.90	1.90
Ca carbonate	1.10	—	—	—	—
Salt	0.30	0.30	0.30	0.30	0.30
Vitamin Premix	0.10	0.10	0.10	0.10	0.10
Nutritional composition					
ME, Mcal/kg	3.20	3.20	3.20	3.20	3.20
Protein, %	20.0	20.0	20.0	20.0	20.0
Methionine, %	0.49	0.49	0.49	0.49	0.49
Met + cystine, %	0.78	0.78	0.78	0.78	0.78
Lysine, %	1.12	1.12	1.12	1.12	1.12
Linoleic acid, %	2.20	3.60	3.60	3.60	3.85
Ca, %	0.90	0.90	0.90	0.90	0.90
Available P, %	0.40	0.40	0.40	0.40	0.40

a. Cassava root meal + fullfat soybeans.
b. Equipment with steam heating.
c. Equipment with propane gas heating.
d. Cassava root meal – cassava foliage meal + fullfat soybeans.

SOURCE: Gil et al. (2001).

Table 27-55. Results on the performance of broilers with maximum levels of cassava root meal and FFSB in the diet during the starting and finishing phases.

	Control (corn-SBM)	CRM + FFSB[a]			CRM + CFM + FFSB[d]
		Solar drying	Artificial drying		
			A[b]	B[c]	
Initial weight, g	39.8	39,5	39.4	39.5	39.7
Final weight, g	2,139	2,279	2,237	2,387	2,113
Feed consumption	4.73	4.88	4.65	4.68	4.72
Feed conversion rate	2.21	2.14	2.08	1.96	2.24

a. Cassava root meal + fullfat soybeans.
b. Equipment with steam heating.
c. Equipment with propane gas heating.
d. Cassava root meal + cassava foliage meal + fullfat soybeans.

SOURCE: Gil et al. (2001).

Table 27-56. Example of layer diets with maximum levels of cassava root meal fullfat soybeans and cassava foliage meal.

Ingredients (%)	Replacement chickens		Laying hens	
	0-6 weeks	7-15 weeks	Phase 1	Phase 2
Cassava root meal	59.3	61.4	41.6	51.9
FFSB[a]	9.6	9.2	38.9	28.0
Cassava foliage meal	—	6.0	6.0	6.0
Soybean meal	26.9	19.6	1.9	3.6
Calcium phosphate	1.4	1.2	1.2	1.2
Calcium carbonate	1.9	1.8	9.5	8.4
DL-methionine	0.21	0.10	0.23	0.23
Salt	0.30	0.30	0.30	0.30
Vitamins and minerals	0.40	0.40	0.40	0.40

a. Fullfat soybean.

Table 27-57. Nutritional composition of layer diets with maximum levels of cassava root meal, fullfat soybeans, and cassava foliage meal[a].

Nutritional composition	Replacement chickens		Laying hens	
	0-6 weeks	7-15 weeks	Phase 1	Phase 2
Metabolizable energy, Mcal/kg	2.80	2.75	2.90	2.80
Protein, %	18.0	15.5	18.0	15.0
Lisine	0.98	0.68	0.86	0.75
Methionine	0.42	0.30	0.38	0.36
Met + cystine	0.72	0.54	0.73	0.64
Threonine	0.65	0.60	0.66	0.50
Calcium	0.90	1.10	4.00	3.60
Available phosphorus	0.38	0.35	0.32	0.32
Fiber	3.8	4.6	4.6	4.4
Fat	2.0	2.9	7.8	6.0
Linoleic acid	1.0	1.0	2.5	2.4
Ash	6.6	7.2	14.2	13.0

a. Nutrient requirements based on NRC (1998).

Table 27-58. Example of layer diets with medium levels of cassava root meal, fullfat soybeans, and cassava foliage meal.

Ingredients (%)	Replacement chickens		Laying hens	
	0-6 weeks	7-15 weeks	Phase 1	Phase 2
Corn	39.0	42.9	19.7	31.0
Cassava root meal	25.0	25.0	25.0	25.0
FFSB	10.0	9.84	34.6	19.1
Cassava foliage meal	—	6.0	6.0	6.0
Soybean meal	21.6	12.2	2.8	7.2
Calcium phosphate	1.3	1.2	1.1	1.1
Calcium carbonate	2.20	2.10	9.9	9.7
DL-methionine	0.14	0.06	0.20	0.17
Salt	0.30	0.30	0.30	0.30
Vitamins and minerals	0.40	0.40	0.40	0.40

Table 27-59. Nutritional composition of layer diets with medium levels of cassava root meal, fullfat soybeans, and cassava foliage meal[a].

	Replacement chickens		Laying hens	
	0-6 weeks	7-15 weeks	Phase 1	Phase 2
Metabolizable energy, Mcal/kg	2.80	2.75	2.90	2.80
Protein, %	18.0	15.5	18.0	15.0
Lisine, %	0.98	0.68	0.86	0.75
Methionine	0.42	0.30	0.38	0.36
Met + cystine	0.72	0.54	0.73	0.64
Threonine	0.65	0.60	0.66	0.50
Calcium	0.90	1.10	4.00	3.60
Available phosphorus	0.38	0.35	0.32	0.32
Fiber	3.8	4.6	4.6	4.4
Fat	2.0	2.9	7.8	6.0
Linoleic acid	1.0	1.0	2.5	2.4
Ash	6.6	7.2	14.2	13.0

a. Nutrient requirements based on NRC (1998).

Table 27-60. Diets for commercial layers with 10% cassava root meal and fullfat soybeans.

	Control (corn)	10% cassava root meal
Ingredients (%)		
Corn	57.8	45.3
Cassava root meal	—	10.0
FFSB (toasted)	5.3	9.1
Soybean meal	16.2	15.0
Fish meal (65 % protein)	5.0	5.0
Wheat bran	3.5	3.5
DL-methionine	0.18	0.20
Calcium carbonate	9.71	9.64
Calcium phosphate	0.95	0.91
Salt	0.30	0.30
Vitamins and minerals	0.60	0.60
Nutritional composition		
Metabolizable energy, Mcal/kg	2.75	2.75
Protein, %	17.5	17.5
Methionine, %	0.44	0.44
Met + cystine, %	0.75	0.75
Lysine, %	0.91	0.91
Calcium, %	3.90	3.90
Available phosphorus, %	0.45	0.45
Linoleic acid, %	1.36	1.39

Table 27-61. Performance of commercial layers fed with 10% cassava root meal and fullfat soybeans[a].

	Control (corn)	10% cassava root meal
Daily feed consumption, g	102.6	103.2
Laying, %	89.2	89.5
Feed conversion (per dozen eggs)	1.4	1.4

a. 48 to 55-week laying period. La Esperanza Poultry Farm. Buga, Valle. 1,010 masl. 26 °C.

SOURCE: Gutiérrez and Martínez (1998).

Table 27-62. Diets for commercial layers with 15% cassava root meal and fullfat soybeans.

	Control (corn)	15% cassava root meal
Ingredients (%)		
Corn	41.1	34.1
Cassava root meal	—	15.0
Fullfat soybeans (extruded)	20.0	20.00
Soybean meal	8.1	11.60
Rice polishings	10.0	—
Wheat bran	9.1	7.60
DL-methionine	0.18	0.19
Calcium carbonate	9.60	9.30
Calcinated bone meal	1.30	1.50
Salt	0.35	0.35
Vitamins and minerals	0.30	0.30
Nutritional composition		
Metabolizable energy, Mcal/kg	2.75	2.75
Protein, %	17.0	17.0
Methionine, %	0.45	0.45
Met + cystine, %	0.70	0.70
Lysine, %	0.85	0.85
Calcium, %	3.90	3.90
Available phosphorus, %	0.42	0.42
Linoleic acid, %	1.74	1.37

Table 27-63. Performance of commercial layers fed with 15% cassava root and fullfat soybeans[a].

	Control (corn)	15% cassava root meal
Layers, No.	15,000	5,000
Daily feed consumption, g	114.0	115.0
Laying, %	78.3	79.0
Feed conversion (dozen eggs)	1.37	1.37

a. 55 to 61-week laying period. Santa Anita Poultry Farm. Pradera, Valle. 1.010 masl. 26 °C. American Soybean Association (ASA), 2000.

SOURCE: Buitrago et al. (2002).

Table 27-64. Diets for commercial layers with 20% cassava root meal and fullfat soybeans.

	Control (corn)	20% cassava root meal
Ingredients (%)		
Corn	20.0	—
Sorghum	30.6	36.2
Cassava root meal	—	20.0
Fullfat soybean (toasted)	15.0	15.0
Soybean meal	12.3	16.5
Wheat bran	10.3	0.20
DL-methionine	0.23	0.23
Calcium carbonate	9.20	9.30
Calcium phosphate	1.40	1.60
Salt	0.35	0.35
Vitamins and minerals	0.60	0.60
Nutritional composition		
Metabolizable energy, Mcal/kg	2.70	2.70
Protein, %	17.0	17.0
Methionine, %	0.45	0.45
Met + cystine, %	0.70	0.70
Lisine, %	0.81	0.81
Calcium, %	3.90	3.90
Available phosphorus, %	0.42	0.42
Linoleic acid, %	1.54	1.25

Table 27-65. Performance of commercial layers fed with 20% cassava root meal and fullfat soybeans[a].

	Control corn	20% cassava root meal
Daily feed consumption, g	111.6	111.1
Laying, %	92.4	91.0
Feed conversion (per dozen eggs)	1.50	1.46

a. 39 to 46-week laying period. Avícola Montegrande Poultry Farm. Tuluá, Valle. 1,025 masl. 25 °C.

SOURCE: Gutiérrez and Martínez (1998).

Table 27-66. Diets for commercial white and brown layers with 10% and 20% cassava root meal and fullfat soybean.

	Control (corn)	10% cassava root meal	20% cassava root meal
Ingredients (%)			
Corn	41.1	34.1	23.0
Cassava root meal	—	10.0	20.0
Fullfat soybean (extruded)	20.0	20.0	20.0
Soybean meal	8.1	10.4	11.8
Rice polishings	10.0	10.0	10.0
Wheat bran	9.1	4.3	3.6
DL-methionine	0.18	0.19	0.21
Calcium carbonate	9.60	9.50	9.40
Calcinated phosphate	1.30	1.40	1.40
Salt	0.35	0.35	0.35
Vitamins and minerals	0.30	0.30	0.30
Nutritional composition			
ME, Mcal/kg	2.70	2.70	2.70
Protein, %	17.0	17.0	17.0
Methionine, %	0.45	0.45	0.45
Met + cystine, %	0.70	0.70	0.70
Lisine, %	0.85	0.85	0.85
Calcium, %	3.90	3.90	3.90
Available phosphorus, %	0.42	0.42	0.42
Linoleic acid, %	1.74	1.49	1.37

Table 27-67. Performance of commercial brown layers fed with 10% and 20% cassava root meal and fullfat soybeans[a].

	Control (corn)	10% cassava root meal	20% cassava root meal
Layers, No.	3,840	10,956	5,160
Daily feed consumption, g	115.1	115.8	114.8
Laying, %	69.3	65.7	65.1
Feed conversion (per dozen eggs)	2.00	2.12	2.11

a. 78 to 88-week laying period. Lohmann Brown layers. Avicauca Poultry Farm. Jamundí, Valle. 1,005 masl. 25 °C. American Soybean Association (ASA), 1999.

SOURCE: Buitrago et al. (2002).

Table 27-68. Swine diets totally based on cassava root meal, cassava foliage meal and fullfat soybean.

	Starting	Growing	Final	Gestation	Lactation
Ingredientes (%)					
Cassava root meal	45.2	50.5	53.4	57.1	51.7
Cassava foliage meal	—	4.0	8.0	8.0	8.0
Fullfat soybean	45.8	42.8	33.8	29.5	35.2
Soybean meal	6.0	—	—	—	—
Vegetable oil	—	0.4	2.8	3.0	2.8
Methionine	0.06	0.05	0.03	—	0.04
Dicalcium phosphate	1.2	0.8	0.5	1.1	1.0
Calcium carbonate	1.2	0.9	0.9	0.7	0.7
Salt	0.35	0.35	0.35	0.35	0.35
Vitamins and minerals	0.20	0.20	0.20	0.20	0.20
Nutritional composition					
Metabolizable energy, Mcal/kg	3.35	3.35	3.35	3.32	3.35
Protein, %	21.00	18.00	15.50	14.00	16.00
Lisine, %	1.20	0.95	0.75	0.58	0.95
Met + cystine, %	0.65	0.54	0.44	0.37	0.48
Calcium, %	0.90	0.90	0.88	0.90	0.86
Available phosphorus, %	0.40	0.32	0.25	0.35	0.35

Table 27-69. High levels of cassava root meal and fullfat soybeans in diets for growing-finishing pigs.

	Control diet		Cassava root meal + FFSB[a]	
	Growing	Finishing	Growing	Finishing
Ingredients (%)				
Corn	36.70	33.80	—	—
Cassava root meal	—	—	44.93	48.10
Fullfat soybean	20.00	18.60	20.00	20.00
Sorghum	16.00	16.00	—	—
Fish meal	—	0.50	—	—
Corn bran	8.00	12.00	—	—
Soybean meal	7.60	3.40	16.71	10.90
Wheat bran	8.00	12.00	12.00	15.00
Vegetable oil	—	—	3.70	3.30
Salt	0.39	0.39	0.39	0.39
Vitamins and minerals	3.31	3.31	2.27	2.31
Main nutrients				
ME, Mcal/kg	3.31	3.32	3.36	3.34
Protein, %	18.3	17.3	16.3	16.3

a. Fullfat soybean.

Table 27-70. Performance of finishing pigs with high inclusion of cassava root meal and fullfat soybean diets[a].

	Control diet	Cassava root meal + FFSB[b]
Initial weight, kg	48.10	49.29
Final weight, kg	96.00	96.41
Daily weight gain, kg	0.75	0.74
Daily consumption, kg	2.22	2.12
Feed conversion ratio	2.96	2.89

a. Granjas Paraíso – CLAYUCA – Nutribal. Palmira, Valle. 2002.
b. Fullfat soybean.

SOURCE: Buitrago et al. (2002).

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To save space, the acronym "CIAT" is used instead of "Centro Internacional de Agricultura Tropical".

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