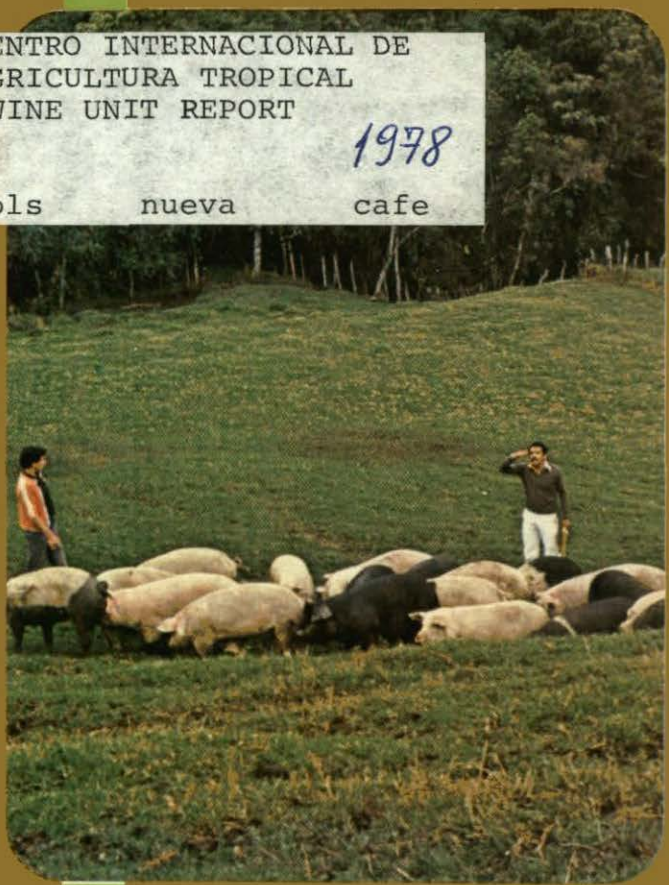
CIAT

swine unit



1978

CIAT is a nonprofit organization devoted to the agricultural and economic development of the lowland tropics. The Government of Colombia provides support as host country for CIAT and furnishes a 522-hectare farm near Cali for CIAT's headquarters. In addition, the Fundación para la Educación Superior (FES) makes available to CIAT the 184-hectare substation of Quilichao, situated near Santander de Quilichao, Departamento del Cauca. Collaborative work with the Instituto Colombiano Agropecuario (ICA) is carried out on several of its experimental stations and similar work is done with national agricultural agencies in other Latin American countries. CIAT is financed by a number of donors represented in the Consultative Group for International Agricultural Research (CGIAR). During 1979 these donors are: the United States Agency for International Development (USAID), the Rockefeller Foundation, the Ford Foundation, the W.K. Kellogg Foundation, the Canadian International Development Agency (CIDA), the International Bank for Reconstruction and Development (IBRD) through the International Development Association (IDA) the Inter-American Development Bank (IDB), the European Economic Community (EEC) and the governments of Australia, Belgium, the Federal Republic of Germany, Japan, the Netherlands, Norway, Switzerland and the United Kingdom. In addition, special project funds are supplied by various of the aforementioned entities plus the International Development Research Centre (IDRC) of Canada and the United Nations Development Programme (UNDP). Information and conclusions reported herein do not necessarily reflect the position of any of the aforementioned agencies, foundations or governments.

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1978 Report

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* Left during 1978

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Swine Unit

International cooperation activites, particularly training, are a major part of the Swine Unit's program to increase the efficiency of production of this species in Latin America. Twenty professionals from national institutions in 10 countries of the region participated in the four-month Third Postgraduate Course in Swine Production. The Unit's cooperative programs with national institutions in Bolivia, Costa Rica, Ecuador and Peru have also intensified their training activities at local and regional levels.

Validation of technology oriented to solving problems limiting swine production has also expanded in the cooperative programs of the respective countries. Technology transfer to swine producers is being emphasized through extension activities and technical consulting by swine specialists in the national programs.

Research activities in the Unit during 1978 were primarily directed to evaluating feeding programs based on cassava roots and products processed from roots. By adding sugar cane molasses to diets based on cassava meal, pigs utilized these diets more efficiently. A series of experiments was done on ensiling chopped cassava roots; using this process, roots were conserved for a minimum of six months. Experimental results of the nutritive evaluations of ensiled cassava roots suggest a good potential for this conservation process for humid tropical regions and for small- and medium-scale farms, where the final product could be used for feeding swine. The utilization of diets containing 20 and 40% levels of cassava leaf meal for growing and finishing pigs was also evaluated. Acceptable results were obtained when this meal was fed at the lower experimental level to partially replace conventional protein sources.

Thirty-five fermentations were done during the year with the 3000-liter fermentor in the pilot plant for producing single-cell protein utilizing grated cassava roots as the energy substrate. Concentrations of 34 to 35% crude protein were obtained from the sun-dried biomass after average fermentation periods of 21 hours. The principal difficulty at this level of production was encountered during harvesting and drying of the final biomass.

The total quantity of biomass material produced enabled nutritional studies to be conducted with pigs. The single-cell protein (fermented with the fungus *Aspergillus fumigatus* I-21A) was the only protein source in diets which were compared to diets with soybean meal as the protein

source. Nutritional quality of the single-cell protein was good for feeding swine, if it is adequately supplemented with methionine. Results of blood parameter analyses suggest that the single-cell protein is not toxic to pigs. Samples of organs and tissues have been taken for histopathological analyses.

Results from measuring the cyanogenic glucoside contents in cassava roots and root products suggest it is necessary to study in more detail the effect of methods of storage and processing on changes in content of this toxic component, especially for products that are to be used for feeding animals. These feed materials normally contain the root peels, which show higher cyanide levels than the parenchymatous tissue.

TRAINING

Third Postgraduate Course In Swine Production

The Third Postgraduate Training Course in Swine Production was held between July 17 and November 17, 1978. Twenty professionals participated from institutions involved in training, research and swine promotion activities in 10 Latin American countries. The objective of the course was to train these professionals in integrated systems of swine production to provide effective support to the Latin American swine industry.

The course was conducted by a group of specialists from various areas of swine production, in governmental and private institutions and firms, and scientific personnel of CIAT's Swine Unit, Data Services Unit and Training Office. Training activities during the course were distributed among production theory (36% of total time), practical activities in CIAT (21%), study tours (14%) and work on commercial farms (28%).

Production Theory

The initial part of the course was dedicated to conferences and seminars on selection, genetic improvement, nutrition and feeding, management, health, marketing and analyzing costs of production. Workshops, examinations and documentation exercises were utilized in this phase to insure that participants became familiar with library information sources and research results from CIAT investigations.

Practical Activities in CIAT

Two aspects of swine production were emphasized during this phase of the course: (1) planning and practical work in management, health, selection, reproduction and feeding; and, (2) conducting experiments planned jointly by trainees and instructors. These experiments involved early weaning, heat synchronization, artificial insemination, and restricted feeding of pigs during finishing. All activities took place in the CIAT Swine Unit.

Study Trips

For two weeks course participants traveled in the most important swine producing zones of Colombia. Twenty-five swine farms under various systems of production and 16 agro-industrial companies involved in the production, processing and marketing of swine supplies and products were visited.

Among some of the important management systems and other activities observed were the following: integrated swine/dairy systems where manure from the swine unit was utilized for pasture fertilization; utilization of whey from milk processing plants for swine feeding; operations of plants producing balanced rations for pigs; use of kitchen wastes and similar garbage in swine feeding; the process of marketing through organized sales, and slaughtering and processing of pork; and, the swine development programs and activities of the animal science and veterinary medicine sections of the Instituto Colombiano Agropecuario (ICA), especially the preventive measures that have been taken in relation to African swine fever.

Work on Swine Farms

Groups of two trainees each were assigned to work on swine farms in the Cauca Valley, near CIAT. Farms utilized were commercial ones dedicated to breeding, raising and fattening pigs; swine populations ranged from 500 to 2000 head per farm. In cooperation with the owners, farms had been selected previously with the objective of analyzing each operation and developing a simulated production program, based on resources available on each enterprise.

Among the principal activities the trainees accomplished on farms were: establishment of production registry systems; programs for selecting reproduction animals; management instruction for personnel of the farms; rearranging installations and programming their rational utilization according to production flow; formulation of rations and establishment of feeding programs; treatment, removal and utilization of swine wastes; and, sanitation programs.

INTERNATIONAL COOPERATION

Bolivia

The CIAT Swine Unit has continued to provide consulting to cooperative projects at the Universidad Boliviana Gabriel René Moreno (UBGRM) and to the Rural Development Commission/Inter-American Development Bank activities, in Monteagudo, Chuquisaca.

During 1978, the breeding herd at the UBGRM was increased to 200 sows to satisfy the growing demand for improved animals in the project's area of influence. Presently, about 100 pigs a month are being distributed to the promotional programs. Fifty purebred pigs were also delivered to the Heifer Project for distribution to small farms of the region, through agricultural extension programs.

The Swine Unit at the UBGRM is being utilized fully and up to this report, 166 farrowings have been obtained with satisfactory experimental results (Table 1). Training activities for producers and students recently graduated from the university have been developed during 1978. Five short courses, each lasting one month, were offered for swine producers of the region.

Research projects done during 1978 as a part of the CIAT/UBGRM cooperation included the following experiments: utilization of rice by-products, evaluation of dry yeast *(Saccharomyces cereviciae)* as a protein and energy source for swine feeding, and the evaluation of commercial additives in rations for nursing pigs. Most of these experiments are thesis projects of

Table 1.

Summary of the reproductive performance obtained in the Universidad Boliviana Gabriel René Moreno-Heifer/CIAT Cooperative Project.

Parameter	Value
Total farrowings	166
Fertility (%)	85
Farrowings/sow/year	1.6
Pigs/litter at farrowing	8.5
Pigs/litter at weaning, 56 days	7.6
Birth weight (kg)	1.25
Weaning weight, 56 days (kg)	13

students of the Faculty of Veterinary Medicine and Animal Science.

The Swine Development Project in Chuquisaca expanded its programs of credit and promotion for swine production during 1978. Credit is restricted to mandatory joint financing for maize growing and swine production; three sizes of enterprises have been established — 15, 30 and 45 breeding sows.

In the demonstration herds, management and production systems are being tested that can be implemented at the user level. Installations utilized are of simple construction and, as much as possible, pastures are on marginal areas or other sites not suitable for crop production on the farms. Areas required for pasturing have been calculated to be 1.5, 3.0 and 4.5 ha, for 15-, 30- and 45-sow units, respectively. The feeding system is based on maize on the cob that is produced on the farm, plus a protein supplement produced at the Project site. The first results from the demonstration herds and one of the commercial herds are presented in Table 2. The productive performances were satisfactory.

In addition, a work-study program has been initiated in connection with the demonstration herds whereby the participants receive training supervised by the professionals in charge of the project, as an **indispensable** requirement to obtaining credit for Project activities.

CIAT collaborated in conducting a swine production seminar, organized by the Rural Development Commission of Chuquisaca. The one-week seminar brought together 30 professionals from the Swine Project and regional credit agencies. In addition, three Bolivians attended the swine production course at CIAT this year;

Table 2.

Summary of the reproductive performance obtained in the swine herds of the Rural Development Committee/Inter-American Development Bank Project.

Parameter	Demonstration Unit (15 sows)	Demonstration Unit (30 sows)	Committee's commercial herd
Total farrowings	33	26	243
Pigs/litter at farrowing	8.0	6.5	7.8
Pigs/litter at weaning, 56 days	6.1	5.3	6.2
Birth weight (kg)	1.4	1.3	1.5
Weaning weight, 56 days (kg)	15.6	16.6	12.5
Mortality, birth-weaning (%)	19.4	18.9	19.9

one professional was from the UBGRM and two represented the Chuquisaca Swine Development Project.

Costa Rica

International cooperation work in Costa Rica has had a major impact during 1978, through the activities developed by the Swine Program of the Ministery of Agriculture and Livestock in the banana growing zone of the Atlantic Coast. In mid-year the Center for Research and Swine Promotion at the Los Diamantes Experiment Station, in Guápiles, was inaugurated as part of an agreement between the Ministry, the National Association of Banana Growers and the Central Bank of Costa Rica. This center has facilities to produce improved foundation breeding herds and for conducting applied research in swine feeding and management. Activities at the center were initiated with purebred pigs imported from the United States; pigs produced in the foundation herd will be distributed principally to banana producers in the Atlantic coastal region.

Research activities are oriented to evaluating practical feeding systems utilizing waste bananas as the principal energy source. CIAT's Swine Unit has collaborated in development of this new center, especially through planning the research work, technical consulting and postgraduate training.

Little progress was made in the Cooperative Swine Project at the University of Costa Rica, principally because construction of the swine unit has not begun. However, by utilizing rented installations, some experimental work was done and purebred pigs have been produced in the foundation herd to furnish breeding stock to farmers of the region.

Ecuador

The Swine Programs of the Instituto Nacional de Investigaciones Agropecuarias (INIAP) continued to develop research and swine promotion activities in their areas of influence.

The Swine Program of the Santa Catalina Experiment Station has enlarged its extension activities to more than 10 agricultural cooperatives in the Andean region near Quito. Similar activities are being initiated in the region (Provinces of El Oro and Guayas) under the Swine Program of the Boliche Experiment Station. Based on results of a partial survey of the farmers of the region, it was found that the majority of the small- and medium-scale farms raise a few pigs under traditional systems of subsistence production. Extension work from these stations consists of technical consulting for the producers, especially regarding simple building installations for housing pigs, in furnishing boars of improved breeds and in calculating simple diets utilizing as much as possible by-products of the crops of the region (barley, wheat and potatoes, in the Andean region, and bananas, rice and sugar cane, in the southwestern region). Normally, practical training in the Swine Program Units of INIAP is provided to personnel of the cooperatives before initiating technical collaboration at the production level. With this objective and for demonstration purposes, thatched huts or sheds made with local materials have been constructed in which a limited number of pigs can be housed in semi-confined, controlled conditions.

Activities in the Swine Program at the Santo Domingo Experiment Station have been restructured and are now oriented to validating technology especially for management and feeding. Experimental results will serve for implementing trials or

practical applications at the regional or local levels, principally for the western region.

The CIAT Swine Unit has provided collaboration through periodic visits and technical consulting according to the new focus of activities of the Swine Programs of INIAP. Two professionals from these programs participated in the swine production course at CIAT in 1978.

Peru

Activities of the Swine Program of the Instituto Veterinario de Investigaciones Tropicales y de Altura (IVITA), in Pucallpa, has been oriented to the continuation of gaining records of swine production on the Program's farm and to conducting research work, especially in some aspects of feeding. Distribution of foundation stock to swine producers of the region has continued, but for economic reasons extension activities and consulting outside of the Program have been limited.

Data of reproductive performance and litter production for three consecutive years (1976-1978) confirm partial results reported earlier (CIAT Annual Report, 1977) in which Yorkshire pigs adapted themselves and performed satisfactorily in the tropical conditions at Pucallpa. Studies of the effect of the seasons on litter size and weight of piglets at birth, and at 21 and 56 (weaning) days show that these parameters were not affected, at least over the two-year observation period (1977-1978).

During 1978 experimental work was completed on the utilization of locally available inputs, especially rice polishings and cassava roots, in feeding programs. The principal trials done were: utilization of fresh cassava roots with protein supplements based on fish meal containing 20, 30 and 40% protein, during the growing period; levels of 50 and 90% rice polishings supplemented with fish meal in swine growing diets; and, the effect of the number of daily feedings of a diet based on rice polishings, during the growing and finishing periods. In addition, trials are still being done on utilizing swine manure in fish production in ponds (jointly with the section of fish production) and for fertilizing cassava crops.

Three Peruvians participated in the swine production course in 1978. The three professionals represented IVITA, the Ministry of Agriculture and Food, and the Technical University of Piura, respectively.

RESEARCH

During 1978 research activities in the Swine Unit focused on utilizing cassava in swine feeding. Studies included the effect of adding sugar cane molasses to swine diets based on cassava meal, the process of ensiling and utilizing silage of cassava roots, feeding of cassava leaf meal, and the production and evaluation of single-cell protein utilizing fresh cassava roots as the energy substrate. In addition, the cyanide content was determined for roots of some cassava varieties as well as for products derived from cassava. A new methodology was used which permits the root content of this toxic compound to be measured more precisely.

Cassava Meal

Previously reported experimental results (CIAT Annual Report, 1976) demonstrated that cassava meal can

furnish the largest part of the caloric requirement of pigs, substituting partially or completely conventional energy sources, especially the cereals. The principal limitation in the practical utilization of cassava meal in swine feeding programs is its relatively high cost, compared to other energy sources. Moreover, inclusion of high levels of cassava meal results in rations with a very powdery texture or appearance.

One possible solution to these problems is the addition of sugar cane molasses to reduce the quantity of cassava meal in the diets and to improve their physical consistency. The feasibility of employing increasing levels of molasses with a diet based on cassava meal has been demonstrated (CIAT Annual Report, 1976); however, management of this type of feeding requires much labor to readjust periodically the levels of molasses to be used. To simplify the management of this system, two molasses levels were tested: 10% during the growing phase and 20% during the finishing period. The composition of the experimental diets for the growing and finishing periods are shown in Table 3; the diets provided 16 and 13% protein for growing and finishing periods, respectively.

Results of the experiment are presented in Table 4. Pigs fed the cassava meal ration had a growth rate (average daily gain) slightly less than those fed the control diets. The addition of molasses improved performances both in diets based on sorghum and in diets of cassava meal. Improvement was more marked with the cassava meal which provided a feed conversion (feed/gain) better than that of the other three experimental groups. Results of this experiment, like those of the previous one, suggest that adding molasses to diets based on cassava meal helps to improve swine performance in the growing phase, by increasing diet consumption when increasing levels of molasses are used or by improving the efficiency or feed conversion when levels on the order of 10 and 20% are utilized in growing and finishing periods, respectively.

Root Ensilage

In tropical regions with high precipitation and high relative humidity it is difficult to dry chopped cassava roots to

Table 3.

Percentage composition of experimental rations based on cassava meal and containing two levels of molasses.

Ingredient	Experimental variable			
	Sorghum + soybean meal (control)		Cassava meal + soybean meal	
	without molasses	with molasses	without molasses	with molasses
Sorghum	77 (85)[1]	65 (60)	-	-
Cassava meal	-	-	65 (72)	55 (51)
Soybean meal	19 (11)	21 (16)	31 (24)	31 (25)
Molasses	-	10 (20)	-	10 (20)
Premix [2]	4	4	4	4

1 Percentages in parentheses are levels of ingredients in finishing rations.
2 Premix composition: bonemeal, 87.5%; iodized salt, 7.5%; premixed minerals and vitamins, 5%.

Table 4.

Results of feeding rations based on sorghum or cassava meal and containing two levels of molasses to pigs during the growing and finishing periods.

Parameter	Experimental variable			
	Sorghum + soybean meal (control)		Cassava meal + soybean meal	
	without molasses	with molasses	without molasses	with molasses
No. experimental days	112	112	119	112
Pigs/group	9	10	9	10
Average liveweight (kg)				
Initial	16.5	16.1	16.0	16.2
Final	95.9	99.0	93.3	93.7
Avg. daily gain (kg)	0.71	0.74	0.65	0.69
Avg. daily consumption (kg)	2.35	2.52	2.22	2.22
Feed:Gain ratio	3.3	3.4	3.4	3.2

produce meal. One practical method for conserving chopped roots under these conditions is to ensile them. The Swine Unit this year conducted several studies of ensiling cassava roots and evaluating the final product for nutritional quality.

Cassava roots were washed to remove excess dirt and then were cut in small chips with a mechanical chipper. These chips can be packed in silos (Fig. 1) when it is necessary to preserve considerable quantities of the product, or in polyethylene bags (Fig. 2), for small quantities.

Silos are made with wooden walls lined with sheet metal (2.3 m long, 1.5 m wide and 1.2 m high, giving a total capacity of 4.1 m^3). In such a portable silo set over a concrete floor five tons of cassava were conserved for six months. The surface of the ensilage was covered with plastic over which was placed wood shavings and tiles to prevent the entry of air; the silo was kept covered with a canvas to protect against rains.

Chemical Changes in Ensiled Roots

Figure 3 shows results from measuring

Figure 1. Silo made of wooden sides covered with sheet metal for conserving cassava roots.

Figure 2. Cassava root ensilage stored in polyethylene bags.

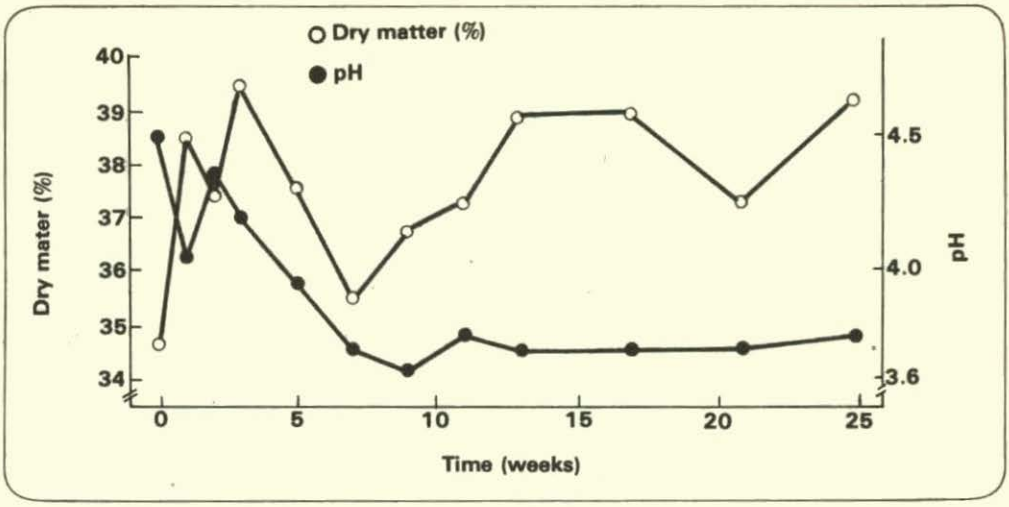

Figure 3. Changes in dry matter content and pH of ensiled cassava roots, over time at CIAT.

the dry matter content and the pH of ensilage samples during the six months of storage. Ensiled roots included a mixture of the varieties M Ven 270, M Mex 53 and M Col 655A. Marked variations, possibly due to the sampling technique, were observed in the dry matter contents and total carbohydrates. Tendencies observed were an increase in dry matter and a reduction in the total carbohydrate through the ensiling period. Initial and final contents of dry matter and carbohydrates were 34.5 and 39.1% and 90 and 80%, respectively. The concentration of dry matter and the reduction in total carbohydrates was due to the loss of water and utilization of the carbohydrates in anaerobic fermentation during the ensiling process. A rapid decrease in pH, from 4.5 to 3.7, was observed during the first seven weeks after the ensiling process was initiated. Although the concentration of volatile fatty acids was not measured, the decrease in pH should have been partly due to production of these acids, especially lactic acid, as products of the anaerobic fermentation that utilizes the root starch as the energy substrate.

Results of the chemical analyses of the initial and final samples of ensiled cassava are presented in Table 5. Non-nitrogen extract (soluble carbohydrates) was estimated in this case by differences and the content was above that reported for samples analyzed specifically for carbohydrates (Fig. 3). The most important changes observed were the reductions in moisture content and nitrogen-free extract and increases in fat (ether extract) and in crude fiber. Chemical analyses of samples taken from the silo throughout the storage period varied widely; part of this variation seemed to be due to the sampling system

Table 5.

Percentage dry matter chemical composition of fresh and ensiled (6 months) cassava roots.

Component	Fresh roots	Ensiled roots
Dry matter	34.6	39.1
Crude protein (N X 6.25)	2.8	3.2
Fat or ether extract	1.2	2.0
Crude fiber	2.4	5.5
Ash	2.3	2.9
Nitrogen-free extract[1]	91.2	86.5

1 Estimated indirectly by difference.

(done at different depths with a soil sampler) and to the fact that the mixed samples represented three cassava varieties.

Effects of Adding Salt, and Duration of Ensiling

To study the effects of the length of the ensiling period and of adding salt to the roots to be ensiled, a nutritional evaluation was conducted with swine during growing and finishing periods. Cassava ensiled in polyethylene bags for a minimum of six months was compared with roots ensiled for less time. In addition, common salt was mixed with one-half of each lot at a rate of 2% of the fresh weight of the chopped cassava at the time ensiling began.

Results of the chemical analysis of the ensiled roots in polyethylene bags were similar to those from cassava conserved in a silo, but the crude fiber content (about 2%) of roots stored in the bags was slightly less; ash content (about 5.4-5.8%) was almost double for the roots ensiled with salt.

The protein supplement employed to balance the cassava ensilage furnished 42% crude protein and contained the following percentages of ingredients: soybean meal, 44; cottonseed meal, 44; bone meal, 9; vitamins and minerals, 1; and salt, 2 (replaced by 2% cassava meal in supplements used with silage to which salt had been added). The supplement was mixed with the cassava silage at the time of feeding pigs on one day and on the following day, only the silage portion was offered.

Performances of pigs fed with rations based on ensiled roots are shown in Table 6. No differences in weight increase of pigs were observed. Average consumption per pig of roots ensiled for six months was slightly less than that of animals fed with roots for less time. In both cases, added salt decreased silage consumption but because the same weight gain was obtained, this diet produced a better feed conversion.

Additional experimental results have demonstrated that similar performance can be obtained by mixing the protein-

Table 6.

Swine performance during the growing and finishing periods when fed rations based on cassava root silage.[1]

Parameter	Cassava roots ensiled - for more than 6 months		for less than 6 months	
	without salt	with salt	without salt	with salt
Avg. liveweight (kg)				
Initial	21.7	22.0	21.9	21.8
Final	96.7	95.7	96.6	97.0
Avg. daily gain (kg)	0.63	0.62	0.63	0.63
Avg. daily consumption (kg)				
Ensilage	3.30	2.87	3.45	3.20
Supplement[2]	0.78	0.78	0.78	0.78
Feed:Gain ratio[3]	3.71	3.45	3.84	3.63

1 Averages for six pigs/treatment, fed individually during 119-day experiment.
2 Supplement of protein, minerals and vitamins that furnished 42% protein.
3 Based on 90% dry matter.

mineral-vitamin supplement with cassava silage each day or every two days. Other results also suggest that adding 10% sugar cane molasses to the ensilage and the supplement mixture every two days provides an improved efficiency of feed conversion during the periods studied.

Evaluation of Different Protein Supplements

In order to evaluate various sources of protein that could be utilized to supplement rations based on ensiled cassava roots, an experiment was done with pigs during growing and finishing, utilizing the protein supplements with compositions shown in Table 7. These supplements furnished protein levels between 41 and 52%, and according to the protein source furnished, quantities mixed with the ensiled roots varied.

Because of the limited availability of ensiled roots, the trial was ended after 18 weeks. Groups of pigs fed with ensiled roots and supplements with soybean meal or the mixture of soybean and cottonseed meal reached the normal expected weight (90 kg) by the end of the experiment, while the other groups showed lower weights (Table 8). Average weight gains of the groups fed with cassava root ensilage were similar to the control group, except that the group fed with the supplement based on fish meal performed poorer than the other groups. Pigs fed a mixture of ensiled cassava roots and the protein supplement based on fish meal consumed a smaller total quantity of the mixture compared with the other groups, suggesting that lower palatability of the mixture limited its consumption. The supplement containing fish meal with cottonseed meal improved animal performances although they were not equal to those obtained with supplements based on soybean meal. Generally, each animal consumed about 3 kg of silage daily, a quantity similar to those reported in feeding programs that used fresh chopped roots (CIAT Annual Report, 1975).

Studies on the process of ensiling cassava roots and subsequent nutritional evaluations suggest this system of conserving roots is promising, especially at the small- and medium- scale farm levels and in regions with humid tropical climates where the drying process for producing cassava meal would be very risky. Additional investigations are being done to

Table 7.

Percentage compositions of supplements prepared with different protein sources for utilization with ensiled cassava roots.

Ingredient	Protein source			
	Cottonseed meal + soybean meal	Soybean meal	Cottonseed meal + fishmeal	Fish-meal
Cottonseed meal	44	-	48.5	-
Soybean meal	44	88	-	-
Fishmeal	-	-	48.5	97
Bonemeal	9	9	-	-
Salt	2	2	2	2
Minerals and vitamins	1	1	1	1
Calculated protein (%)	41	44	47	52

Table 8.

Performance of swine fed with rations based on silage of cassava roots combined with various sources of supplemental protein.[1]

Parameter	Control ration	Ensiled cassava roots + Cottonseed meal + soybean meal	Soybean meal	Cottonseed meal + fishmeal	Fishmeal
Avg. liveweight (kg)					
Initial	16.3	16.1	16.3	16.2	16.2
Final	87.0	90.9	90.4	85.0	79.2
Avg. daily gain (kg)	0.56	0.59	0.59	0.55	0.50
Avg. daily feed consumption (kg)					
Ensilage	-	2.85	3.10	3.01	2.98
Supplement	(2.06)[2]	0.86	0.73	0.67	0.60
Feed:Gain ratio[3]	3.68	3.61	3.58	3.65	3.84

1 Avg. of 10 pigs/group; 126-day experiment. Ensiled roots contained approximately 40% dry matter.
2 Avg. daily consumption of the control ration.
3 Based on 90% dry matter.

try and improve the ensiling process and to develop an adequate management system for feeding ensiled cassava roots to pigs.

Cassava Leaf Meal

Preliminary studies done by the Cassava Program suggest that aerial parts of the cassava plant (leaves and younger stems) can yield good levels of dry matter and crude protein per surface unit (CIAT Annual Report, 1973). The green or fresh foliage has good feeding value for ruminants (CIAT Annual Report, 1976); for monogastric animals it could be utilized in dry form as a protein source.

The cassava variety M Col 12 was used to produce vegetative matter. Entire plants were cut 20 cm above the soil and then passed through a forage chopper. Chopped forage was sun-dried in trays or on concrete floors; dried material was milled to obtain a whole meal. The chemical composition (in percentages) of this meal used for feeding pigs during the growing stage was: moisture, 8.5; crude protein, 17.2; total fat or ether extract, 5.8; crude fiber 17.5; ash, 9.6; calcium, 1.8 and phosphorus, 0.3. Percentages are expressed in the dry sample that contained 8.5% moisture; the moisture content of the fresh forage after chopping averaged 70%.

Nutritive Evaluation

In order to increase experimental information on the utilization of foliar protein and, especially meal of cassava leaves and young stems, an experiment was conducted with pigs during the growing and finishing periods utilizing two levels of leaf meal (20 and 40% of the diets) and adding sugar cane molasses to improve palatability of the experimental rations. Diet compositions are presened in Table 9.

Although the experiment had two replications per treatment, results in the second replication differed significantly

Table 9.

Percentage composition of the experimental diets for swine utilizing cassava leaf meal during growing and finishing periods.

Ingredient	Soybean meal control	Cassava leaf meal 20%	Cassava leaf meal 40%
Cassava meal	53.7 (49.8)[1]	40.5 (36.6)	27.0 (23.3)
Molasses	10.0 (20.0)	10.0 (20.0)	10.0 (20.0)
Soybean meal	31.6 (25.5)	24.8 (18.7)	18.3 (12.0)
Cassava leaf meal	-	20.0	40.0
Bonemeal	4.0	4.0	4.0
Salt	0.5	0.5	0.5
Minerals and vitamins	0.2	0.2	0.2

1 Numbers in parentheses are percentages of the finishing diets.

from those of the first, over all treatments. Data in Table 10 are the results from the first replication. These suggest that the utilization of increasing levels of cassava leaf meal tended to reduce pigs' performances during growing and finishing periods. However, results obtained with 20% cassava leaf meal, and even with 40%, are acceptable, taking into account the initial weights of the experimental animals. Total consumption of the diets per pig over the experimental period was 276, 358 and 381 kg for the control diet and the diets with 20 and 40% cassava leaf meal, respectively.

Experimental information suggests a potential for incorporating relatively low levels (about 20%) of cassava leaf meal in swine diets. As these trials were done on a limited scale, the actual cost of this protein source is not known. The pigs ought to be able to utilize high levels of this class of protein during the gestation period, but due to lack of raw materials, these experiments were not able to be done.

Production and Evaluation of Single-Cell Protein

Activities with the CIAT pilot plant for

Table 10.

Effects of utilizing two levels of cassava leaf meal in swine rations during growing and finishing periods.[1]

Parameter	Soybean meal control	Cassava leaf meal 20%	Cassava leaf meal 40%
Avg. liveweight (kg)			
Initial	15.1	15.1	15.3
Final	101.1	98.3	96.8
Days on experiment	119	147	147
Avg. daily gain (k)	0.72	0.57	0.55
Avg. daily feed consumption (kg)	2.32	2.44	2.59
Feed:Gain ratio	3.2	4.3	4.7

1 Avg. of five pigs/group.

producing single-cell protein by fermentation of cassava roots progressed well during 1978. Successful operation of the 3000-liter fermentor permitted sufficient quantities of biomass to be produced for nutritional studies with pigs during growing and finishing periods.

Production

Thirty-five fermentations were done with the 3000-liter fermentor (Table 11). The substrate employed was grated fresh cassava roots from different varieties with the total quantities utilized varying between 420 and 430 kg of cassava per fermentation. The initial concentration of soluble carbohydrates obtained was about 4% or 40 g/liter. The fungus *Aspergillus fumigatus* I-21A was used in all the fermentations following the procedure previously described (CIAT Annual Report, 1976). Results with the 3000-liter fermentor have been superior to those obtained with the 200-liter fermentor last year, especially with reference to the crude protein in the final dried biomass that has resulted from more efficient utilization of the cassava carbohydrate by the fungus.

The principal difficulty had been harvesting the biomass produced in the large fermentor and, especially, the extraction of water to sufficiently low levels to permit rapid drying of the biomass. To extract the water a special harvesting machine (filter-press) has been used which was designed and constructed at the University of Guelph, Canada (Fig. 4). In addition, another press operated by a hydraulic jack has been used. This device, constructed in CIAT's shops, permits better extraction of the water from the biomass and forms a meal cake which is easily milled in the cassava chopping machine. The meal from the ground biomass (with 65% water) can be sun-dried in 6-8 hours or dried in a forced air oven.

Table 11.

Production of single-cell protein from fresh cassava roots using *Aspergillus fumigatus* I-21A in a 3000-liter fermentor.

Parameter	Value
Fresh cassava/fermentation (kg)	423
Concentration of soluble carbohydrates (g/liter)	
Initial	41.1
Final	15.1
Avg. pH of fermentation medium	
Initial	3.5
Final	5.2
Crude protein in dry biomass (%)	34.2
Avg. duration of fermentation (hrs)	21
Avg. quantity of dry biomass produced/fermentation (kg)	55.5

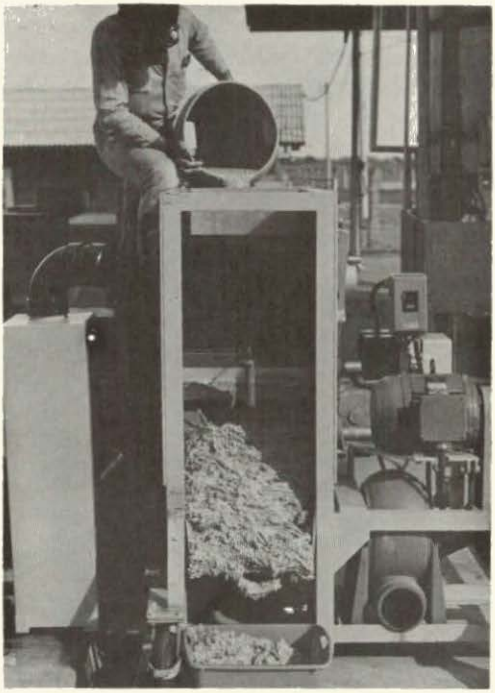

Figure 4. Partial extraction of water from single-cell protein biomass, utilizing a filter-press constructed at the University of Guelph, Canada.

Nutritive Evaluation

Table 12 shows the percentage composition of the experimental diets used for the nutritional evaluation of the protein biomass for feeding pigs in the growing and finishing periods. Previous results obtained in Guelph and in CIAT showed that the single-cell protein had a marked deficiency in the sulfur amino acids — particularly methionine. These experiments had also shown the beneficial effects of supplementing this amino acid during biological evaluations with rats. In the swine feeding experiments this year, single-cell protein was utilized as the only protein source in diets, with (0.3%) or without adding DL-methionine. The sun-dried protein biomass had the following chemical composition (in percentages): moisture, 11.6; crude protein (NX6.25), 35.0; ether extract or total fat, 3.0; crude fiber, 19.3; non-nitrogen extract, 30.0; ash, 4.1; calcium, 0.2 and phosphorus, 0.8. The total energy of the single-cell biomass was 4260 cal/g, as measured in a calorimeter bomb.

Experimental results of the nutritional evaluation of the single-cell protein are presented in Table 13. The nutritive quality of the protein was good, and compared well with soybean meal if supplemented with methionine. The protein biomass without methionine produced inferior results; pigs needed three additional weeks to reach a final average weight similar to those of the group fed methionine-supplemented, single-cell protein. These two experimental groups had similar average daily consumption rates per pig for the diets, but methionine supplementation significantly improved weight gain and feed efficiency conversion performances. This latter parameter for the single-cell protein supplemented with methionine appears slightly better than that obtained with the diet based on soybean meal and cassava meal, but the final weight of the pigs in the two groups is different and no definite conclusions can be drawn. The results of the performances of pigs fed with the diet based on single-cell protein without methionine supplementation varied the most compared with the other three experimental groups.

Table 12.

Percentage composition of experimental growing and finishing diets for swine utilized for nutritional evaluations of single-cell protein (SCP).

Ingredient	Sorghum + soybean meal	Cassava meal + soybean meal	Cassava meal + SCP without methionine	Cassava meal + SCP with methionine
Sorghum	77.8 (85.4)[1]	-	-	-
Cassava meal	-	66.1 (72.4)	52.8 (61.0)	52.5 (60.7)
Soybean meal	18.0 (10.4)	29.4 (23.1	-	-
A. fumigatus I-21A biomass	-	-	43.0 (34.8)	43.0 (34.8)
Bonemeal	3.5	3.5	3.5	3.5
Salt	0.5	0.5	0.5	0.5
Minerals and vitamins	0.2	0.2	0.2	0.2
DL-methionine	-	0.3	-	0.3

1 Numbers in parentheses are percentages of the finishing diets.

Table 13.

Results of the nutritional evaluation of single-cell protein (SCP) in growing and finishing diets for swine.[1]

Parameter	Sorghum + soybean meal	Cassava meal + soybean meal	Cassava meal + SCP without methionine	Cassava meal + SCP with methionine
Days on experiment	112	119	140	119
No. of pigs	7	6	6	6
Avg. liveweight (kg)				
Initial	15.8	15.8	15.8	15.8
Final	94.4	95.7	90.0	90.7
Avg. daily gain (kg)	0.70	0.67	0.53	0.63
Total consumption/pig (kg)	288.2	282.4	292.1	252.8
Avg. daily gain (kg)	2.57	2.37	2.09	2.12
Feed:Gain ratio	3.67	3.53	3.94	3.37

1 Averages for pigs fed individually throughout the experiment.

Eleven pigs (two from the group fed cassava meal plus soybean meal and three from each of the other three groups) were slaughtered to assess carcass qualities and to take tissue and organ samples for histopathological studies. No significant differences were observed in qualities of the dressed carcasses, judged by measurements of dorsal fat and proportions of the different cuts made. Samples of a total of 18 tissues or organs were taken from each pig, and these are being analyzed. No gross changes were observed in any of the organ samples. Personnel of the CIAT Beef Program's Animal Health Section are collaborating in these studies.

During the course of the experiment, blood samples were taken from all pigs for hemotological analyses and other determinations of biochemical parameters of the blood. Results indicated that the single-cell protein fed to the pigs did not significantly alter any of the parameters studied, confirming results from previous experiments with laboratory animals at the University of Guelph.

Experience acquired over two years of operating the pilot plant demonstrates the technical feasibility of producing single-cell protein using grated cassava roots as the energy substrate to obtain a biomass having a good crude protein content. The nutritional quality of this protein is good for animal feeding if it is adequately supplemented with methionine, the most limiting amino acid. The protein biomass apparently does not adversely affect the health of the animals that consume it.

Security precautions normally observed in operating a pilot plant can be considered adequate protection for the management of the microorganism employed for fermentations. The transfer of this technology requires, however, careful consideration of aspects such as economic feasibility and other factors that could affect production performance on a practical, commercial scale.

Cyanide Contents in Cassava Roots and Products

Investigations reported in relation to the nutritional value of the roots or products derived from cassava and used especially

for animal feeds show a lack of consistency in the repeatibility of results. Some of these discrepencies are due to variations in the chemical compositions of the products, which can be caused by various factors. Often the cassava variety used is not identified and information related to the cyanide content in products used is not included. Until a short time ago, the majority of the analytical methods for determinations were not fully reliable due to inexact and nonreproducible techniques. Recently, the Tropical Products Institute (TPI), in the United Kingdom, developed an enzymatic method to determine the cyanide content in cassava. The method surpasses the sensitivity, reproducibility and speed of the quantitative methods used previously. In collaboration with Dr. Rodney Cooke, who developed the new methodology at the TPI, the technique has been established in the CIAT laboratories.

Five roots from three cassava plants of each of the varieties Llanera, M Ven 218, M Col 1684 and M Col 22 were analyzed. Plants had been grown in experimental lots of CIAT's Cassava Program, Varietal Improvement Section. Total and free cyanide contents were determined in the root peel and the parenchymatous tissue of a central disk cut from each root. Average results of these analyses in relation to free cyanide/total cyanide and of total cyanide in the parenchyma/total cyanide in the peel are presented in Table 14.

Variations between roots of the same variety were considerable and have been reported in similar studies done at the International Institute for Tropical Agriculture. The relation of free cyanide/total cyanide varied around the 10% level, especially in the peel. Total cyanide contents in the peels are rather high, even in varieties like M Col 22 which is considered to be low in cyanide. Taking into account that, for animal feeding, the entire root including the peel is utilized, one can observe that the relationship of total cyanide in peels is about 15-25 times greater than the content in the parenchymatous tissue. In "bitter" cassava varieties like M Col 1684, the cyanide content in the parenchyma is very high, about one-half the concentration of the peel.

The analysis for cyanide done in other products derived from cassava, such as meal, root silage, leaf meal, fresh leaves and single-cell protein biomass were done with too few samples to permit valid conclusions. In general, cyanide concentrations of these products were much less than those observed in samples from fresh roots. For example, two samples of root

Table 14.

Total and free cyanide contents in the peel and parenchyma of roots of four cassava varieties.

Variety	Cyanide in peel			Cyanide in parenchyma			Cyanide ratio
	total	free	free:total	total	free	free:total	parenchyma:
	(ppm)		(%)	(ppm)		(%)	peel
Llanera	777	58.3	7.5	29.9	0.98	3.3	1:26
M Ven 218	1221	160.3	13.1	55.3	6.50	11.8	1:22
M Col 1684	796	87.2	11.0	401.8	7.18	1.8	1:2
M Col 22	2251	92.7	4.1	153.9	7.84	5.1	1:15

1 Averages of five measurements; contents expressed on fresh basis; plants were 9 months old.

silage analyzed after six months of conservation showed contents of 30 and 38 ppm total cyanide, all of which was in the form of free cyanide.

The new analytical method will allow more precise studies to be conducted to measure changes in cyanide content following different methods of storage or processing of cassava roots and products.

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