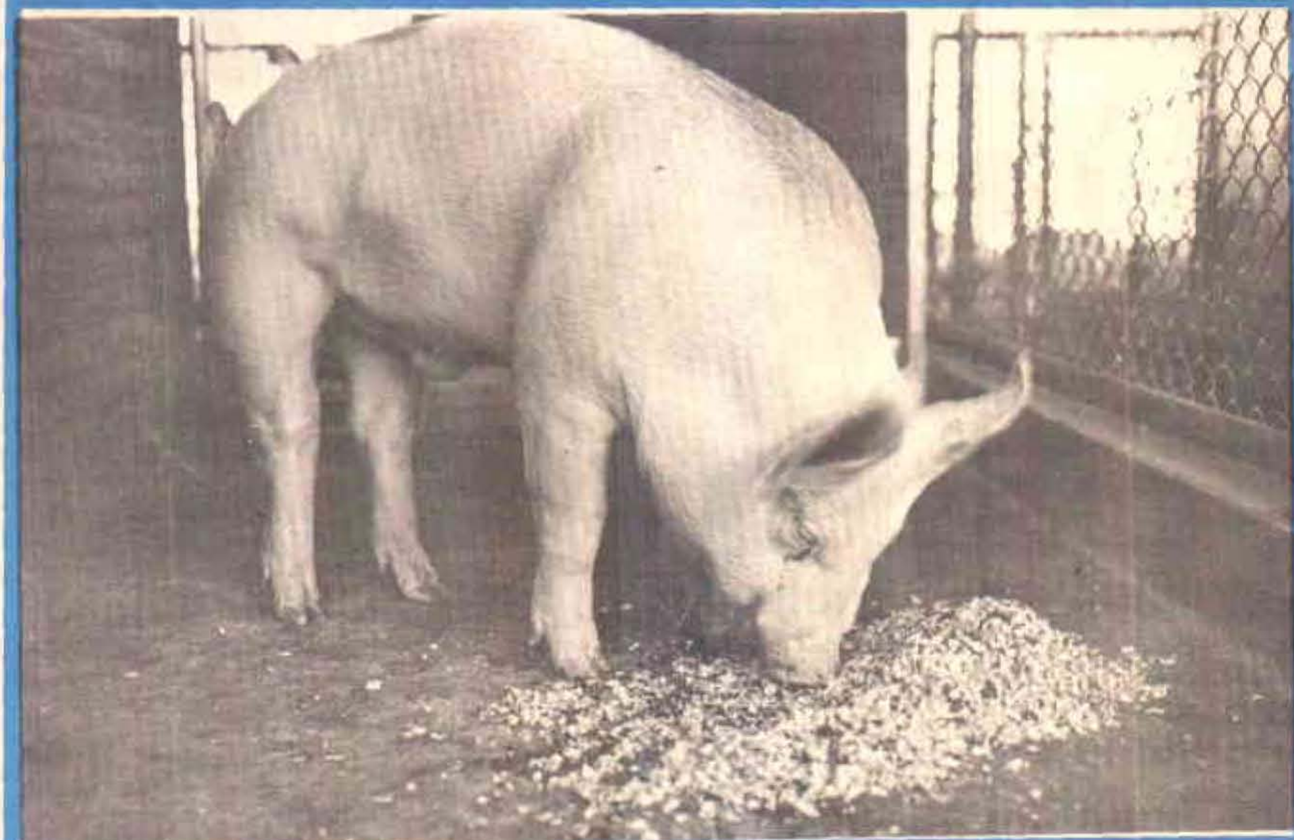
Bulletin
RB-1

CASSAVA in SWINE FEEDING

JEROME H. MANER



May 1973

Centro Internacional de Agricultura Tropical

662

Analizado

CASSAVA IN SWINE FEEDING

JEROME H. MANER

CENTRO INTERNACIONAL DE AGRICULTURA TROPICAL

Seminar:

First Latin American Swine Seminar

September 18-21, 1972

CASSAVA IN SWINE FEEDING

Swine require large quantities of energy and moderate quantities of protein for growth and development. In the leading pork producing areas, large supplies of grains available at a reasonable price provide this energy source. In other countries, production of cereal grains is insufficient for human and animal needs. Many of these countries, however, have the potential or are already producing large quantities of other feed sources that, if properly fed and supplemented, could support a large and efficient swine industry. One feed source with a great unrealized potential in many tropical areas in *Manihot esculenta* Crantz, commonly known as cassava, yuca, manioc, tapioca or mandioca.

Cassava is grown in the lowland tropics throughout the world, generally between latitudes 30°N and S and almost always below 1800 meters altitude within these regions (Rogers, 1963). These areas generally delineate regions of production because of the frost sensitive nature of the plant. Cassava has a wide range of adaptability, resistance to drouth, tolerance of poor soils and relative ease of cultivation. As there are varieties adapted to nearly every soil type and degree of annual rainfall, the plant offers an almost unlimited production potential.

Large quantities of cassava are now being produced utilizing a wide range of generally unimproved genetic materials and under very poor agronomic conditions.

The annual world production of cassava, as reported by FAO (1970), was 90,958,000 metric tons. These figures may not, however, reflect an accurate production because cassava, except around a few cities, is not a "cash" or "plantation" crop. Most of the crop is produced on small farms in small acreages and many times as a "back-yard" staple for home consumption. Of the total world production, approximately 39 percent is produced in the Latin American countries, with 33 percent or 30,074,000 metric tons of the world's total being produced annually in Brazil.

Although cassava is ninth in terms of world production of all crops and fifth in world production of tropical crops, its importance and potential as a feed crop in the tropical regions throughout the world is not widely recognized by researchers and livestock producers. Cassava, other root crops, and the plantains are a major source of carbohydrates for the human population of both Latin America and Africa. The usefulness and potential of cassava for supporting an animal industry in these same regions has not been given the attention deserved by either researchers or producers of livestock.

Yields

Present farm yields of cassava as reported in agricultural statistics are generally low, ranging from 3 to 30 tons per hectare. Some varieties require 16 to 20 months to mature, yet varieties exist that will yield up to 78 tons of fresh cassava in experimental plots in 10 months (Varon, 1968). Given the wide range and diversity of genetic materials available in the world and the ease with which cassava can be sexually crossed, the development of new varieties and strains should offer important opportunities for increased production. Once these improved, disease resistant strains and varieties have been genetically formed, their continual propagation and genetic purity can be easily maintained because the plant is normally reproduced vegetatively from stem cuttings.

Yields already realized experimentally (ICA-1969) indicate that the total caloric output per hectare per year of well managed, improved cassava is up to 3 times that of such crops as rice and corn.

One kilo of fresh cassava containing 35 percent dry matter has a gross energy value of approximately 1225 kilocalories. A yearly production of 75 metric tons of cassava per hectare will yield 91.8 million kilocalories. Future yields will possibly far surpass those of presently produced and these increases will be accomplished through selection and genetic improvement and by improved agronomic practices.

Chemical Analysis

The fresh cassava root contains on the average 65 percent moisture and 35 percent dry matter (table 1). The pulp or internal portion of the root contains slightly more dry matter than the peeling (37.8 vs 27.8%) and represents approximately 86.8 percent of the total root with the remaining 13.2 percent made up by the peeling (table 2). The percentage composition of pulp and peel does not vary significantly with increasing maturity of the root.

The cassava root contributes basically carbohydrates (energy) to the diet of humans and animals. An average of 30.84 percent of the fresh root is nitrogen-free extract, composed mainly of starch and sugar (Table 1). The nitrogen-free extract fraction of cassava consists of approximately 80 percent starch and 20 percent sugar and amides (Vogt, 1966). Sucrose is present in variable amounts and some varieties may contain, up to 5 percent (Brautlecht, 1953). The fundamental unit of the starch molecule is d-glucose, as this is the only monoaccharide obtained on total hydrolysis. The two chief constituents of starch are amylose, which is non-branching in structure, and amylopectin, which consists of highly branched chains. According to Kerr (1950) and Johnson and Raymond (1965), cassava starch is about 20 percent amylose and 70 percent amylopectin.

Cassava contains only small quantities of fiber (1.45%) and is almost devoid of ether extract (0.29%). The ash content comprises only about 1.5 percent of the total root (Table 1). The levels of calcium (0.12%), phosphorous (0.16%), sodium (0.06%) and magnesium (0.37%) are generally low (table 3). As in the situation with most root crops, the potassium level is relatively high (0.86%).

The majority of the varieties now being produced contain very small quantities of nitrogen. The crude protein (N_2 X 6.25) content of the majority of the varieties tested do not exceed 3.0 percent when expressed on an air dried basis (approx. 10% moisture). However, other varieties have been reported to contain higher levels of crude protein. Beck (1969) reported an African variety that contained 9 percent crude protein and Jaramillo and Herrera (1970) have reported a world collection (Manihot Carthagenensis that contained 15.4 percent crude protein when expressed on a moisture free basis. Maner (1969) has reported varieties that contain up to 2.33 percent crude protein in the fresh root or 7.25 percent when expressed on a moisture free basis.

Further studies by Maner and Daniels (1970) clearly indicate that all of the nitrogen present in the cassava root is not in the form of true protein. Data presented in Table 5 demonstrates the high nitrogen content of samples of the variety "Llanera" which were harvested at approximately biweekly intervals for a period of about five months. The total nitrogen in the whole root varied from 0.74 percent to 1.02 percent during this period of time (4.63% to 6.35% crude protein). From the same table it can be seen that the level of total nitrogen is higher in the peel than in the remaining portion of the root but the internal portion contains 4 to 5.5 percent crude protein. Tricloroacetic acid (TCA) treatment of samples of root clearly indicate that 50 to 60 percent of the total nitrogen present is non-protein-nitrogen and does not precipitate. The percentage of non-protein-nitrogen is higher in the peel than in the pulp (Table 5). Similar results (Maner and Daniels, 1971) have been obtained on three other samples that are known to produce higher levels of hydrocyanic acid (HCN) (Table 6). These results do not agree with those reported by Oyenuga (1955) who reported that 62 percent of the nitrogen of the crude root was true protein and that 87 percent of the nitrogen of the peel was true protein.

Detailed chemical analysis (Calderon, 1971, unpublished data) of the nitrogen fraction of 15 cassava varieties show that the total content of nitrates, nitrites and HCN represents only about 1.0 percent of the total nitrogen. It appears from these studies that aspartic and glutamic acid may be present in the root as free amino acids and represent a portion of the non-protein-nitrogen that is not precipitated with TCA.

The amino acid content of two samples of cassava root of the Llanera variety are presented in Table 7, expressed as a percentage of the crude protein and of the true protein. The levels of several essential amino acids such as lysine and tryptophan are very promising and compare favorable with those observed in opaque-2 corn. However, the level of the sulfur-containing amino acids methionine and cystine are extremely deficient and limiting.

According to Close et al. (1953), the protein of cassava meal contains the following amino acids; 4.4% aspartic acid, 2.1% threonine, 1.9% serine, 12.7% glutamic acid, 1.6% proline, 2.4% glycine, 4.6% alanine, 2.6% valine, 0.6% cystine, 1.0% methionine, 2.0% isoleucine, 2.9% leucine, 1.6% tyrosine, 2.3% phenylalanine, 3.5% lysine, 0.5% tryptophan, 10.4% ornithine, 1.2% histidine and 3.7% arginine. Sruramamurthy (1945) also reported that the essential amino acids present in the total protein (1.33% in the sample) are arginine 7.74%, histidine 1.50%, isoleucine, 5.33%, leucine 5.56%, lysine 6.23%, methionine 0.60%, phenylalanine 3.45%, threonine 3.83%, tryptophan 0.53% and valine 4.51%.

Toxic Factor

The presence of a toxic factor in cassava presents some problems in its use as animal feed. The toxicity of the cassava roots and leaves is due to the presence of a hydrogen compound of cyanogen (C_2N_2) that is commonly known as hydrocyanic acid (HCN) or prussic acid (Oke, 1969). Free hydrocyanic acid as such is not found in healthy growing plants, but develops when normal growth has been retarded or stopped by drought or other adverse climatic conditions or by the bruising or chopping of the roots and leaves. HCN is usually formed by chemical reaction between two substances, a glucoside and an enzyme contained in the plant. Neither the glucoside nor the enzyme is poisonous by itself (Couch, 1932). The two B-glucosides identified in cassava are linamarin and lotaustralin. The glucosides consist of a chemical combination of sugar and hydrocianic acid with perhaps another compound such as an aldehyde or ketone. Linamarin is composed of hydrocyanic acid, glucose and ketone and only when liberated chemically is the hydrocyanic acid poisonous.

The degree of toxicity of cassava roots has been widely discussed and differences of opinion exist. A complete review of the role of hydrocyanic acid in nutrition has been made by Oke (1969).

In animals the symptoms of acute hydrocyanic acid poisoning are increased rate and depth of respiration, increased pulse rate, no response to stimuli and spasmodic muscular movements (Oke, 1969). Most of the symptoms of HCN poisoning can be explained on the basis of its affinity for metal ions such as copper and iron. It combines with hemoglobin to form cyanohemoglobin which is not an oxygen carrier. HCN also forms a reversible combination with the copper of the cytochrome oxidase which thereby inhibits its functions as an oxidative enzyme in electron transfer and provides the classic example of histotoxic anoxin

(Peters and Van Syke, 1931). These chemical abnormalities cause neuronal depression in the medullary centers which leads to respiratory degression and death. Hydrocyanic acid is therefore a violent protoplasmic poison for all forms of life.

Although acute HCN toxicity is a problem, of greater toxicological, physiological and nutritional importance is the continued ingestion of small quantities of hydrocyanic acid. These small quantities are not large enough to cause death, but affect the general health and condition of the subject.

The body has the ability to detoxify varying quantities of HCN, the total quantity varying according to species, physical condition, nutrient consumption and probably other unidentified factors. It has been postulated that an enzyme called "rhodanase" is responsible for the reaction of hydrocyanic acid with thiosulfate or colloidal sulphur under aerobic conditions to produce the detoxification product thiocyanate. The enzyme is widely distributed in all tissues with the highest concentration in the liver. Detoxification can therefore take place in all parts of the body but with the liver as the chief site. The detoxification of HCN appears to be limited by several nutrients but mainly by the availability of sulfur since Himwick and Sanders (1948) calculated that at least for the dog the quantity of enzyme present in the whole liver could detoxify 4015 g of cyanide and the skeletal muscles 1763 g of cyanide in 15 minutes. However, these same authors have shown that the actual rate of detoxification for the dog is much less than would be expected based on enzyme concentration. It has been found that the injection of thiosulfate will increase the minimal lethal dose by a factor of 3 or 4. On the other hand injection of other sulfur sources such as cystine, thiourea, or sodium sulfide are not effective. The ineffectiveness of these latter compounds in reducing acute HCN toxicity when injected is probably due to the slowness in which they are converted to thiosulfate, since Wood and Cooley (1952) have shown that labeled SCN is produced when cyanide is administered with labeled ^{35}S-cystine.

It has been proposed that rhodanase forms a lose combination with thiosulfate which breaks down to yield sulfur in a form that can be accepted by the cyanide ion. The rhodanase system is not the only route of detoxification through which thiocyanate can be formed from cyanide. It has been found that B-mercaptopyruvic acid can provide sulfur as rapidly as thiosulfate for cyanide detoxification.

Vitamin B_{12} has also been postulated to play a direct or indirect role in cyanide detoxification. A dietary deficiency of vitamin B_{12} leads to an increase in thiocyanate excretion. Injection of sub-lethal doses of cyanide into rats causes a significant depletion of liver stores of vitamin B_{12}, indicating that it is an important detoxifying agent during cyanide poisoning. It has been shown that vitamin B_{12} is not necessary for the conversion of cyanide to thiocyanate through the action of rhodanase or 3-mercaptopyruvate sulfur-transferase. Therefore, it appears that the best explanation for the effect of vitamin B_{12} in cyanide detoxification is that the cyanide combines readily with the hydroxyl form of vitamin B_{12}, hydroxocabalamin, and through this compound the cyanide is incorporated into the 1-carbon metabolic pool probably in the form of formate. This is the pathway that is significantly impaired in a vitamin B_{12} deficiency.

It therefore appears that the differences in toxicity reported may be in many cases explained by the presence or absence of substances such as methionine, cystine, sulfur, vitamin B_{12}, iodine and other elements such as copper and iron. At the same time, symptoms related to the deficiency of methionine, vitamin B_{12} and iodine that have been reported to occur when dietary levels of these nutrients were apparently adequate, may be explained by the presence of sub-lethal levels of HCN which reduced the efficiency and proper metabolic utilization of nutrients.

Several methods of processing can be utilized to reduce HCN toxicity. Some of these methods are more effective than others. Drying in a forced air oven, at moderately high temperatures (70-80°C), boiling in water and sun drying have been practiced.

Oven drying in the absence of moisture drives off the free HCN and destroys the enzyme linamarinase which is necessary for hydrolyzing the glucoside to form HCN. Dry heat has little if any effect on the glucoside present and thus this is consumed in the cassava root. If it is true that HCN is slowly released from the glucoside in the stomach through the action of hydrocloric acid hydrolysis, then small but metabolicly significant quantities of HCN will be absorbed from cassava that has been processed in this manner.

Boiling in water destroys the free HCN along with the enzyme, linamarinase or linase, as well as causing a reduction of the total glucoside which is soluble in water. If boiling is rapid and continued for only short periods of time, significant quantities of glucosides may remain in the cassava root, causing chronic ingestion of HCN when this cassava is consumed.

Shredding, mixing and sun drying offers a practical and effective way of reducing both the HCN and glucoside level. This process initiates the action of the enzyme on the glucoside to cause a release of HCN. If drying is accomplished over a period of several days much if not most of the glucoside will be hydrolyzed to release HCN which is disipated into the air.

Harvesting, Storage, Feeding and Processing

Some of the greatest problems in using cassava are related to harvesting, storage, processing and feeding.

The root system of the plant, which must be harvested, is deep irregular in its placement and generally extends over a wide area. The large and fibrous stalks must be removed before the roots can be harvested. Mechanical harvesting methods have not yet been developed and harvesting is usually manual. In damp, lighter soils, hand harvesting is not a difficult task. Drier and more compact soils present somewhat of a problem if the roots are to be removed intact. Manual harvest will probably not be a deterrent to efficient utilization on small operations but might become a limiting factor if large quantities are required daily on farms with large numbers of swine. The use of a tractor equipped with a single bottom plow to expose the roots may be advantageous. It would be preferable to have a machine to dig and lift the roots out of the ground. A machine similar in design to a potato digger but with greater depth range and heavier structure might be effective.

Cassava in its fresh, high moisture state cannot, under most tropical environments, be stored for more than 3 to 4 days without the onset of fermentation and deterioration. Even under refrigeration, which is costly, it cannot be conserved in satisfactory condition for more than 2 to 3 months. It must be harvested two or three times per week to assure a satisfactory, palatable product for feeding as it has been demonstrated that spoiled or fermented cassava will not be consumed at a level adequate to support optimum growth, and if consumed, will cause digestive disturbances and reduce consumption.

In its fresh, wet condition, cassava can be efficiently used to feed swine. It is generally better to wash the harvested cassava to remove the bulk of the soil, although this is not essential, and to chop, shred or grind the root before it is fed. Because of the fairly rapid rate of fermentation of cassava and especially of the ground or chopped material, it should be offered daily to the pigs in quantities controlled to supply all that the animal will voluntarily consume but not at a level that will leave an excess of unconsumed material. If the fresh cassava is to be used in the swine operation, alternate plantings at 2 to 3 month intervals will assure an adequate and stable supply of an acceptable product.

Grinding, shredding, or chopping of cassava roots can be accomplished in many ways. If small quantities are needed a knife or machete is the most simple method. If larger quantities are required, a mechanical grinder or shredder should be used. A commercially available soil shredder has satisfactorily reduced the size of the whole root to pieces sufficiently small that they are well accepted and consumed by the pig.

Temporary storage of the roots can be accomplished by leaving the roots undisturbed in the field. Long term storage of the cassava roots must follow processing. The roots can be either dried or ensiled. They can be dried either mechanically or by exposure of the chopped or shredded material to the sun in thin layers on large trays. If the moisture content is reduced to 10 percent or less, the dried root can be safely stored for as much as a year.

The roots alone or in combination with the leaves can be successfully ensiled and maintained for some time if the material is stored in small air-tight silos or plastic containers.

Cassava in Swine Feeding

Studies to measure the feeding value of cassava roots as an energy (carbohydrate) source for pigs have been reported in the literature since early 1900 (Tracy, 1903, Conner, 1907; Gavin y Andouard, 1914; Henke, 1923; Mondoñedo y Bayan, 1927; Mondoñedo, 1928; Fullerton, 1929; Howie, 1930; Mondoñedo y Alonte, 1931; Woodman et al., 1931; Alba, 1937; Asico, 1941; Zárate, 1956; Oyenuga y Opeke, 1957; Mejía, 1960; Moebe, 1963; Maner y Buitrago, 1964; Castillo et al., 1964; Peixoto, 1965; Lang et al., 1965; Maner y Jiménez, 1967; Maner, et al., 1967; Aumaitre, 1969; Shimada, 1970; y Maner, 1971).

As can be seen from the summary of results of studies carried out between 1927 and 1941 to evaluate cassava as a feed for growing and finishing pigs (Table 8) the maximum level of cassava that had been incorporated into the diet was 40 percent. In the majority of the cases the level of production was low and feed required per unit gain was high. However, these data compare favorable with the results obtained on control diets which were also much lower than would be acceptable today. Because of the advances that have been made in nutrition since these early studies were carried out, more favorable results would not be expected under the conditions under which the studies were conducted. These data are then more of historical interest and are of very little nutritional value today, except as similar feeding conditions may exist in less developed swine productinn systems in the tropics.

In africa, Oyenuga and Opeke (1957) utilized 40 and 55 percent dietary cassava for growing and finishing pigs, respectively. The fresh cassava was fed either raw or boiled to the pigs along with a supplemented dry feed source that supplied protein, energy and minerals but was not supplemented with vitamins. The pigs were hand fed three times per day, in an attempt to equalize nutrient intake of cassava fed animals and control animals fed sorghum (guinea corn) based diets. From these studies the authors concluded that cassava has a feeding value for pigs equal to that of sorghum and that raw cassava was highly palatable and equal or superior to cooked cassava.

In a later trial at the same station (Modebe, 1963), sorghum or corn was replaced by sun dried cassava meal at 32, 37 and 40 or 42, 47 and 50 percent of the diet for pigs weighing 23-36, 37-55 and 55-75 kg, respectively. The pigs fed the lower levels of cassava meal (32, 37 and 40%) grew at a rate that was not different from that of the control (0.491 vs 0.482 kg day) or from that of the higher levels of cassava meal (0.491 vs 0.473 kg/day).

Feed consumption was not different between the different treatments nor was it optimal for any of the groups (4.38, 4.39 and 4.51 for the control, low and high cassava groups, respectively).

Levels of 20 and 40 percent sun-dried cassava meal was used by Mejía (1960) to replace a similar quantity of corn in rations for growing-finishing pigs. As seen from the summary of these results presented in table 9, the growth rate of the pigs was similar with that of the 40 percent cassava fed pigs higher than the control. These results do not indicate that cassava has the same or superior nutritive value as corn, because all diets contained a level of protein superior to that required by pigs of these weights. These results do however indicate that the energy value of cassava is similar to that of corn.

Aumaitre (1969) compared the feeding value of corn, wheat, barley and oats to that of dried cassava meal. The 20 percent protein diets were fed to baby pigs between the ages of 5 and 9 weeks. Maximum performance were obtained with cassava (416 g/day) as compared to barley, oats, corn and wheat (386, 380, 354 and 360 g/day, respectively). It was reported that the improvement due to cassava substitution was due to a reduction in the frequency of diarrhea observed in the pigs. The results of a digestibility trial conducted with these animals show that wheat, barley, corn and decorticated oats have comparable digestible energy values (3973, 3955, 4046 and 4024 kcal/kg M.S., respectively) which compare closely to a digestible energy value of 4185 for cassava meal.

Shimada (1970) used 0, 22, 44 and 66 percent sun-dried cassava meal to replace corn in diets for pigs between 30 and 90 kg. Although inadequate numbers of pigs were employed for statistical analysis, the general results of the study indicate that up to 44 percent cassava meal can be used to replace corn without causing a reduction in overall performance. The highest level of substitution caused both reduced gains and efficiency of feed conversion.

Cassava silage was used by Castillo, et al. (1964) to replace corn in diets for growing pigs. Forty percent of the diet was supplied by cassava silage and the remaining ingredients were added to provide a diet similar to that of the corn-based control. Because of the low level of crude protein present in the cassava silage, higher levels of supplemental protein were provided by protein of higher nutritive value, providing a final diet of higher protein quality than that provided by the corn-based control. Although the performance of all pigs in the study was relatively low, pigs fed the cassava silage diet gained faster and required less feed than those fed the corn diet. In the opinion of the authors cassava silage is a satisfactory feed for growing swine.

Extensive studies on the value of cassava meal, fresh cassava and cassava silage as feeds for swine in life-cycle production systems have been carried out at the Palmira Station of the Colombian Agricultural

Institute and in collaboration with the International Center for Tropical Agriculture (Maner and Buitrago, 1964; Maner and Jimenez, 1967; Maner, Buitrago and Jimenez, 1967; Maner, Buitrago and Gallo, 1970; Maner, 1971; Maner and Daniels, 1970; Mesa and Maner, 1971).

The cassava used in studies 1, 2, 3 and 5 was a mixture of several varieties commonly eaten by humans and was grown at the Palmira Experiment station of the Colombian Agricultural Institute (ICA). That used in experiments 4, 6, 7 and 8 was a high yielding variety, "Llanera", grown at the same station. The fresh cassava was harvested two or three times weekly to prevent spoilage and to insure a palatable feed. After harvest the cassava was washed to remove the soil and chopped daily as required. Cassava for the initial studies was chopped using a large knife (machete); a soil shredder was later used for chopping. The dried cassava meal was prepared from fresh chopped cassava by first drying at 180°F in a forced-air oven for 24 to 36 hours or by exposing it to the sun in thin layers in large drying pans and subsequently grinding the dried material.

Growing-Finishing Trials

Fresh Cassava

The cassava and protein supplements for all growing-finishing trials using freshly choppped cassava were fed in automatic metal feeders, and all cassava not consumed by the pigs within 24 hours after feeding was collected, weighed and discarded.

Experiment 1: Fifteen weanling Duroc pigs weighing an average of 18.1 kg. were used in an experiment with a completely randomized design. The pigs were allotted to the three treatment groups on the basis of sex and litter and maintained in pasture lots of pangola grass. Each lot was equipped with a shade over a concrete slab. Feed and water were supplied according to treatment in automatic feeders and waterers. The three treatments were:

1. A basal diet of corn, soybean meal, cottonseed meal, bone meal, and vitamin-trace mineral premix offered ad libitum.
2. Raw, chopped cassava fed ad libitum and a protein supplement also offered ad libitum.
3. Raw, chopped cassava fed ad libitum and a protein supplement fed daily in quantities sufficient to supply minimal daily requirements.

The composition of the basal diet and the protein supplement are presented in Table 10. The basal diet was calculated to contain 16 percent crude protein, but laboratory analysis indicated a level of 19.81 percent and the protein supplement contained 42.88 percent protein (Table 11). The cassava contained 63.75 percent moisture and 1.04 percent crude protein.

The performance data are presented in Table 12 and Figure 1. The pigs on both the control diet and those receiving the raw cassava plus protein supplement free choice grew at a satisfactory rate and efficiency and performance of both treatment groups were similar. The group of pigs receiving raw cassava,but with quantities of protein supplement controlled to supply the minimal needs of the pig (Table 13), grew at a slower rate than either the control or raw cassava plus free-choice supplement groups. Efficiency of feed conversion was not different between the two yuca groups, both of which were more efficient than the corn-soybean control group.

The pigs offered chopped cassava and protein supplement free choice consumed much more protein than would be normally required (Figures 2 and 3). The pigs choose a diet containing an average of 25.3% protein during the initial week of the experiment. This level of consumption of protein, brought about by an over-consumption of the protein supplement, and concomitant reduction in cassava consumption was gradually reduced to approximately 16.5 to 16.9 percent during the final weeks of the 112 day trial. These data indicate that the pigs were consuming the dry protein supplement to fulfill partially their daily energy needs that were not being met by their daily level of consumption of fresh, chopped cassava.

Experiment 2: Fifteen Duroc pigs with an average body weight of 17.8 kg. were randomly allotted to the same treatments described in Experiment 1. This experiment duplicated Experiment 1 except that the pigs were fed in confinement and without access to pasture.

The performance data are presented in Table 14. The growth rates of the basal group and the cassava group offered protein supplement free choice were very similar, 0.843 and 0.834 kilograms daily gain, respectively. The efficiency of feed utilization was not greatly different for the two groups. The group receiving cassava plus a controlled amount of protein supplement (Lot 3) consumed less fresh cassava and only 0.75 kilogram of protein supplement daily as compared to 1.17 kilograms consumed by the free choice group. As a result, this group had 4.7 percent slower daily gains but required 15.9 percent less total feed to produce a kilo of gain when compared to the free choice group. This controlled protein feeding in effect resulted in a restriction of total feed consumed, which has been shown to improve feed efficiency.

The growth curves of the three treatment groups (Figure 4) demonstrate that the pigs consuming both cassava and 42.88 percent protein supplement free choice gained as rapidly as those receiving the 16 percent protein corn-soybean meal control diet. In doing so, however, they voluntarily consumed a ration that was excessive in protein (see Figure 5 and 6). The implications of the excessive consumption of protein supplement observed in this experiment as in Experiment 1 are not readily apparent. These data may indicate that the stomach capacity of the pig is not great enough to consume enough fresh cassava to meet the daily energy requirements and therefore energy needs are met by an over-consumption of protein supplement or that cassava consumption is low due to poor palatability of the fresh, raw cassava.

Those pigs fed controlled quantities of protein supplement (Lot 3) grew at a slightly slower rate but converted the feed more efficiently and consumed a diet lower in protein. Reducing the daily consumption of protein supplement, however, failed to increase the daily consumption of fresh cassava. The improved efficiency of feed conversion of treatment group 3 could be the result of restricted feeding and/or to more efficient utilization of the protein supplement associated with the elimination of excess nitrogen.

Experiment 3: Ninety-six Duroc and Duroc-Landrace crossbreed pigs weighing an average of 23 kilograms were divided according to weight, sex, litter and condition to 12 outcome groups of 8 pigs each. These outcome groups were then allotted to six treatments, each with two replications. Each group was fed fresh, chopped cassava daily to allow voluntary consumption, and the excess was removed, weighed and discarded each morning before offering additional cassava. Two basic protein supplements with two levels of vitamin-trace mineral supplementation (Table 15) were compared. A combination of cottonseed meal and soybean meal was compared with soybean meal alone, both with a normal level of vitamin-trace mineral supplementation and with two times this normal level. Supplements 2 and

5 were offered *ad libitum* (Treatments 2 and 5) and in daily rations (Treatments 3 and 6) calculated to exceed the pig's daily protein requirements (National Research Council, 1964) by 10 percent (Table 16).

The pigs were housed in 2.5 x 8 meter concrete lots during the entire 84 day experimental period and body weight changes and protein supplement consumption were recorded for each lot at weekly intervals. Cassava consumption was recorded daily.

The performance data are presented in Table 17. The average daily gains and growth curves (figure 7) were similar for all groups fed either of the basic protein supplements free choice. There was no consistent advantage of adding higher than recommended levels of vitamins and trace-minerals. The average gains obtained from the groups fed controlled daily rations of protein supplement were not different between treatments, but were inferior to those recorded from pigs receiving *ad libitum* quantities of either supplement.

Average daily intakes of wet cassava were similar, varying an average of only 480 grams between the highest and lowest average daily consumption (3.89 to 3.41) as indicated in Table 17 and Figure 8. Higher daily intakes of protein supplement were observed among the groups fed *ad libitum* the combination of cottonseed meal-soybean meal (CSM and SOM) when compared to the groups offered voluntary consumption of the supplement containing only soybean meal (SOM). As a result of this higher daily consumption the CSM + SOM groups required more total feed (cassava + supplement) to produce a unit of gain. Feed required to produce a unit of gain was not different among the SOM groups nor between the groups receiving controlled quantities of either supplement.

It was observed that the pig does a fairly acceptable job of balancing his diet when offered fresh, chopped cassava and protein supplement free choice (see Table 17). Young pigs, when they are initiated on such a diet, however, will greatly overeat protein supplement as indicated in Figure 9. Limiting the daily consumption of protein supplement to a level calculated to supply 10 percent more than the National Research Council's published requirements did not result in an increase in daily cassava consumption. These data confirm results from the previous studies which seem to indicate that there is an upper limit of about an average of 4 kg. daily that the pig will consume over the growing-finishing period. The pig tends to overeat protein when calculated over the entire experimental period. This over-consumption is, however, basically, although not completely, the result of excessive consumption during the early stages of the feeding trial. In general, the daily voluntary consumption of wet cassava increases progressively from weaning to market weight, and the daily voluntary consumption of protein remains almost constant over the entire period (Figure 8).

Experiment 4: The first three trials demonstrated the effectiveness of soybean oil meal or this meal in combination with cottonseed meal as a protein supplement for growing-finishing pigs fed fresh, chopped cassava. These ingredients are not, however, universally available, especially in the lowland tropics. This experiment was conducted to evaluate a large variety of protein sources as potential supplements for cassava in order to broaden the application of these data over a wider area.

Forty eight Duroc x Landrace weanling pigs with an average initial weight of 19.2 kilograms were allotted at random according to weight, sex and litter to six treatments with two replications each. The pigs were housed in confinement on concrete and water was supplied *ad libitum* in automatic waterers. The cassava was supplied fresh daily and was chopped in a soil shredder before feeding in automatic feeders. The six experimental protein supplements tested were also fed free choice in separate feeders. The composition of the supplements utilized and laboratory analysis for crude protein for each are presented in Table 18. Fresh cassava consumption per lot was recorded daily and body weight changes and protein supplement consumption were recorded at biweekly intervals. The pigs were maintained on these experimental diets for 111 days and weighed an average of 95 kilos each at the termination of the trial.

The pigs fed fresh, chopped cassava with a protein supplement of good quality performed similarly and satisfactory (Table 19 and Figure 10). The highest growth rates were obtained from the supplements containing combinations of either, soybean meal, meat and blood meals or meat, blood and cottonseed meals. Inferior but not significantly different performances were obtained from pigs consuming meat meal alone or a combination of fish meal and cottonseed meal. Significantly slower gains were recorded when cottonseed meal supplied the only source of protein. These results from the cottonseed meal supplement might be expected as cottonseed meal is deficient in lysine and can contain levels of a pigment, gossypol, which is toxic to the pig. As acute toxicity symptoms were not observed, the depression is probably related to protein quality and especially to a lysine deficiency.

The average daily consumption of fresh chopped cassava was similar among most of the groups (Table 19 and Figure 11) except the meat meal and the cottonseed meal groups and corresponded closely to the 4 kg. daily consumption previously observed in other studies. The reason for the lower consumption of these two groups is not readily apparent, especially for the meat meal group; however, the lower consumption recorded by the cottonseed meal group could be related to the protein quality of the supplement.

Average daily consumption of protein supplement was 0.83 kg when averaged over all treatments and was similar for all groups (Table 19 and Figure 11), although slightly higher for those pigs fed combination of either meat and blood meals or meat, blood, and cottonseed meals.

The variable daily consumptions of cassava and supplements had little effect on overall feed conversion which averaged 3.31 for all treatment groups. The variation in the analyzed level of protein in the various supplements and the variation in daily cassava consumption (Figure 11) did, however, appreciably effect the percentage of protein consumed in the ration (Figure 12). The pigs on all treatment groups over-consumed protein during the entire experimental period and especially during the first 14 to 28 days. The increased consumption of protein observed during the last 28 days of the trial was associated with a reduced consumption of cassava. The original field of cassava used to initiate the experiment was terminated during the time and a new lot was introduced. Although this new lot was the same variety seeded at the same time and with a similar chemical composition, the quality of the cassava was inferior. The roots were smaller and more stringy and as a result, daily consumption was greatly reduced in all lots. These observations clearly indicate the necessity of using good quality cassava for maximum daily consumption.

<u>Dried Cassava</u>

The dried cassava used was first washed to remove the soil and then chopped in a soil shredder. This chopped material was placed on wire shelves and dried in a forced-air oven at 180°F to a final moisture content of approximately 10 percent. This dried material was then reground in a hammermill before being mixed in the final diets. Cassava meal prepared in this manner is a fine powdery and dusty material.

Experiment 5: Dried cassava meal was incorporated into complete-balanced diets to measure its value as an energy source and as a substitute for corn in growing-finishing swine diets. The cassava meal was substituted for 33, 66, and 100 percent of the corn in the basal, 16 percent protein, corn-cottonseed meal - soybean meal diet and the protein level equalized in these diets by varying the proportion of corn and soybean meal. The level of cottonseed meal was held contant at 7 percent in all diets to avoid problems of gossypol toxicity. Since the cassava meal is dusty, the same four treatment diets were repeated adding 10 percent cane molasses to reduce dustiness and to measure its effect on palatability and feed consumption. The composition of the diets are presented in Table 20.

Forty-eight weanling pigs with an average initial weight of 18.5 kg. were allotted according to weight, sex, litter and condition to the eight treatment groups. The pigs were housed in confinement on concrete and fed and watered ad libitum during the entire 111 day experimental period.

The summary of performance data is presented in Table 21. Each increase in level of dried cassava resulted in a corresponding decrease in average daily gain with or without 10 percent molasses. These decreases in gains were not caused by decreased feed intake as the average daily voluntary consumption among treatments without added molasses were not different. Adding 10 percent molasses increased daily feed consumption by 13.7 percent and supported a 9.8 percent increase in average daily gains when treatments with and without molasses were compared. As contrasted to the treatments without molasses, increasing the cassava level in the presence of molasses resulted in a decrease in average daily consumption. Feed conversion was not greatly different among treatments.

The overall quality of the protein was improved in the diets as the cassava replaced corn and the proportion of soybean meal was increased so that the depression in average daily gain was probably directly associated with the cassava fraction of the diet and could possibly be associated with the utilization of the carbohydrates, mainly starch, of the dried cassava. The low level of fiber present in the cassava should not greatly affect its utilization.

Cassava Silage

Cassava silage was made from the roots alone and from a combination of the roots, stalks and leaves. The root silage was prepared by chopping the fresh roots in a soil shredder to a medium-fine particle size (0.5 to 2.0 mm diameter) and placing this fresh chopped material in air tight plastic bags. The root plus stalk and leaf silage was prepared in a similar manner, with the whole plant being put through the soil shredder. The particle size for the roots in both silages were similar, however, because of the fibrous nature of the stalk, the particle size of this portion was larger. Both of these silage preparations produced adequate fermentation for storage and were in excellent condition when fed.

Experiment 6: Because of the limited quantity of silage available, 15 pigs were used in the experiment. These pigs, averaging 18.34 kg in weight, were randomly allotted to the three treatment groups. The treatments were:

1) Fresh chopped cassava plus protein supplement.
2) Cassava root silage plus protein supplement.
3) Cassava root, leaf and stalk silage plus protein supplement.

The protein supplement used is presented in Table 22. Cottonseed meal was used as the only source of supplemental protein. Both the protein supplement and the cassava preparations were fed free-choice in separate feeders.

The feed consumption and performance data are presented in Table 23. Average daily consumption of protein supplement was not different among treatment groups, averaging 1.02 kg over all groups. Daily consumption of root silage was similar to that of fresh chopped cassava. The inclusion of the stalks and leaves, however, greatly affected daily consumption of the whole plant silage, reducing it by approximately 25 percent. This reduced consumption of whole plant silage was reflected in average daily gains which were reduced by 14.7 percent when compared to the control, fresh chopped cassava ration. The root silage supported gains equal to those produced by fresh chopped cassava. Feed required per unit gain was not different among treatments.

It appears that the inclusion of the stalk in the whole plant silage reduced the acceptability of this silage by the pig. The hard, fibrous nature of the stalk prevents easy mastication and increased selection and separation of the silage. It is suggested that the roots and the leaves be ensiled for pigs but that the stalks not be included.

Gestation Trial

Fresh Cassava

Gestating sows should be maintained in a thin condition and never allowed to become fat. To prevent the sows from becoming too heavy, they are usually limit fed daily in individual feeding stalls. Sows maintained in confinement normally require about 1.82 to 2.5 kilos (4 to 5.5 pounds) of a complete feed containing 15 to 16 percent protein. As cassava is generally a poor source of protein, it must be properly supplemented with protein, vitamins and minerals. This supplementation can be supplied by a specially prepared high protein feed or protein supplement.

A feeding level of 1.82 kilos (4 lbs.) of a 15 percent protein feed will provide approximately 273 grams of crude protein.

1.82 kg x 15% = 273 grams.

Therefore, a ration of fresh cassava plus protein supplement must provide the same daily intake of protein and dry matter. A daily ration of 620 grams of 40 percent protein supplement and 3.1 kilos of fresh cassava containing 1.0 percent protein will supply 279 grams of crude protein.

Supplement:	0.62 kg	x 40%	= 248	grams
Cassava:	3.10 kg	x 1%	= 31	grams
Total protein:			279	grams

These same quantities of cassava (35 percent dry matter) and supplement (10 percent dry matter) will also supply approximately 1.82 kilos of air-dried feed (approximately 10 percent moisture).

Sows on good pasture will consume forage to meet a portion of their daily feed requirements. Therefore, they require less daily supplemental feed to meet their nutrient needs.

<u>Experiment 7</u>: Thirty Duroc x Landrace gilts and sows were allotted by weight and previous record at the time of service to the three treatment groups. Equal numbers of sows in each group were bred to the same boar. All sows and gilts were bred on pasture and received a kilo of the control diet until bred. At the time of service the sows were moved to the appropriate crorral and started on one of the following three treatments:

1. Sows were maintained on pasture and received 1 kg of a 16 percent protein cor-soybean meal diet daily.
2. Sows were maintained on pasture and received 1.7 kg of fresh, chopped cassava and 0.4 kg of a 40 percent protein supplement daily.
3. Sows were maintained in confinement on concrete and received 3.1 kg of fresh, chopped cassava and 0.62 kg of a 40 percent protein supplement daily.

The composition of the diets and supplements used are presented in Table 24. The composition of the vitamin-trace mineral premix is presented in Table 25.

All sows from the time of farrowing until weaning were fed <u>ad libitum</u> a standard 16 percent protein cron-soybean meal diet.

The performance data for the three sow groups are presented in Table 26. As can be seen from these data, the sows maintained in confinement and fed 3.1 kg of fresh cassava and 0.62 kg of protein supplement gained appreciably more during gestation than the other two treatment groups. These sows farrowed less pigs per litter which resulted in a corresponding lower average number of pigs weaned per litter. Birth weights and weaning weights of these groups were similar.

Sows fed cassava and supplement on pasture farrowed 10 live pigs per litter as compared to 10.4 pigs per litter recorded for the control. Although its nutritional significance is not known, the cassava fed sows maintained on pasture produced an increased number of still born pigs (16.7 percent).

Although additional information is needed, it was demonstrated that fresh cassava can be successfully included as an energy source for gestating sows maintained on pasture or in confinement.

Lactation Trial

Dried and Fresh Cassava

Sows must produce large quantities of milk if they are to produce heavy litters at weaning. The type of diet offered and the quantity of feed consumed greatly influences the milk production of the lactating sow. During lactation, sows are generally fed to appetite to maintain milk production and prevent excessive body weight loss. It was of interest to determine if cassava in both its fresh form and dried and ground into a meal could support adequate production when incorporated into rations for lactating sows.

Experiment 8: Forty-four sows were assigned at parturition to three treatment groups to evaluate fresh and dried cassava as an energy source for lactating sows. The diets and protein supplement used for the three nutritional treatments are presented in Table 27. Diets 1 and 2 were complete mixed, dry diets and were supplied ad libitum in self-feeders during the entire 35 day lactation. Sows on treatment 3 were offered daily a mixture of fresh, chopped cassava and protein supplement. These two ration ingredients were mixed in proportions that would provide a 16 percent protein ration. The proportions used are presented in

Table 28. The proper mixture of supplement and cassava was obtained by combining 1 kg of fresh, chopped cassava with 0.16 kg of 40 percent protein supplement. Each sow was allowed *ad libitum* consumption of this mixture in a self-feeder present in the farrowing crate.

All pigs were weaned at 35 days and body weight changes of the pigs and the sow were recorded. Consumption of cassava and supplement was recorded daily and consumption of the other two diets was recorded at 21 and 35 days.

Performance data for the sows and pigs are presented in Table 29. Because of chance, sows allotted to the fresh cassava treatment farrowed less and slightly heavier pigs. This reduced number of pigs at farrowing resulted in a corresponding lower average number at weaning at 35 days, as percentage mortality from birth to weaning was similar in all groups and only slightly higher in group 2.

Average weaning weights were lowest for pigs from the control sows and heaviest for pig from the fresh cassava fed sows. These results might be expected in consideration of the smaller litters of the fresh cassava group and the differences are probably not associated with treatment. The dried cassava treatment groups were intermediate in weaning weight.

Sows fed the dried cassava diets consumed an average of 5.24 kg. of diet daily as compared to the 4.82 kg. consumed by the control sows. Sows fed the fresh cassava and supplement ration consumed less air-dried than either of the complete, dry diet groups. These sows consumed an average of 6.5 kg. of fresh cassava and 1.21 kg. of 40 percent protein supplement per day.

Average sow body weight gains were not different in groups 1 and 2 (11.0 vs. 12.6 kg.) and only slightly inferior in treatment 3 (7.6 kg.).

Table 1. Proximate analysis of 15 Colombian cassava varieties [1/].

Variety	Moisture	Protein	Fiber	Fat	Ash	Nitrogen-free-extract
	%	%	%	%	%	%
Llanera	67.90	2.33	0.97	0.18	0.95	27.67
Santa Catalina	64.76	2.14	1.16	0.24	1.00	30.71
H-50	66.71	0.56	2.03	0.35	1.71	28.58
Tolima	61.85	0.40	1.35	0.25	1.54	34.61
C.M.C.-50	60.61	1.55	1.09	0.36	1.40	35.07
I-35 Brava	61.21	2.06	1.18	0.31	1.03	34.14
Blanca No. 2	62.70	1.25	1.02	0.29	1.36	33.36
C.M.C.-1	62.18	1.97	2.16	0.30	2.49	30.89
C.M.C.-3	61.50	1.70	1.77	0.24	1.38	33.34
C.M.C.-4	67.59	1.71	3.46	0.35	1.59	25.27
Seis Meses Común	65.35	0.67	1.00	0.43	1.29	31.35
Amarilla	64.16	0.59	1.64	0.33	1.81	35.90
Tempranita	77.32	0.63	1.07	0.24	1.58	19.17
La Respetada	62.84	1.03	1.02	0.22	1.36	33.49
Bartolita	68.81	0.18	0.77	0.25	0.94	29.05
Average	65.03	1.25	1.45	0.29	1.43	30.84

1/ Nutrition Laboratory - ICA

TABLE 2. The effect of cassava maturity in the dry matter content and the pulp and peel percentage[1/]

Date of harvest	% Dry matter whole root	% Dry matter pulp	% Dry matter peel	% Composition pulp	% Composition peel
1970					
February 23	34.6	37.3	22.8	87.3	12.7
March 10	34.9	37.3	25.0	87.1	12.9
March 30	41.1	41.3	36.1	86.6	13.4
April 17	33.9	35.2	27.5	86.1	13.9
Average	36.1	37.8	27.8	86.8	13.2

1/ Maner, J. H. and A. Henao. 1970. Unpublished data.

Table 3. Mineral content of 10 Colombian cassava varieties 1/.

Variety	Calcium	Phosphorus	Sodium	Potassium	Magnesium
	%	%	%	%	%
Llanera	0.06	0.17	0.05	0.92	0.40
Santa Catalina	0.09	0.15	0.04	0.66	0.40
H-50	0.14	0.23	0.04	1.30	0.33
Tolima	0.06	0.20	0.04	1.07	0.22
C.M.C.-50	0.06	0.15	0.07	0.80	0.22
I-35	0.05	0.16	0.07	0.70	0.34
Blanca No. 2	0.07	0.17	0.04	1.05	0.31
C.M.C.-1	0.28	0.10	0.09	0.84	0.45
C.M.C.-3	0.13	0.11	0.08	0.72	0.35
C.M.C.-4	0.21	0.19	0.05	0.58	0.70
Average 2/	0.12	0.16	0.06	0.86	0.37

1/ Samples of dried cassava, approximately 10 percent moisture.

2/ Average at 10 samples.

Table 4. Variation of crude protein contained in 87 varieties of cassava 1/.

Protein level, % ($N_2 \times 6.25$)	Number of samples
0.00 to 1.00	4
1.00 2.00	39
2.00 3.00	29
3.00 4.00	10
4.00 5.00	3
5.00 6.00	1
6.00 6.40	1
Average of 2.3 percent protein for	87 varieties.

1/ Samples of dried cassava, approximately 10 percent humidity.

TABLE 5. The effect of cassava maturity in the total nitrogen and non-protein nitrogen content of cassava roots, "Llanera" variety[1/,2/]

Date of harvest	Whole Root			Pulp			Peel		
	Total N_2	Crude Prot. (NX6.25)	NPN	Total N_2	Crude Prot. (NX6.25)	NPN	Total N_2	Crude Prot. (NX6.25)	NPN
1970									
January 10	.89	5.58	.70	.89	5.50	.13	1.48	9.25	.86
February 23	.87	5.50	.60	.50	3.12	.25	1.30	8.20	.50
March 10	.91	5.68	.52	.73	4.55	.43	1.14	7.10	.46
March 30	.87	5.43	.45	.73	4.58	.34	.87	5.43	.43
April 17	1.02	6.35	.63	.82	5.15	.39	1.92	12.00	1.14
May 4	.93	5.81	.65	.85	5.31	.48	2.13	13.30	-
June 3	.74	4.63	.31	.56	3.50	.26	-	-	-

1/ Maner, J. H. and A. L. Daniels. 1970. Unpublished data. CIAT.

2/ Dry matter containing approximately 10% moisture.

TABLE 6. Total nitrogen and non-protein nitrogen content of three varieties of cassava[1/]

	Fresh Sample			Dry Basis		Oven-dried sample	
	H_2O	N Total	NPN	N	NPN	N	NPN
	%	%	%	%	%	%	%
CMC-84							
Whole root	63.9	0.16	.063	.45	.20	.36	.18
Pulp	64.3	0.12	.073	.33	.17	.35	.16
Peel	76.0	0.33	.160	1.37	.67	.78	.38
CMC-60							
Whole root	70.2	.142	.068	.48	.23	.40	.24
Pulp	68.1	.099	.066	.31	.21	.32	.21
Peel	71.9	.200	.140	.71	.50	.85	.46
CMC-11							
Whole root	58.62	.36	.24	.86	.57	.69	.54
Pulp	58.24	.32	.20	.80	.48	.65	.46
Peel	64.06	.41	.29	1.14	.81	1.10	.80

1/ Maner, J. H. and A. L. Daniels. 1971. Unpublished data. CIAT, Cali, Colombia.

TABLE 7. Analysis of the amino acids of two samples of cassava, "Llanera" variety[1/]

Amino acid	Sample 1	Sample 2	Sample 1	Sample 2
	% Crude Protein		% Protein Nitrogen	
Arginine	17.10	12.90	44.34	32.26
Histidine	.60	.53	1.67	1.33
Isoleucine	.77	1.04	1.93	2.61
Leucine	1.24	1.52	3.09	3.80
Lysine	1.54	1.56	3.86	3.90
Methionine	NC	.33	-	.82
Cystine	.51	NC	1.27	NC
Threonine	.86	1.00	2.16	2.51
Phenylalanine	.78	.94	1.90	2.34
Valine	1.23	1.32	3.08	3.29
Tryptophan	.50	.50	1.26	1.26

1/ Maner, J. H. 1971. Unpublished data.

TABLE 8. Summary of the results obtained in evaluation surveys of cassava as feed for growing-finishing pigs. 1927-1941.

Level of Cassava %	Pig weight, kg.	Average daily gain kg.	Feed/ Gain, kg.	Source Author Date
20	11-26	0.206	2.65	Mondoñedo & Bayon, 1927
20	28-40	0.175	6.52	"
30	39-62	0.325	6.46	"
20	32-60	0.396	4.76	Mondoñedo, 1928
10-25	-	0.559	4.10	Fullerton, 1929
25	10-20	0.068	9.56	Mondoñedo & Alonte, 1931
24-40	35-82	0.609	4.03	Woodman, *et al.*, 1931
5	-	0.420	5.32	Alba, 1937
10	-	0.420	5.38	"
15	-	0.400	5.47	"
20	-	0.350	6.01	"
15	12-30	0.250	3.51	Asico, 1941
20	30-50	0.280	6.35	"
25	50-70	0.300	6.86	"
15-25	12-70	0.270	5.68	"

TABLE 9. Performance of growing-finishing pigs fed diets containing 0, 20 and 40% sun-dried cassava meal.1/

Level of cassava meal	Protein Percentage of the diet	Average daily gain, kg.	Feed Conversion Feed/Gain
0	21.0	0.527	5.29
20	20.0	0.544	5.19
40	18.7	0.607	4.63

1/ Mejia, 1960. Seven pigs per treatment; initial weight 15.2 kg., final weight 89-100 kg.

Table 10. Composition of basal diet and protein supplement utilized in Experiment 1 and 2.

Ingredients	Basal Diet	Protein Supplement
	%	%
Soybean meal	10.59	61.50
Cottonseed meal	3.53	20.53
Corn	81.33	-
Bone meal	2.00	7.90
Vitamins-trace mineral premix 1/	2.55	10.07
Total	100.00	100.00

1/ Contributed 2500 I.U. vitamin A; 250 I.U. vitamin D; 2.5 mg. riboflavin; 12.5 mg. niacin; 7.5 mg. pantothenic acid; 125 mg. choline chloride; 16.5 mg. vitamin B12; 50 mg. chlorotetracycline; 51.5 mg. Mn; 2 mg. Co; 4.4 mg. Cu; and 45.4 mg. Zn per kg. of finished feed in the control diet; approximately 4 times this amount was added to the protein supplement.

Table 11. Proximate analysis of basal diet, protein supplement and cassava utilized in Experiments 1 and 2.

Proximate Analysis	Source		
	Basal Diet	Protein Supplement	Cassava
	%	%	%
Moisture	10.84	8.60	63.76
Protein	19.81	42.88	1.04
Fiber	3.86	4.40	1.06
Ether extract	4.64	1.67	0.26
Ash	6.57	14.85	0.86
Nitrogen-free extract	51.11	20.74	32.02

Table 12. Performance of pigs fed basal diet or raw cassava and protein supplement. Experiment 1.

Item	1 Basal Diet	2 Raw cassava + Supplement Ad. Lib.	3 Raw cassava + Supplement Controlled
Av. daily gain,kg.[1/]	0.765	0.774	0.730
Av. daily in., wet cassava,kg.	-	3.66	3.84
Av. daily in., dry cassava,kg.[2/]	-	1.47	1.53
Av. daily in., supplement,kg.	-	0.92	0.75
Av. daily in., total,kg.[2/]	2.69	2.39	2.28
Feed/unit gain,kg.	3.52	3.09	3.12

1/ Five pigs per treatment; 112-day experiment; Av. initial wt., 19.1 kg.; Av. final wt., 102.8 kg.

2/ Intake expressed on a 10% moisture basis.

Table 13. Level of protein supplement fed to pigs on controlled protein intake based on body weight 1/.

Weight of Pig	Daily (NRC) requirement for Protein plus 10%	Level of Supplement Fed daily
Kg.	Kg.	Kg.
25	0.250	0.582
30	0.275	0.641
35	0.295	0.688
40	0.320	0.747
45	0.344	0.803
50	0.360	0.839
55	0.375	0.875
60	0.385	0.898
65	0.400	0.931
70	0.415	0.967
75	0.429	1.001
80	0.444	1.036
85	0.461	1.075
90	0.477	1.113
95	0.490	1.142
100	0.509	1.188

1/ Levels as indicated supplied per pig on treatments 3 and 6 of experiment 3.

Table 14. Performance of pigs fed basal diet or raw cassava and protein supplement. Experiment 2.

Item	1 Basal	2 Raw cassava+ Supplement Ad. Lib.	3 Raw cassava+ Supplement Controlled
Av. daily gain, kg.1/	0.843	0.834	0.794
Av. daily intake, wet cassava, kg.	--	4.05	3.89
Av. daily intake, dry cassava, kg.2/	--	1.63	1.57
Av. daily intake, supplement, kg.	--	1.17	0.73
Av. daily intake, total kg.2/	2.89	2.80	2.30
Feed/unit gain, kg.	3.43	3.36	2.90

1/ Five pigs per treatment; 98-day experiment; av. initial wt., 17.8 kg.; av. final wt., 98.6 kg.

2/ Total expressed on an approximately 10% moisture basis.

Table 15. Composition of protein supplements fed with raw cassava to growing-finishing pigs. Experiment 3.

Treatments Ingredients	1	2	3	4	5	6
	%	%	%	%	%	%
Soybean meal (SOM)	65.00	64.00	64.00	90.00	88.00	88.00
Cottonseed meal (CSM)	25.00	24.00	24.00	-	-	-
Bone meal	8.00	8.00	8.00	8.00	8.00	8.00
Vitamin-trace mineral premix 1/	2.00	4.00	4.00	2.00	4.00	4.00
Total	100.00	100.00	100.00	100.00	100.00	100.00

1/ Contributed 3 mg. riboflavin; 11 mg. pantothenic acid; 25 mg. niacin; 125 mg. choline chloride; 16.5 mg. vitamin B12, 250 I.U. vitamin D, 2500 I.U. vitamin A; 51.5 mg. of Mn; 4.4 mg. Cu; 2 mg. Co; 45.5 mg. Zn; and 5 mg. chlorotetracycline per kg. of finished feed.

Table 16. Level of protein supplement fed to pigs on controlled protein intake based on body weight [1].

Weight of Pig	Individual Daily Requirement for Protein	Level of 42.88% Protein Supplement to Supply daily requi.
Kg.	Kg.	Kg.
25	0.227	0.529
30	0.250	0.583
35	0.268	0.625
40	0.291	0.679
45	0.313	0.730
50	0.327	0.763
55	0.341	0.795
60	0.350	0.816
65	0.363	0.846
70	0.377	0.879
75	0.390	0.910
80	0.404	0.942
85	0.419	0.977
90	0.434	1.012
95	0.445	1.038
100	0.463	1.080

1/ Level as indicated supplied per pig on treatment 3 in experiments 1 and 2.

Table 17. Influence of protein source and vitamin-trace mineral level of growing-finishing pigs fed raw cassava. Experiment 3.

Protein Source:	SOM + CSM			S O M		
Vit.-trace Min-Supplement:	Normal	2 X Normal	2 X Normal	Normal	2 X Normal	2 X Normal
Method Fed:	Ad-Lib.	Ad-Lib.	Control	Ad-Lib.	Ad-Lib.	Control
Av. daily gain, kg.1/	0.687	0.657	0.614	0.627	0.661	0.618
Av. daily intake, fresh cassava, kg.	3.89	3.65	3.50	3.41	3.67	3.60
Av. daily intake, dry cassava, kg. 2/	1.38	1.30	1.25	1.21	1.31	1.28
Av. daily intake, supplement, kg.	0.83	0.93	0.67	0.70	0.73	0.61
Av. daily intake, total, kg.2/	2.21	2.23	1.92	1.91	2.04	1.89
Feed/unit gain, kg.	3.22	3.38	3.10	3.03	3.07	3.06
Percent Protein in Diet Cons.,%	17.20	18.60	15.80	17.50	17.40	15.40

1/ Sixteen pigs per treatment, 8 pigs in each of two replications; 84-day experiment; Av. initial wt., 23.0 kg.

2/ Cassava calculated on 10 percent moisture basis.

Table 18. Composition of protein concentrates to supplement fresh cassava diets for growing-finishing pigs.

Ingredients	Protein Supplements 1	2	3	4	5	6
	%	%	%	%	%	%
Corn	11.20	26.80	11.20	33.00	25.00	29.60
Soybean meal	78.10	-	-	-	-	-
Meat meal	-	70.50	-	44.30	21.30	-
Blood meal	-	-	-	20.00	20.00	-
Cottonseed meal	-	-	78.10	-	30.00	30.00
Fish meal	-	-	-	-	-	36.70
Bone meal	8.00	-	8.00	-	1.00	1.00
Vitamins and minerals 1/	2.70	2.70	2.70	2.70	2.70	2.70
Total	100.00	100.00	100.00	100.00	100.00	100.00
Crude Protein Analysis,%.	43.00	49.44	37.75	48.50	44.69	40.25

1/ The vitamin and mineral premix supplied the following quantities per kilo of finished diet: vitamin A, 2633 I.U.; vitamin D3, 287 I.U.; riboflavina, 4.6 mg.; pantothenic acid, 10.12 mg.; niacin, 33.75 mg.; Calcio, 1350 mg.; B12, 24.95 mg.; Mn., 52.65 mg.; Cu, 12.03 mg.; Zn, 67.57 mg.; clorotetracycline, 27.35 mg. and salt 6.75 gm.

Table 19. Performance of growing-finishing pigs fed protein supplements of different protein sources.

Treatment[1]	Av. daily gain	Av. daily cons. fresh cassava[2]	Av. daily cons. suppl.	Feed/ Gain[3]
Fresh Chopped Cassava plus:	Gm.	Kg.	Kg.	Kg.
1. SM	723	4.00	0.80	3.25
2. MM	684	3.40	0.78	3.07
3. CM	592	3.13	0.79	3.38
4. MM + BM	728	3.88	0.94	3.32
5. MM + BM + CM	724	4.00	0.90	3.38
6. FM + CM	679	4.08	0.79	3.47
Average	687	3.75	0.83	3.31

1/ SM is soybean meal; MM is meat meal; CM is cottonseed meal; BM is blood meal and FM is fish meal.

2/ Expressed on 65 percent moisture or 35 percent dry matter basis.

3/ Calculated on 10 percent moisture basis.

Table 20. Composition of experimental diets containing different levels of cassava meal. Experiment 5.

Ingredients	Diets 1	2	3	4	5	6	7	8
	%	%	%	%	%	%	%	%
Dried ground yuca[1/]	-	25.72	48.65	69.25	-	21.70	41.04	58.26
Ground yellow corn	81.31	51.43	24.33	-	69.00	43.38	20.52	-
Soybean meal	7.69	11.85	16.02	19.75	10.00	13.92	17.45	20.74
Cottonseed meal	7.00	7.00	7.00	7.00	7.00	7.00	7.00	7.00
Cane molasses	-	-	-	-	10.00	10.00	10.00	10.00
Bone meal	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00
Vitamin-trace-mineral premix[2/]	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00
Totals	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00

1/ Dried in forced-air oven at 180°F.

2/ Contributed the same concentration of vitamins and trace minerals as in premix in Table 10.

Table 21. Influence of level of cassava meal on performance of growing finishing pigs.

Results [1/]: Treatments:	Av. daily gain, kg.	Daily feed intake, kg.	Feed/unit gain, kg.
1. Basal	0.772	2.68	3.47
2. 25.72% cassava	0.744	2.66	3.57
3. 48.65% cassava	0.743	2.79	3.76
4. 69.25% cassava	0.708	2.48	3.49
5. Basal+10% molasses	0.888	3.38	3.84
6. 21.70% cassava+10% molasses	0.827	2.95	3.56
7. 41.04% cassava+10% molasses	0.777	3.00	3.85
8. 58.26% cassava+10% molasses	0.767	2.73	3.54

1/ Six pigs per treatment; 111-day experiment; Av. initial wt., 18.5 kg.; Av. final wt., 104.8 kg.

Table 22. Composition of Protein Supplement utilized with Cassava Silage for Growing-finsihing Pigs.

Ingredients:	40% Protein Supplement
Corn	11.20
Cottonseed meal	78.10
Bone Meal	8.00
Vitamin and Mineral Premix	2.70
Total	100.00

Table 23. Cassava silage for growing-finishing swine.

Treatment:	Av. daily intake of fresh cassava	Av. daily intake suppl.	Av. daily[1/] weight gain	Feed/gain[2/]
Protein supplement plus:	kg.	kg.	gm.	kg.
1 Fresh chopped cassava	4.04	1.00	750	3.43
2 Cassava root silage	3.84	1.01	770	3.25
3 Root and foliage silage	3.05	1.06	640	3.52

1/ Five pigs per treatment, Av. initial weight 18.34 kg., Av. final wt. 98.8 kg. Length of trial, 112 days.

2/ Ingredients expressed on approximately 10% moisture basis.

Table 24. *Composition of Diet and Supplements used for Gestating Sows.*

Treatments:	1 16% Control Diet	2 40% Supplement Fed on Pasture	3 40% Supplement Fed in Confinement
Ground Corn	74.80	-	-
Soybean meal	18.00	64.08	66.75
Cottonseed meal	-	20.53	20.53
Iodized salt	0.90	-	-
Calcium Carbonate	0.30	-	-
Bone meal	3.00	7.90	7.90
Vit. and Min. Premix	3.00	7.49	4.82
Total	100.00	100.00	100.00

Table 25. Vitamin-Trace Mineral Premix Used in Rations for Gestating Sows fed Fresh Cassava.

Ingredients:	Quantity per 100 kg. Control Diet
Vitamin A (325.000 I.U./gm.)	1.84
Vitamin D_3 (200,000 I.U./gm.)	0.15
Riboflavin, 40%	2.25
Calcium Pantotenate (70.6 gm./kg.)	47.79
Niacin, 50%	15.00
Coline chloride, 25%	300.00
Vitamin B_{12} (52.8 mg./kg.)	59.55
Manganese Sulfate	22.50
Copper Sulfate	5.25
Zinc Sulfate	37.50
Aurofac 10 (10 gm./kg.)	150.00
Ground corn	2.358.16
Total	3.000.00

Table 26. Fresh cassava in gestation in pasture and confinement.

Treatments:	1 kg. Control diet daily-pasture	1.7 kg.fresh cassava+0.4 kg.suppl. protein on pasture	3.1 kg.fresh cassava+0.62 kg.suppl. protein in confinement
No. of sows served,No.	10	10	10
No. of sows farrowing,No.	9	7	7
Av. sow wt.at service,kg.	165.8	163.6	152.8
Av. sow wt.at 30 days,kg.	172.6	173.0	170.6
Av. sow wt.at 60 days,kg.	181.4	180.8	183.0
Av. sow wt.at 90 days,kg.	182.1	185.1	190.2
Av. sow wt.at 105 days,kg.	185.7	188.5	190.5
Av. sow gain gestation,kg.	19.9	24.9	37.7
Av. sow wt.24 hrs. post-partum,kg.	164.3	163.9	173.9
Av. sow wt.21 days post-partum,kg.	171.0	176.9	182.1
Av. sow wt.35 days post-partum,kg.	177.5	171.6	182.3
Av. sow gain,lact.,kg.	13.2	7.7	8.4
Total no. pigs born,No.	97	84	54
Total no. pigs born dead,No.	3	14	0
Total no. pigs born alive,No.	94	70	54
Av. no. pigs per litter,No.	10.4	10.0	7.7
Av. no. pigs at 21 days,No.	8.6	7.3	6.9
Av. no. pigs at 35 days,No.	8.3	7.3	6.9
Av. birth wt.,kg.	1.28	1.12	1.18
Av. 21 day wt.,kg.	4.24	3.61	3.84
Av. 35 day wt.,kg.	6.94	6.05	6.49

Table 27. Composition of diets and supplement used for lactating sows.

Ingredients:	Control diet, 16%	Cassava meal diet, 16%	40% protein supplement
Cassava meal	-	59.20	-
Ground corn	81.35	-	-
Cane molasses	-	10.00	-
Soybean meal	15.00	27.40	87.10
Salt	0.50	0.50	1.61
Bone meal	2.50	2.40	9.68
Calcium carbonate	0.15	-	-
Afeilin[1/]	0.50	0.50	1.61
Total	100.00	100.00	100.00

1/ Commercial Vitamin and trace mineral premix.

Table 28. Proportion of cassava and supplement for 16% protein ration.

Fresh cassava 1/, kg.	40 percent protein supplement, kg.
1.00	0.16
2.00	0.32
3.00	0.48
4.00	0.64
5.00	0.80
6.00	0.96
7.00	1.12
8.00	1.28
9.00	1.44
10.00	1.60

1/ Based on cassava containing 35 percent of dry matter basis and 2.41% protein.

Table 29. Performance of Lactating Sows Fed Fresh and Dried Cassava Diets.

Treatments:	1 16% Control Diet	2 16% Dried Cassava	3 40% Protein Supplement, Fresh Cassava
No. of sows, No.	13	15	16
Av. number pigs at birth, No.	10.8	10.1	9.3
Av. number pigs at 35 days, No.	9.0	7.9	7.6
Mortality, %	16.4	22.4	18.1
Av. birth wt., kg.	1.18	1.22	1.36
Av. wt. at 35 days, kg.	6.03	6.80	7.63
Av. intake creep diet, kg./pig.	0.302	0.530	0.368
Av. wt. of sows 24 hrs. post-partum.	179.3	170.6	158.3
Av. wt. of sows at 21 days.	187.9	177.2	165.8
Av. wt. of sows at 35 days.	190.3	183.0	165.8
Av. sow gain, kg.	11.0	12.6	7.5
Av. daily intake cassava[1/], kg.	-	-	6.50
Av. daily intake supplement, kg.	-	-	1.21
Av. total daily intake, kg.	4.82	5.24	3.74

1/ Cassava contains 35 percent dry matter.

FIGURE 1. Growth Curves of Treatment Groups in Experiment 1.

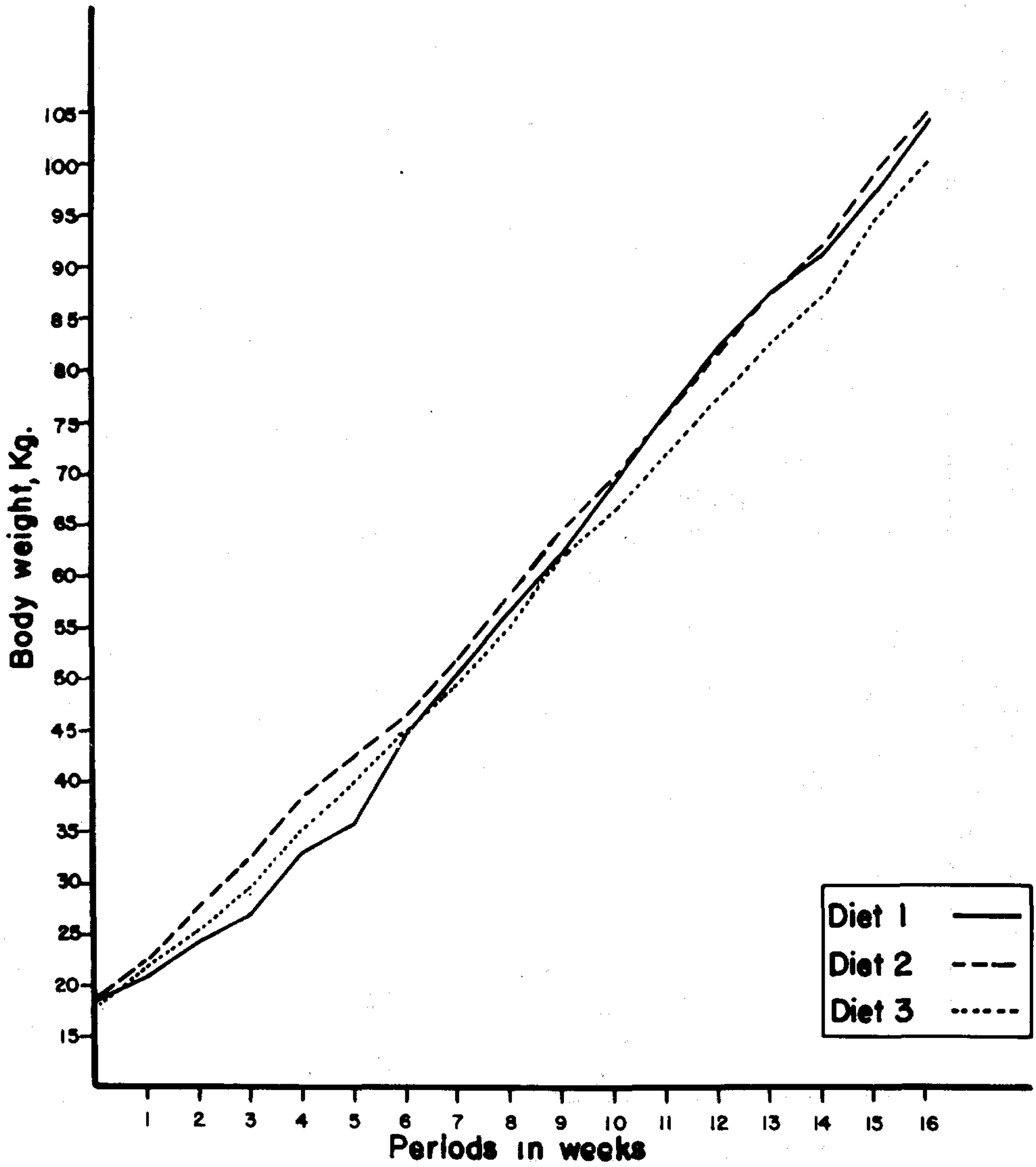
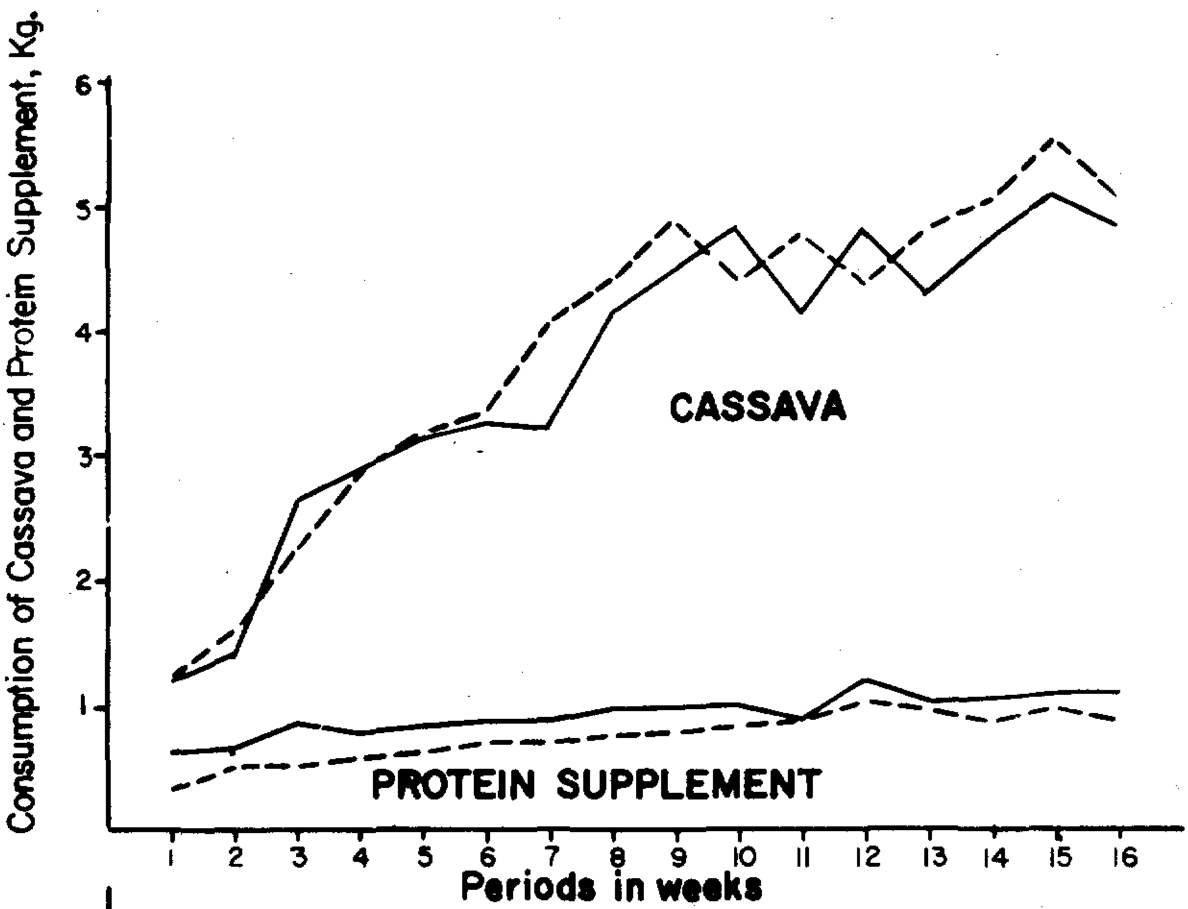


FIGURE 2. Average Daily Voluntary Consumption of Cassava and Protein Supplement Fed Free Choice, Calculated at Weekly Intervals.



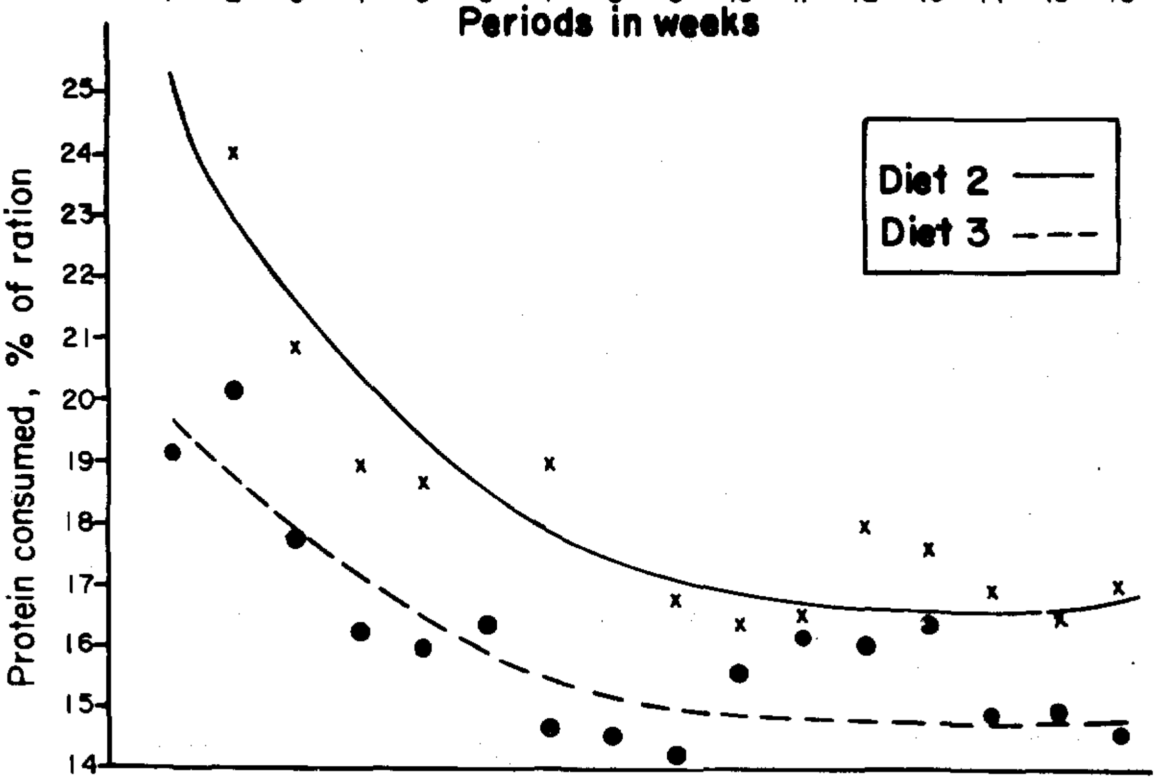


FIGURE 3. Protein Consumed as Percent of Free Choice Cassava and Protein Supplement Ration.

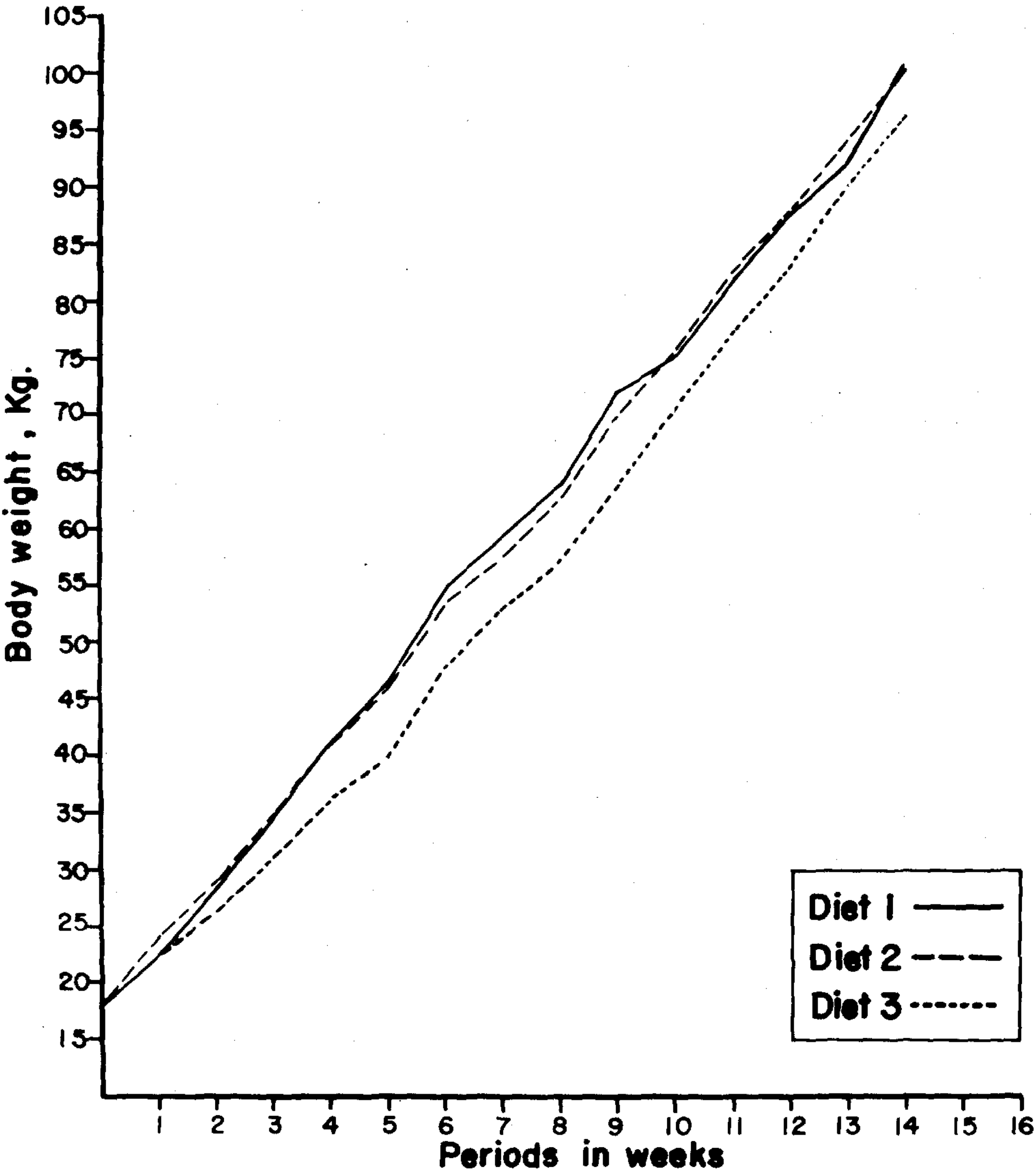
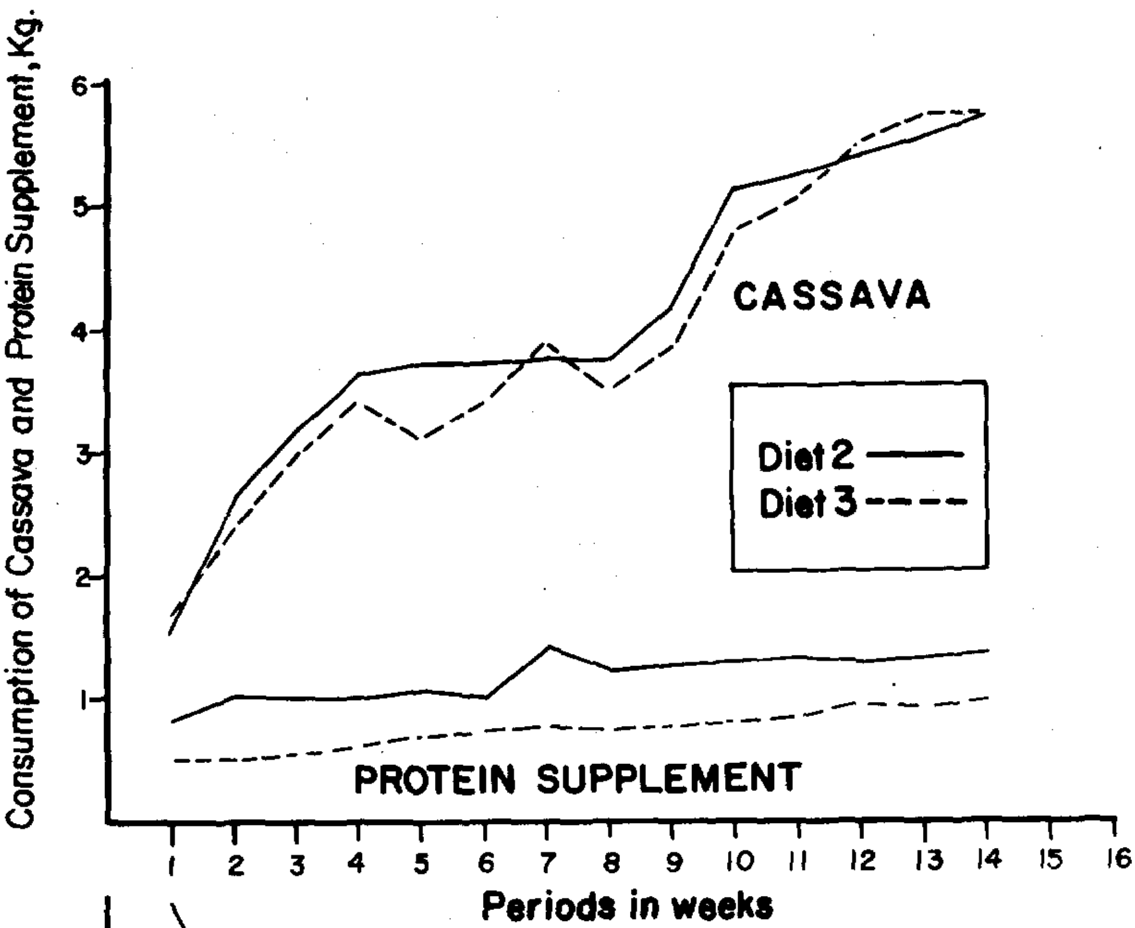


FIGURE 4. Growth Curves of Treatment Groups in Experiment 2.

FIGURE 5. Average Daily Voluntary Consumption of Cassava and Protein Supplement Fed Free Choice, Calculated at Weekly Intervals.



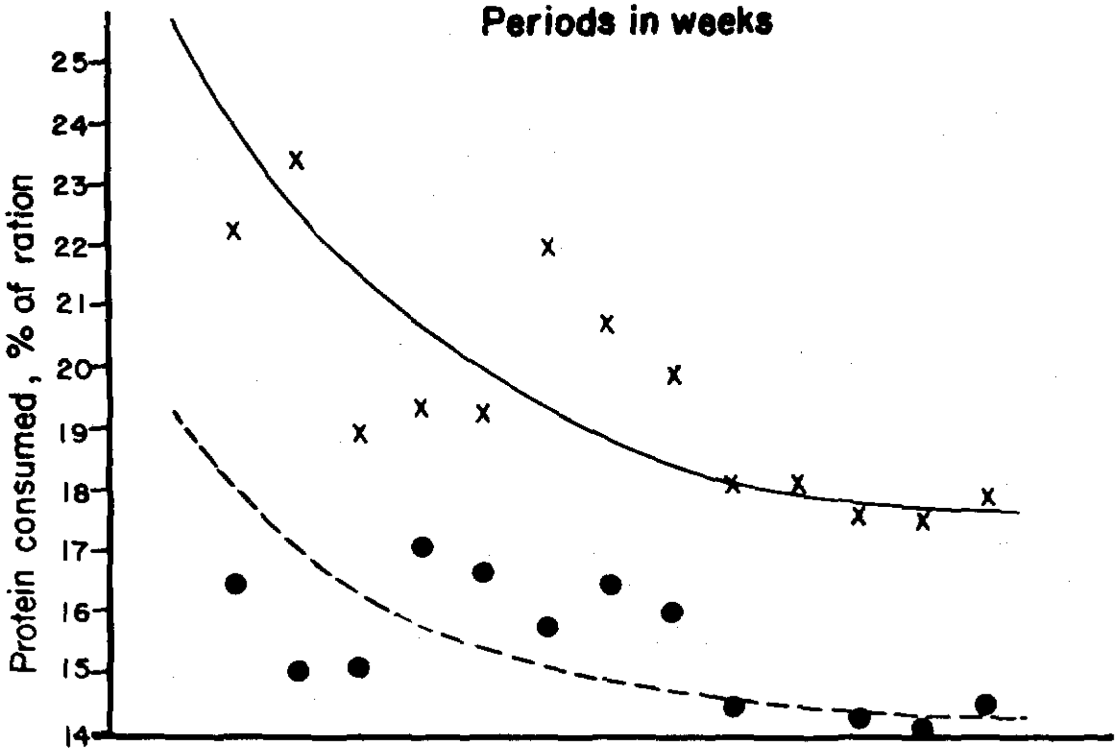


FIGURE 6. Protein Consumed as Percent of Free Choice, Cassava and Protein Supplement Ration.

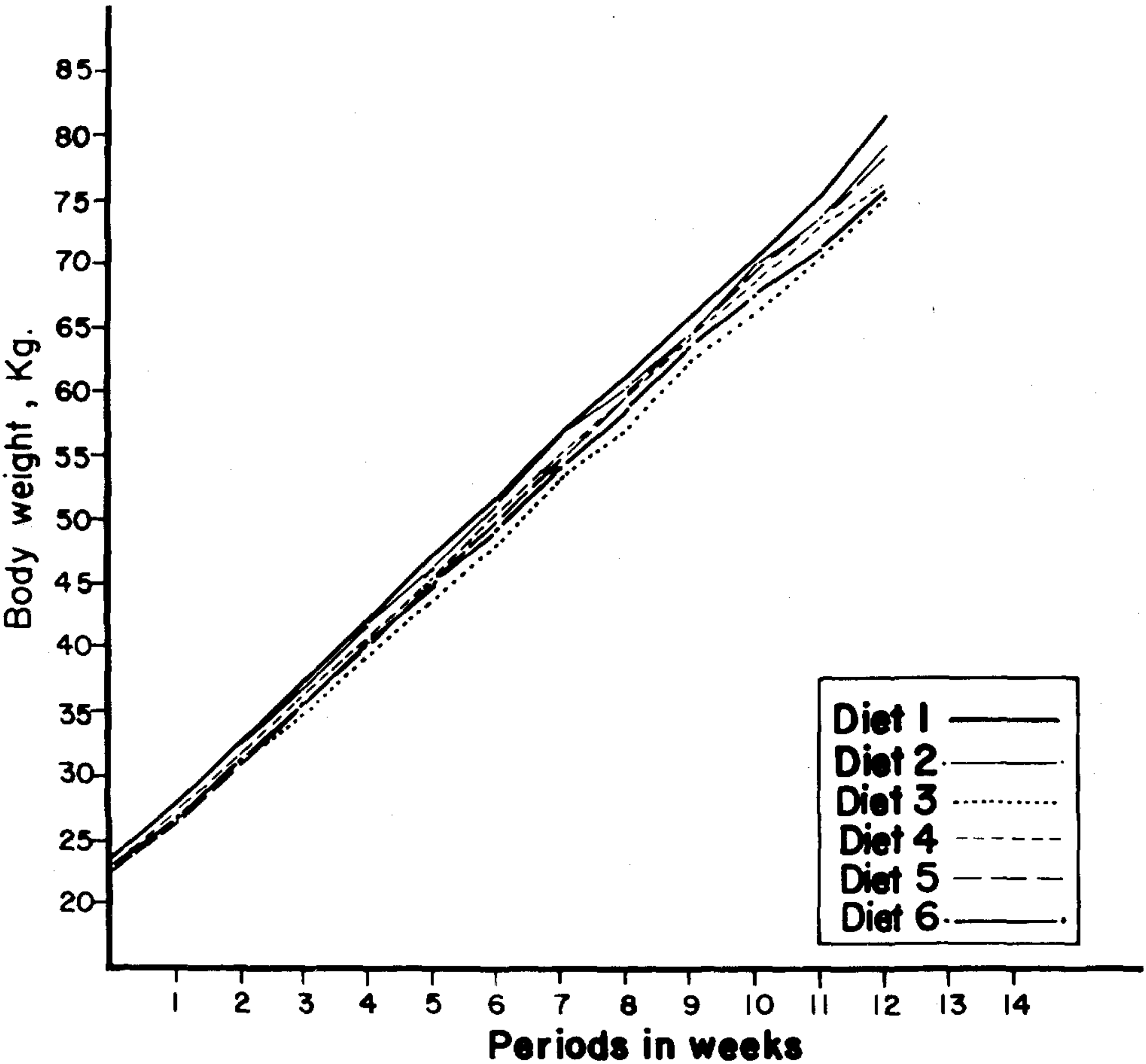


FIGURE 7. Growth Curves of Treatment Groups in Experiment 3.

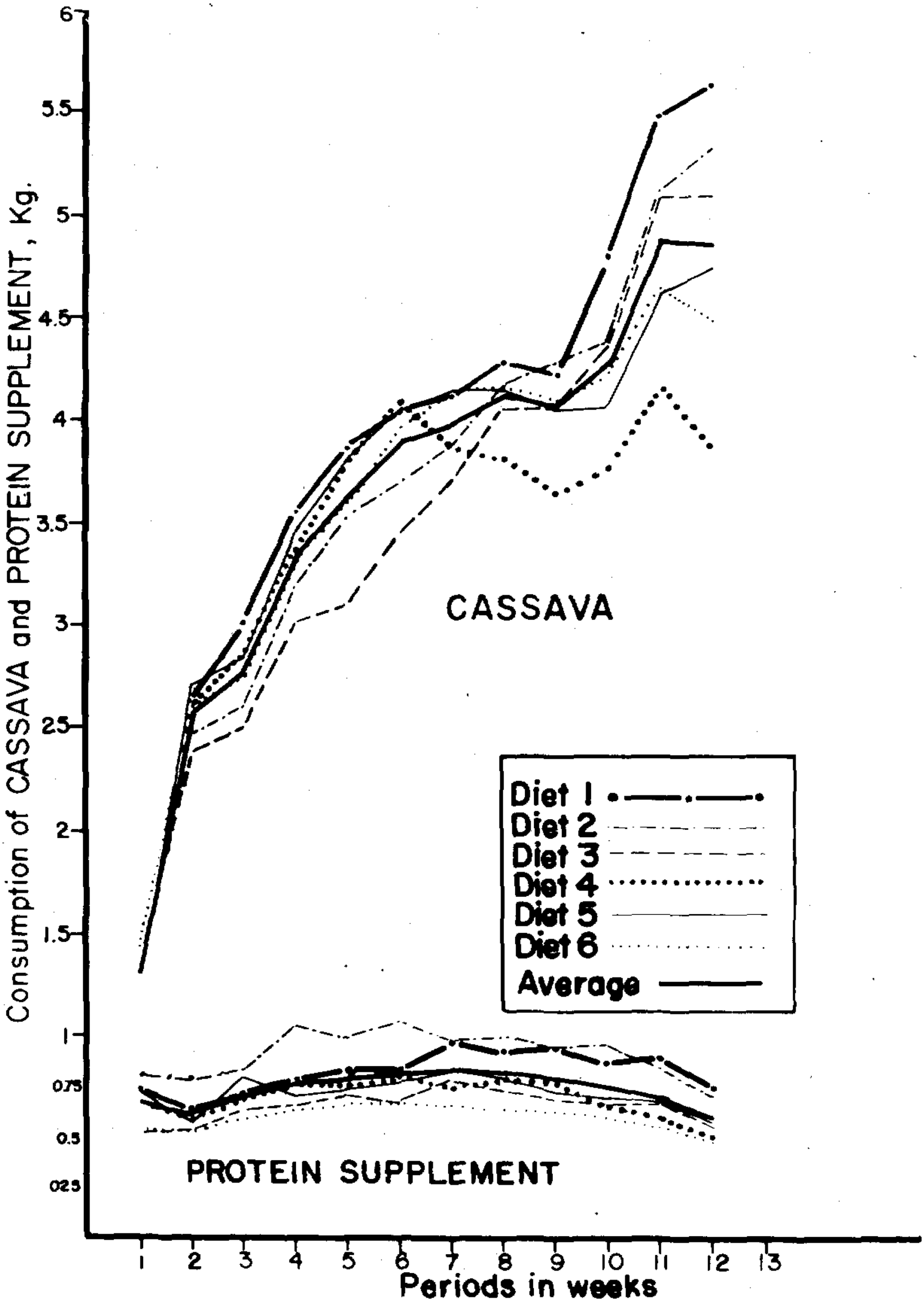


FIGURE 8. Average Daily Voluntary Consumption of Cassava and Protein Supplementation Fed Free Choice, Calcultated at Weekly Intervals.

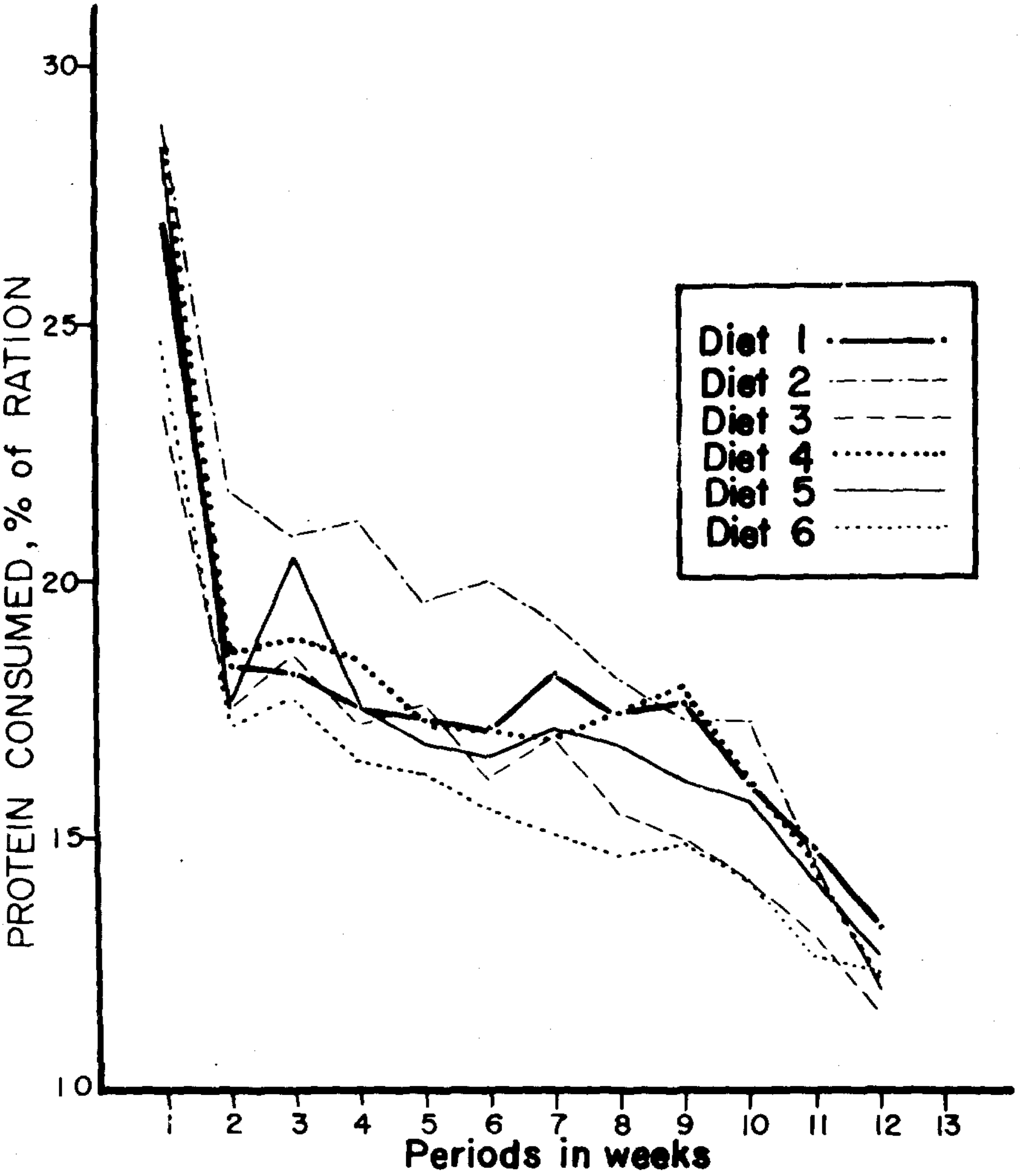


FIGURE 9. Protein Consumed as Percent of Free Choice Cassava and Protein Supplement Ration.

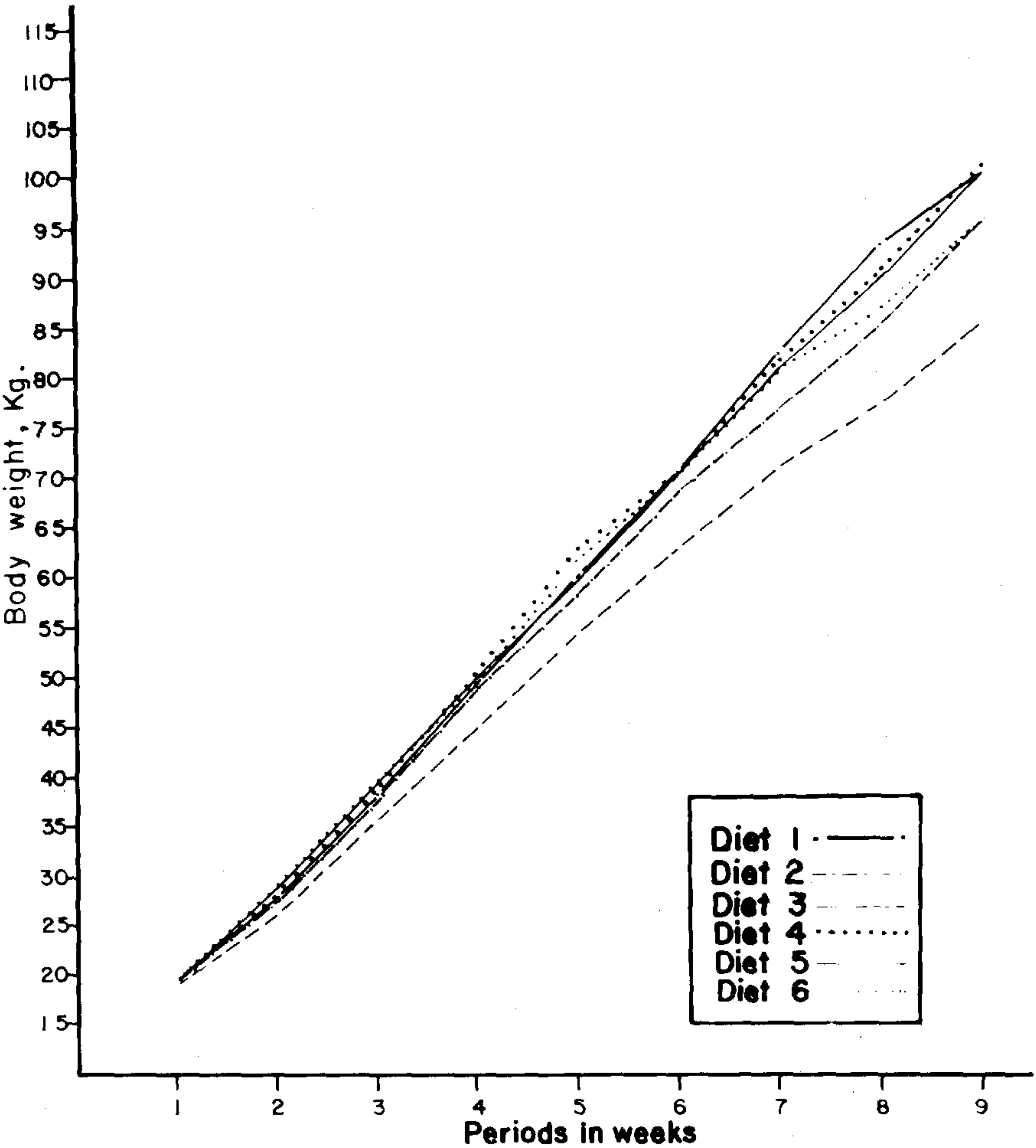


FIGURE 10. Growth Curves of Treatment Groups in Experiment 4.

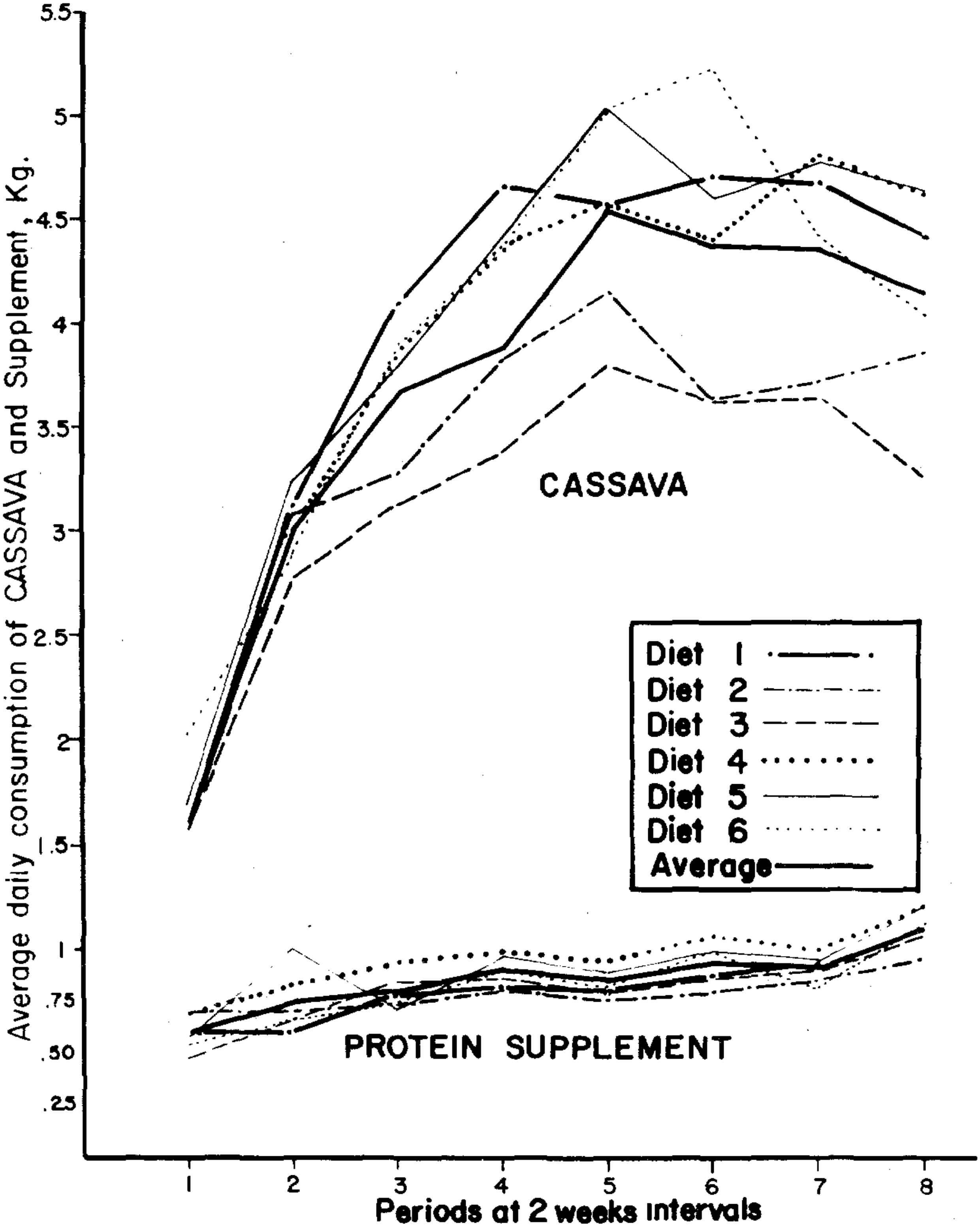


FIGURE 11. Average Daily Voluntary Consumption of Cassava and Protein Supplement Fed Free Choice, Calculated at Biweekly Intervals.

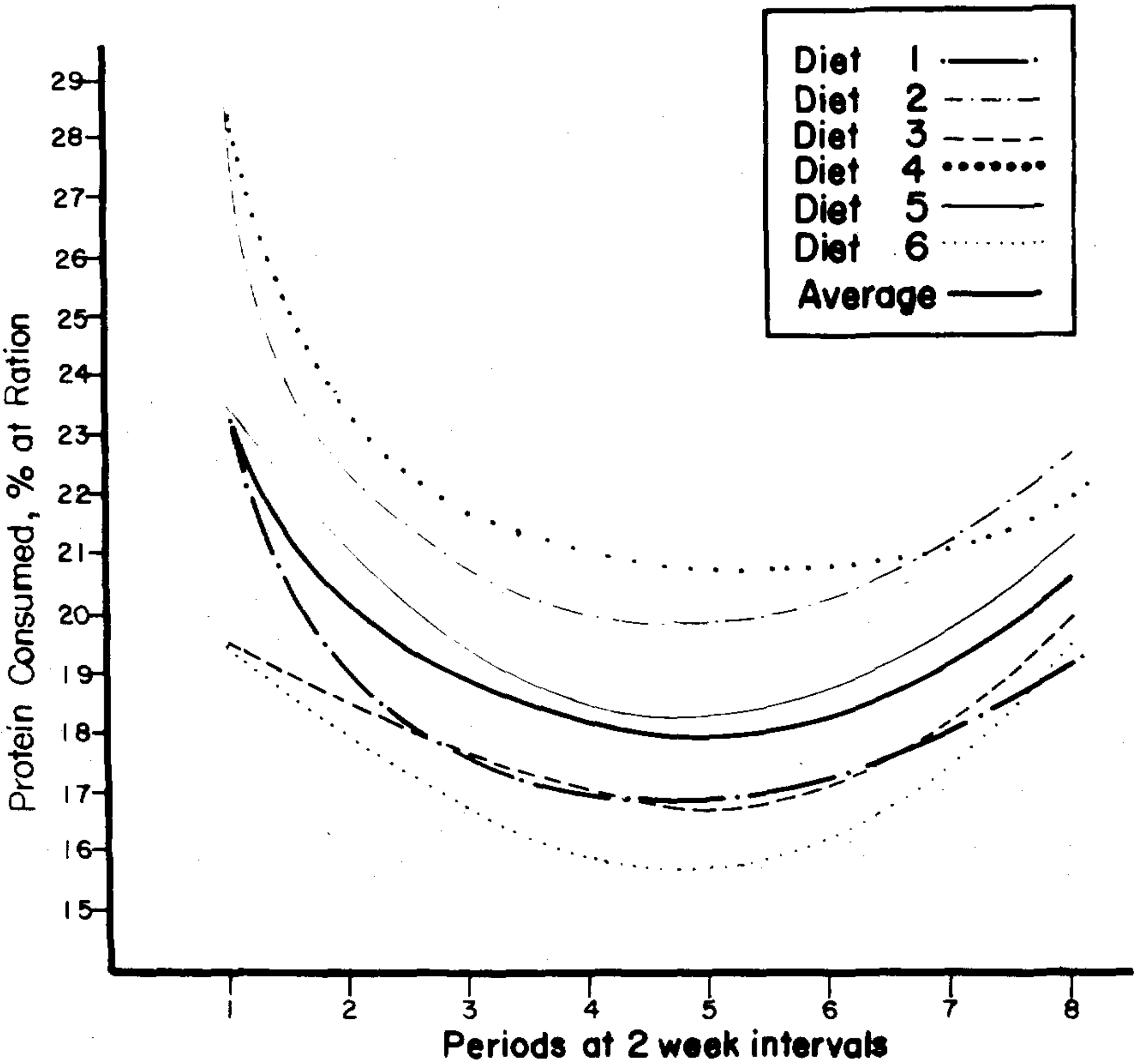


FIGURE 12. Protein Consumed as Percent of Free Choice Cassava and Protein Supplement Ration.

REFERENCES

Alba, M. G. 1937. A study of different varieties of cassava for hog feeding purposes. Philipp. Agric. 25: 782.

Asico, P.M. 1941. A comparative study of gaplek meal and corn as basal feed for growing and fattening pigs. Philipp. Agric. 29: 706.

Aumaitre, A. 1969. Valeur alimentaire du manioc et de differentes cereales dans les régimes de seurage precoce du porcelet; utilisation digestive de l'aliment et effet sur la croissance des animaux. Ann. Zootech., 18 (4): 385.

Beck, 1969. Personal communication.

Bolhuis, G. G. 1954. The toxicity of cassava roots. Netherlands Journal of Agricultural Science. 2: 176.

Boorsma, W. G. 1905. Vergiftige Cassava (Poisonous Cassava). Teysmannia 17: 483.

Brautlecht, C. A. 1953. Starch. Its sources, production and uses. Reinhold Publishing Co. New York, N. Y.

Close, J., E. L. Adriaens, S. Moore and E. J. Bigwood. 1953. Composition en acides amines de hydrosysats de farine de manioc roni, variete Amere. Bull. Soc. Chem. Biol. Brussels, 35: 985.

Couch, J. F. 1932. U.S. Department of Agr. Leaflet 88.

FAO Production Yearbook 1970. Vol. 24.

Fullerton, J. 1929. Tapioca meal as food for pigs. J. Ministry of Agr., Gr. Brit. 36: 130.

Govin, A. and P. Andouard. 1914. Fatening pigs on cassava. Bull. Soc. Nat. Agr. France. 74: 481.

Henke, L. A. 1919. I sweet potatoes vs cassava. Col. Hawaii Bull. 6: 24.

Henke, L. A. 1923. Feeding test with hogs. Hawaii Univ. Quart. Bull. 2:29.

Johnson, R. M. and W. D. Raymond. 1965. The chemical composition of some tropical food plants. IV. Manioc. Tropical Sci., 7 (3): 109.

Kerr, R. W. 1950. Chemistry and Industry of Starch. 2nd. Ed. Academic Press. New York, N. Y.

López, L. and H. Herrera. 1970. Manihot Carthagenensis. Una yuca silvestre con alto contenido protéico. VIII Reunión de Fitotécnia, Bogotá, Colombia, Noviembre 22-28, 1970.

Maner, J. H. and J. Buitrago. 1964. Utilización de yuca en dietas para crecimiento y acabado de cerdos. II Congreso Nal. de la Industria Porcina, Junio 25-29, Cali, Colombia, 1964.

Maner, J. H. and I. Jiménez. 1967. Comparación de varios suplementos protéicos a utilizar con yuca fresca para cerdos en crecimiento y acabado. Día de Campo sobre Porcinos. ICA, Palmira, Colombia, Abril, 1967.

Maner, J. H., J. Buitrago and I. Jiménez. 1967. Utilization of yuca in Swine Feeding, Proc. Int. Symp. on Trop. Root Crops. Univ. W.I., St. Augustine, Trinidad 2 (6): 62.

Maner, J. H., J. Buitrago and J. T. Gallo. 1970. Protein sources for supplementation of fresh cassava (Manihot esculenta) rations for growing finishing swine. J. Animal Sci. 31: 208 (Abst).

Maner, J. H. and A. Henao. 1970. Unpublished data.

Maner, J. H. and A. L. Daniels. 1970 and 1971. Unpublished data.

Maner, J. H. 1971. Alimentación de cerdos con raciones a base de yuca. Boletín Técnico No. 9. ICA, Colombia.

Maner, J. H. 1971. Unpublished data.

Mejía T. R. 1960. Valor comparativo entre la yuca y el maíz en la alimentación de cerdos. Rev. Fac. Nal. de Agron. Medellín, Colombia. 20: 3.

Mesa, J. and J. H. Maner. 1972. Unpublished data.

Modebe, A.N.A. 1963. Preliminary trial on the value of dried cassava. (Manihot utilissima Pohl) for pig feeding. J. West Afric. Sci. Ass. 7: 127.

Mondoñedo, A., and P. V. Bayone, 1927. A comparative study of corn and cassava as feeds for hogs. Philipp. Agric. 15: 523.

Mondoñedo, M. 1928. A comparative study of corn and cassava as feeds for hogs: II Ground corn vs raw chopped cassava. Philipp. Agric. 17(2):105.

Mondoñedo, M. and F. Alonte. 1931. A comparative study of corn, cassava, sweet potatoes and pong-apong as feeds for swine. Philipp. Agric. 2: 113.

Oke, O. L. 1969. The role of hydrocyanic acid in nutrition. World Review of Nutrition and Dietetics. 11: 170.

Oyenuga, V. A. 1955. Nigerian Feedstuffs. University College. Ibadan, Africa.

Oyenuga, V. A. and L. K. Opeke. 1957. The value of cassava rations for pork and bacon production. W. A. Jour. Biol. Chem. 1: 3.

Peixoto, R. R. 1965. Estudio comparativo entre farinha de mandioca e milho, como alimento para porcos em crescimento e engorda. Bul. Escala de Agron. Eliseu Maciel, Univ. Rural do Sul. Brasil. Novembre, 1965.

Peixoto, R. R. and N. Islabão. 1969. Substituicao do milho ao nivel de 50%, farinha de mandioca na alimentaçáo de suinos em crescimento e engorda. Bul. Tec. No. 5. Min. de Educación y Cultua. Rio Grande do Sul, Brasil

Rogers, D. J. 1963. Studies of Manihot esculenta, Crantz and related species. Bull. Torrey Bot. Club. 90 (1): 43.

Shimada, A. S. 1970. Valor alimenticio de la harina de yuca (Manihot utilissima pohl) para cerdos. IV Día del Ganadero INIP, Veracruz, México, Nov. 21-22, 1970.

Sreeramamurthy, V. V. 1945. Investigations on the nutritive value of tapioca (Manihot utilissima). Indian J. Med. Res. 33: 229.

Varon, L. A., 1968. Annual Report - Potato and Yuca programs. Instituto Colombiano Agropecuario.

Vogt, H. 1966. The use of tapioca meal in poultry rations. World's Poultry Science. J. 22: 113.

Woodman, H. E., A. W. Manzies Kitchin and R. E. Evans. 1931. The value of tapioca flour and sago pith meal in the nutrition of swine. J. of Agr. Science. 21: 526.

Zarate, J. J. 1956. The digestibility by swine of sweet potato vines and tubers, cassava roots, and green papaya fruits. Philipp. Agric. 40: 78.