Swine unit

1977/CIAT

Cover: A herd of swine in the field at the cooperative project at Monteagudo, Bolivia.

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 1977 these donors were 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) and the governments of Australia, Belgium, the Federal Republic of Germany, Japan, the Netherlands, 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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Swine Unit
1977 Report

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Apartado Aéreo 6713, Cali, Colombia, S.A.

PERSONNEL OF THE SWINE UNIT

(As of 31 December 1977)

CIAT General Direction

Senior staff
John L. Nickel, PhD, Director General
Alexander Grobman, PhD, Associate Director General, International Cooperation
Kenneth O. Rachie, PhD, Associate Director General, Research

Other professional staff
Cecilia Acosta, Administrative Assistant

Swine Unit

Senior staff
Guillermo Gómez, PhD, Nutritionist/Biochemist
Julián Buitrago, PhD, Nutritionist

Research associate
Jorge Santos, MS

Research assistants
Luis Enrique Beltrán, DVM
Elkin Taborda, Zootecnista

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Swine Unit

In 1977 the CIAT Swine Unit conducted the second Postgraduate Course in Swine Production. Sixty percent of the course was practical work assigned on swine farms in the Cauca Valley of Colombia. Twenty-five professionals from 10 Latin American countries attended the course.

The Swine Unit, through its collaborative programs with national institutions in Bolivia, Colombia, Costa Rica, Ecuador and Peru, continued to adapt swine production technology at the regional level. Nutritional studies on the use of locally available feedstuffs for swine feeding programs were also conducted as part of the cooperative projects.

Thirty-five former CIAT trainees from 12 Latin American countries participated in a workshop at CIAT to analyze the problems and future of swine production in the region, especially in those countries where the Center cooperates in projects. Workshop participants also discussed the organization of an international network for swine production.

At CIAT, experiments were done using high levels of rice polishings in diets for the gestation and lactation periods. Results showed that rice polishings are feasible as the main energy ingredient in all periods of the swine life cycle. Research on methionine supplementation in diets based on cassava meal suggested that the addition of this amino acid is not essential.

The pilot plant for producing microbial protein from cassava at CIAT continued functioning with the 200-liter fermentor. Studies indicated that the pH of the fermentation medium is an important factor for satisfactory results. The microbial biomass being produced had a fairly stable crude protein content (33-35%) in the final sun-dried product.

International Cooperation

TRAINING

Postgraduate Course in Swine Production

Twenty-five professionals from institutions which carry out swine production, training and research activities in 10 Latin American countries were selected to participate in an intensive (six weeks) course taught by specialists from state and private Colombian institutions and staff of the Swine Unit at CIAT.

Approximately 40 percent of the time was devoted to theory and the remainder to

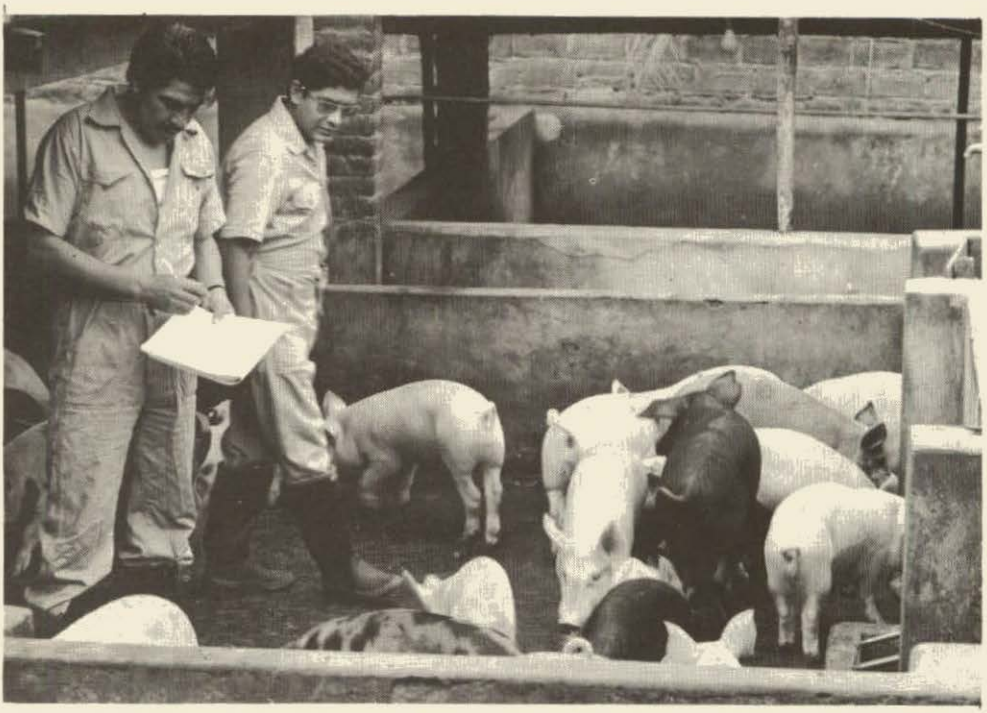

Figure 1. Trainees in the Postgraduate Course in Swine Production conducted practical activities on commercial farms in the Cauca Valley of Colombia.

practical work at the CIAT Swine Unit and at commercial farms in the Cauca Valley. The trainees worked on eight pig farms to evaluate the principal production problems and introduce some technical changes. They also visited state and private institutions involved with several aspects of swine production, such as manufacturing of composite rations or veterinary products, pig marketing and pork processing facilities. Trainees also toured a group of pig farms in part of the western region of Colombia to analyze the swine production potential of the region.

Other Training

Individualized training was also provided in the Swine Unit. Two trainees each from Bolivia and Peru who participated in the formal course received an additional month of training at CIAT in order to help plan future activities between their institutions and those formally collaborating with CIAT in these countries. One Colombian trainee spent a month at CIAT studying the genetic parameters of the Swine Unit's breeding herd, in collaboration with the CIAT Biometrics Unit. Two professionals from Thailand received special six-month training in utilizing cassava for swine feeding programs.

ASSISTANCE TO NATIONAL PROGRAMS

Bolivia

The Swine Unit of the Universidad Gabriel Rene Moreno/Heifer/CIAT Cooperative Project now has a breeding herd of 150 sows (Duroc, Hampshire and Yorkshire breeds). Selected animals of these improved breeds are being used for foundation herds of regional swine promotion programs. As part of the strategy of the cooperative project at the Swine Unit at Santa Cruz, training courses for small-

scale farmers were taught using part of the educational material produced at CIAT. The physical facilities are also used for a postgraduate internship through an arrangement with the Veterinary and Animal Science Faculty of the Universidad Gabriel Rene Moreno. This internship will provide recent graduates with practical experience for their thesis projects.

CIAT's Swine Unit provided technical assistance in evaluating available local products useful as feed sources for pigs. The effect of increasing levels of a yeast *(Saccharomyces cerevisiae)* protein (levabol) locally produced from sugar cane molasses was studied as a protein source in diets for growing pigs. Chemical analyses of the final dried product showed a crude protein content of 35-45 percent. Initial results of the feeding trial (Table 1) showed that when yeast protein is used at levels of 7.5, 15 and 20 percent in maize- and sorghum-based diets, it could partially or completely replace conventional protein sources (soybean or cottonseed meal). Growth performance, expressed as weight gain and feed conversion efficiency, was similar for all three levels of yeast protein used. The preliminary results are being confirmed in further experiments during the growing-finishing periods and throughout the reproductive periods.

Table 1. Growing performance of pigs[1] receiving various levels of levabol[2] as a protein source.

Parameters	Values		
Protein sources	**Diet 1**	**Diet 2**	**Diet 3**
Soybean meal (%)	8	5	-
Cottonseed meal (%)	7.5	-	-
Levabol (%)	7.5	15	20
Performance factors			
Daily gain (kg)	0.77	0.80	0.79
Daily feed consumption (kg)	2.63	3.06	2.60
Consumption/gain	3.42	3.27	3.29

[1] Eighteen pigs with inititial weight of 28 kilograms and final weight of 64 kilograms.
[2] Yeast *Saccharomyces cerevisiae*.

During 1977 the Swine Promotion Program in Chuquisaca completed construction of three swine units, each with a foundation herd of 120 Duroc and Hampshire sows and six boars. The Program has also provided credit for medium- and small-scale swine producers for maize cultivation and to buy breeding stock as part of the agreement between the Bolivian government and the Inter-American Development Bank (BID) to develop 150 swine farms in the region. CIAT provided technical assistance and training for three professionals who are to conduct the Program.

Colombia

Ten small-scale pig farmers at La Victoria (Cauca Valley) were selected for a group financing project through the Caja de Credito Agrario. Each farmer bought a group of 15 weaned pigs which was managed throughout the growing-finishing period. CIAT, collaborating with the Instituto Colombiano Agropecuario (ICA), provided the technical assistance for training the farmers, planned and evaluated their projects and conducted field days.

The growing-finishing diets utilized local feedstuffs such as sorghum, sugar cane molasses, soybean meal and cottonseed meal. Due to the easy availability and low cost of molasses in this sugar cane growing area, high levels (30% molasses diluted with water) were fed *ad libitum* separately from a controlled supply of a diet based on sorghum (75%), cottonseed meal (18%) and soybean meal (7%). Each pig consumed approximately 30 percent of its total feed intake (110 of 320 kilograms) as sugar cane molasses, producing economical daily gains above 500 grams (Table 2).

Table 2. **Average results of individual swine performances in a family swine unit.**[1]

Parameter	Values/pig
Initial weight (kg)	32.0
Final weight (kg)	90.5
No. of days	108
Feed consumption:	
Molasses (kg)	110
Concentrate (kg)[2]	211
Costs (Col. pesos)[3]	3850.00
Sales value (Col. pesos)	4500.00

[1] Each farmer received a group of 15 pigs during each cycle.
[2] Concentrate contained sorghum (75%), cottonseed meal (18%) and soybean meal (7%).
[3] Includes costs for feed, labor, electricity, water, drugs, interest and depreciation.

Costa Rica

Although construction for the Swine Unit of the Universidad de Costa Rica/CIAT project has not been finished, the University rented a swine farm to house the imported Yorkshire breeding stock and to initiate training and extension activities.

A swine development project for the banana producing area of Guapiles was initiated by an agreement of the Ministerio de Agricultura y Ganadería with the Asociación Nacional de Bananeros and the Banco Central de Costa Rica. CIAT's Swine Unit provides technical assistance to this project through the Ministry's swine specialists previously trained at CIAT.

Ecuador

Contacts were re-established between the CIAT Swine Unit and the Swine Program of the Instituto de Investigaciones Agropecuarias (INIAP) in Ecuador.

Green waste bananas were used as raw material to prepare a banana meal commercially marketed in Ecuador as a substitute for conventional energy sources in swine feeding programs. The nutritive quality of the banana meal has been evaluated through the different periods of the swine life cycle.

Experimental results suggested that up to 42 percent of banana meal can be included in the diets of growing-finishing pigs and lactating sows; for gestating sows up to 64 percent can be included. At these dietary levels, banana meal would substitute approximately 50 percent of the cereal grains in swine feeding programs.

Technical assistance has been provided by the CIAT Swine Unit to the INIAP Swine Program through regular visits and planning of future activities. Emphasis on local training and applied research has been given to encourage the development of swine production in the coastal western region of Ecuador where crops such as banana, rice and sugar cane predominate and wastes or by-products from these crops would be available for swine feed. Validation of technology on the practical level is being started at the banana producing area of the Provincia El Oro.

Peru

The Swine Unit of the Instituto Veterinario de Investigaciones Tropicales y de la Altura (IVITA) at the principal Tropical Experiment Station in Pucallpa obtained preliminary data on the technical and economical feasibility of swine production in the jungle region of Peru. Observations were made on the adaptation of an improved breed (Yorkshire) brought from the coast to the Peruvian tropics. Performance during three consecutive reproductive cycles (Table 3) indicated that under adequate nutritional and management practices satisfactory results were obtained with a Yorkshire herd of 20 sows in the tropical environment of Pucallpa. Housing facilities were constructed using local materials and pigs are managed in

Table 3. **Performance of Yorkshire sows introduced in the Peruvian tropics.**[1]

Parameter	Value[2]
Farrowing data	
No. of pigs/litter	11.4
Weight per pig (kg)	1.2
Weaning data (56 days)	
No. of pigs/litter	9.5
Weight per pig (kg)	16.5
Mortality during lactation (%)	17.0

[1] Experiments were done at the Tropical Experiment Station of the Instituto Veterinario de Investigaciones Tropicales y de la Altura (IVITA), Pucallpa.
[2] Average values for a herd of 20 sows during three lactation periods.

partial confinement. These practical conditions could be easily adapted by local farmers interested in developing swine production in this region.

Complementary nutritional studies were done on locally available feed products such as fresh cassava roots and rice polishings for growing-finishing pigs. The CIAT Swine Unit and IVITA also provided technical assistance to the integrated program of the Sociedad Agricola de Interes Social (SAIS) Tupac Amaru I for the development of swine production in its colonization project at Pucallpa. In addition, IVITA's Swine Program sells breeding stock to farmers interested in improving their stock and provides technical assistance in collaboration with the Ministerio de Alimentación. Currently, the IVITA-CIAT Swine Project is visiting a group of small-scale pig farmers in Masisea, on the banks of the Ucayali River, three hours by boat from Pucallpa.

Other Countries

In addition to the above collaborative projects, the CIAT Swine Unit has maintained contact with other Latin American institutions where swine production could be developed in the future. Most of the support has been through training professionals who would form core groups of swine specialists for national programs.

During 1977, the Swine Unit did a survey for the swine promotion project of the Ministerio de Agricultura y Ganadería/United States Agency for International Development (AID) Mission in Paraguay. The project is based on utilizing crops — notably cassava, maize and soybeans — produced on small farmes in swine feeding programs, which could help stabilize prices of these products at the small-farm level. Former CIAT trainees working at the Ministerio de Agricultura y Ganadería have conducted practical demonstrations for the farmers on different aspects of swine production, especially management, feeding and animal health.

WORKSHOP ON SWINE PRODUCTION IN LATIN AMERICA

Thirty-five former trainees of the CIAT Swine Unit now working with national institutions gathered at CIAT for a Workshop on Swine Production, in October. The countries represented and participants from each were: Bolivia (6); Brazil (1); Colombia (6); Costa Rica (1); Ecuador (5); Guatemala (1); Honduras (2); Mexico (3); Nicaragua (3); Panama (2); Paraguay (4); and Peru (1).

Objectives of the workshop were: (1) to review the situation of national and regional programs for development of swine production, with special emphasis on collaborative projects established by the CIAT Swine Unit; (2) to sharpen the focus on the factors limiting expansion of swine production and plan strategies for their solution; and, (3) to establish an international cooperative swine production network.

The following were identified as some of the common features of swine production

in Latin America, notably in the countries where CIAT has established collaborative projects.

- Swine production is traditionally operated as a secondary livestock enterprise lacking government support, and it is not considered as part of integrated agricultural development projects.

- The extensive, small type of production using native pigs is widespread although improved breeds are being accepted rapidly.

- Swine productivity is low under most conditions and practically no extension service is available to small- and medium-scale farmers. The number of professionals and technicians trained in swine production is very limited.

- The most important constraints for swine production development are limited availability of conventional feedstuffs, deficient health programs, inadequate marketing systems, limited pork processing facilities and restricted financial support.

The conclusions and recommendations of the workshop were summarized in the following proposals.

- To undertake technical, economic and marketing feasibility studies for the integration of agricultural development and swine production as a special component. These studies should lead to establishing regional programs within a given country.

- To support swine development programs for small- and medium-scale farmers, but with an entrepreneurial focus. Associative or cooperative projects for small farmers dedicated to swine production are advisable.

- To intensify and increase extension services for transferring swine technology, notably at the small producer level. Integration of research or experimental work with extension services is required.

- To search for the means of improving the technological level of swine development and to reduce production costs, especially through the displacement of conventional feedstuffs and the maximum use of agro-industrial by-products and nonconventional feedstuffs.

- To integrate Latin American swine producing regions and to form a network to avoid duplication of efforts and to permit the more efficient transfer of technology to these areas.

Research

ENERGY FEEDSTUFFS

The feasibility of replacing cereal grains with agro-industrial by-products such as rice polishings or sugar cane molasses has been studied for diets of growing-finishing pigs (CIAT Annual Report, 1975 and 1976). However, because little information is available on the use of these by-products during the reproductive period of the swine life cycle, experiments were undertaken to study this possibility.

Rice Polishings

Partial or total substitution of cereal grains (maize and sorghum) by rice polishings was tested in diets for the gestation and lactation periods of the sow as well as for baby pig feeding. Levels of 85.3 and 60 percent of rice polishings were used for total and partial substitution, respectively; the control diet was based on common maize (78%). Experimental diets were balanced with soybean meal to provide 16 percent crude protein. The gestation and lactation diets for each experimental group were the same, varying only in quantity and form of supply during the two periods. During gestation, each sow was individually fed 2 kg/day of the diet; during lactation, diets were supplied

Table 4. **Evaluation of rice polishings in swine diets during the gestation and lactation periods.**

Parameters	Diet		
	Maize + soybean meal	Rice polishings (85%) +soybean meal	Rice polishings + maize + soybean meal
No. of sows	5	7	5
Farrowing data			
No. of pigs/litter	8.4	9.0	10.0
Weight per pig (kg)	1.11	1.26	1.24
Weaning data (56 days)			
No. of pigs/litter	7.2	7.7	9.0
Weight per pig (kg)	15.27	14.85	15.29
Litter weight (kg)	110.20	113.25	136.45

ad libitum in an automatic feeder. The diets for suckling pigs contained 18 percent protein and were supplied *ad libitum* from the tenth day after birth through weaning (56 days). Pigs in litters from sows fed diets with 85.3 or 60 percent rice polishings received the same starter diet based on 50 percent rice polishings, whereas the litters from sows on the control diet were fed a diet based on 60 percent maize. In all cases, soybean meal was used as the protein ingredient.

The results in Table 4 indicate that total or partial substitution of cereal grains by rice polishings produced similar litter performance as the control diet at farrowing and weaning. The intake of experimental diets and of the basic ingredients is presented in Table 5. Total diet consumption was similar for all experimental groups. Therefore, total substitution of

Table 5. **Consumption of diets based on rice polishings during the gestation and lactation periods of swine.**

Parameters	Diet and consumption (kg)		
	Maize + soybean meal	Rice polishings (85%) + soybean meal	Rice polishings (60%) + maize + soybean meal
Diet consumed/sow (kg)			
Gestation (115 days)[1]	230.0	230.0	230.0
Lactation (56 days)	290.3	279.6	295.4
Diet consumed/litter (kg)			
Starter diet for pigs	47.5	50.9	63.9
Total basic ingredients consumed (kg)			
Maize	434.4	7.7	128.9
Rice polishings	-	460.2	347.2
Soybean meal	102.2	61.5	79.4

[1] Each sow received two kilograms of diet daily, and fed individually.

cereal grains by rice polishings is feasible without adversely affecting reproductive performance.

Cassava Products

Because of cassava's potential as an animal feed more detailed experimental information was obtained during 1977. Previous experimental evidence from using cassava meal or flour in feeding programs throughout the life cycle of the pig indicated that slightly inferior reproductive performance was obtained with the cassava meal-based diets as compared to the control diet (CIAT Annual Report, 1974). It was suggested that the lack of supplementary methionine could be responsible. Methionine supplemented in swine diets based on cassava has been recommended, not only to improve protein quality of the diets (particularly when plant protein sources are used), but also to provide a labile source of sulfur for detoxifying cyanide in the cassava.

The effect of DL-methionine supplementation (0.2%) to dietary combinations of cassava meal combined with various protein sources was studied in an experiment with growing pigs. Levels of 62-68 percent cassava meal were combined with either soybean meal, cottonseed meal or with a mixture of cottonseed and fish meals. Experimental diets supplied 16 and 13 percent crude protein for the growing and finishing periods, respectively. A control diet based on common maize and soybean meal and supplemented with DL-methionine (0.2%) was used.

Table 6 presents the experimental results. Body weight gains of pigs fed the cassava meal/soybean meal diets were similar to gains from the control diet; the combination of cassava meal with cottonseed meal produced the lowest body gains. Methionine supplementation did not improve the results with either soybean or cottonseed meal. The protein combination of cottonseed meal with fish meal improved the pigs' performance. The results suggest that supplementary

Table 6. Effect of supplementing methionine in swine diets based on cassava flour and combined with different protein sources and fed during growing and finishing periods (18-95 kilograms).

Diets	No. of pigs	Days on trial	Avg. daily Gain	Avg. daily Consumption	Final weight[1]	Feed/Gain
			(kg)			
Maize + soybean meal + methionine	10	112	.70	2.17	96.1	3.10
Cassava flour +						
Soybean meal	9	112	.70	2.41	95.5	3.47
Soybean meal + methionine (0.2%)	10	112	.70	2.49	95.6	3.59
Cottonseed meal	9	133	.58	2.43	95.0	3.98
Cottonseed meal + methionine (0.2%)	9	133	.56	2.21	92.7	3.94
Cottonseed meal + fish flour	9	119	.66	2.26	95.5	3.44

1 Average initial individual weight in each group was 17.6 kilograms.

methionine is not essential in diets based on cassava meal and plant protein sources (soybean or cottonseed meal) for growing-finishing pigs. Further studies are required to determine the relationships between the quality of the supplementary protein and the addition of specific amino acids.

Experimental results (CIAT Annual Report, 1974) have indicated that feeding programs based on cassava meal produced a reproductive performance inferior to the control feeding program based on common maize. It was suggested that the lack of supplementary methionine could be at least partially responsible for these results. An experiment was undertaken to study the effect of methionine supplementation (0.3%) to cassava meal/soybean meal diets during the gestation and lactation periods. Reproductive performance did not improve by adding methionine and was similar to that of the control diet (Table 7).

Experimental evidence obtained from different periods of the life cycle of the pig suggests that methionine supplementation does not seem to be indispensable for swine feeding programs based on high levels of cassava meal. Because of the limited quantity of protein supplied by cassava, nearly all the dietary protein is supplied, and the quality of the protein determined, by the protein ingredient(s).

PRODUCTION OF MICROBIAL PROTEIN

Additional experimental information for producing microbial protein was obtained with the 200-liter fermentor installed at CIAT. Most of the studies have continued with the asporogenous mutant *Aspergillus fumigatus* I-21A. However, another mutant of the I-21 parent culture, designated ON-5, that is unable to grow at temperatures below 40°C, was isolated at the University of Guelph (Canada). The use of these mutants, along with the safety precautions normally taken, might well be considered as a sufficient safeguard during practical operation.

One problem encountered in producing microbial protein was the large quantity of soluble carbohydrates left at the end of the

Table 7 **Effect of supplementing methionine in swine diets based on cassava flour and fed during gestation and lactation periods.**

Parameter	Control	Cassava flour + soybean meal	
	Maize + Soybean meal	Without methionine	With methionine (0.3%)
Number of sows	14	10	10
Farrowing data			
No. of pigs/litter	8.5	9.1	9.4
Pig weight (kg)	1.09	1.06	1.07
Weaning data (56 days)			
No. of pigs/litter	7.1	8.2	8.0
Pig weight (kg)	16.74	16.15	16.54
Total litter weight (kg)	117.02	128.50	131.95

fermentation. This resulted in limited fungal growth and lower concentrations of protein than expected. Average data for the changes in carbohydrate concentration and product yield throughout 20-hour fermentation periods using either fresh rasped cassava roots (10 fermentations) or cassava meal (7 fermentations) as the substrates are shown in Figure 2. At the end of the fermentation period a large proportion of the original carbohydrates remained; the final concentrations of total carbohydrates were, on the average, 41.4 and 48.2 percent of the initial values for cassava mash- and cassava meal-based media, respectively. Data from laboratory scale fermentations at Guelph indicated nearly complete use of total carbohydrates by *A. fumigatus* I-21A when finely ground cassava was used. Figure 3 shows the crude protein yield for both substrates

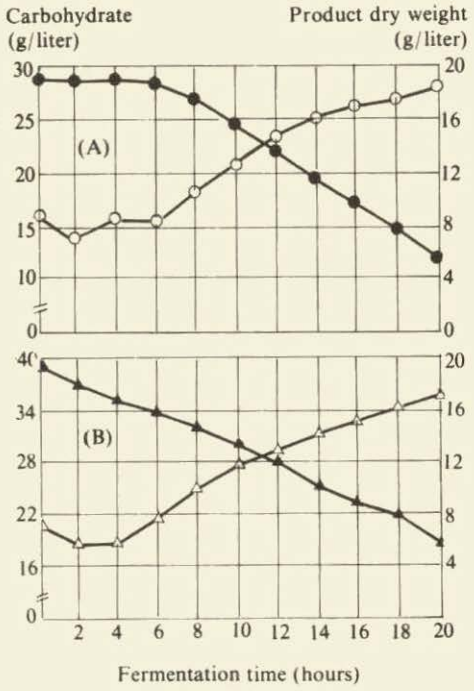

Figure 2. **Changes in dry product yield (○ , △) and carbohydrate concentrations (●,▲) during the fermentation of fresh cassava mash (A) and cassava meal (B) based-media by *A. fumigatus* I-21A.**

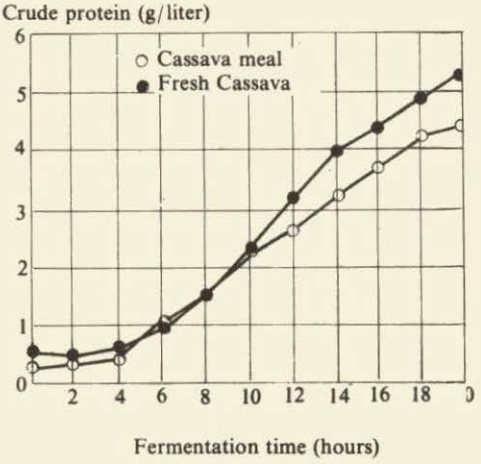

Figure 3. **Changes in protein concentration during the fermentation of fresh cassava (●) and cassava meal (o) by *A. fumigatus* I-21A.**

throughout the fermentation period. No major differences were observed during the first half of the fermentation period; during the second half, however, the values obtained with the cassava meal medium were lower than those observed with the fresh cassava mash. The differences found during the fermentation period are reflected in the protein content of the final biomass (Table 8). The results with the fresh cassava mash were slightly better than those previously published (CIAT Annual Report, 1976). The dry biomass yield as a percentage of the dry matter before fermentation (fermentation efficiency) was 49.7 percent in the wet mash and 44 percent in the meal treatment. The fermentation efficiency varied considerably between batches as can be seen by the magnitude of the standard deviations.

Since the protein yields reported at the pilot plant level were not as high as expected from previous experimental work at the laboratory scale, a study was done to determine the factors responsible. First, the mineral nutrients required by the fungus and added to the medium were individually varied in several fermentation

Table 8. **Fungal (*Aspergillus fumigatus* I-21A) protein production in a 200 liter fermentor using fresh roots or cassava meal as substrates (4% concentration of carbohydrates).**

Parameter	Values
Fresh Cassava Roots[1]	
Amount of cassava mash (kg)	25.51 ± 0.81
Amount of sun-dried biomass obtained (kg)	4.43 ± 0.62
Product yield (g/liter)	22.15 ± 3.08
Yield: weight of dried biomass in relation to	
Fresh cassava (%)	17.38 ± 2.42
Cassava, dry matter basis (%)	49.67 ± 6.97
Crude protein content in dried biomass (%)	29.60 ± 0.41
Cassava Meal[2]	
Amount of cassava meal (kg)	10.98 ± 0.62
Amount of sun-dried biomass obtained (kg)	4.33 ± 1.10
Product yield (g/liter)	21.65 ± 5.50
Yield: weight of dried biomass in relation to	
Amount of cassava meal (%)	39.61 ± 10.56
Cassava meal, dry matter basis (%)	44.00 ± 11.72
Crude protein content in dried biomass	26.70 ± 0.91

[1] Mean of ten fermentations ± standard deviation.

[2] Mean of seven fermentations ± standard deviation.

runs. Increased concentrations of the nitrogen source (urea) and mineral salts required did not improve yields. The mineral elements contributed by the cassava roots were determined analytically. The average cassava variety was found to supply adequate amounts of all mineral elements required except sulfur and possible zinc; the addition of zinc, however, was not found necessary.

A temperature of 45°-47°C and a pH of 3.5 are selective conditions for growth of *A. fumigatus* in the medium. Variations in these conditions were also studied throughout the fermentation period. The temperature remained constant during the process. Figure 4 shows the changes in pH when fresh cassava mash was suspended in tap water and a sulfuric acid solution was added throughout the fermentation period to maintain a pH of 3.5. This was compared with variations found when no acid solution was added to a similar medium and with those obtained for a medium using deionized water instead of tap water. With tap water the pH increased rapidly to fairly high levels, even though sulfuric acid was added every three hours. This might be due to the quality of the tap water which contains high concentrations of carbonates and bicarbonates.

The pH remained quite stable when deionized water was used and very little additional acid was required. Therefore, the quality of water used to suspend the substrate and the other ingredients may have some effect on the growth of the microorganism. The values for crude protein and true protein in the sun-dried biomass samples from I-21A and ON-5 respectively, are shown in Table 9. Proximate analyses of dry biomass samples of *A. fumigatus* I-21A and ON-5 grown in different media varied slightly in crude protein. Ether extract, crude fiber and ash contents were rather similiar for all the

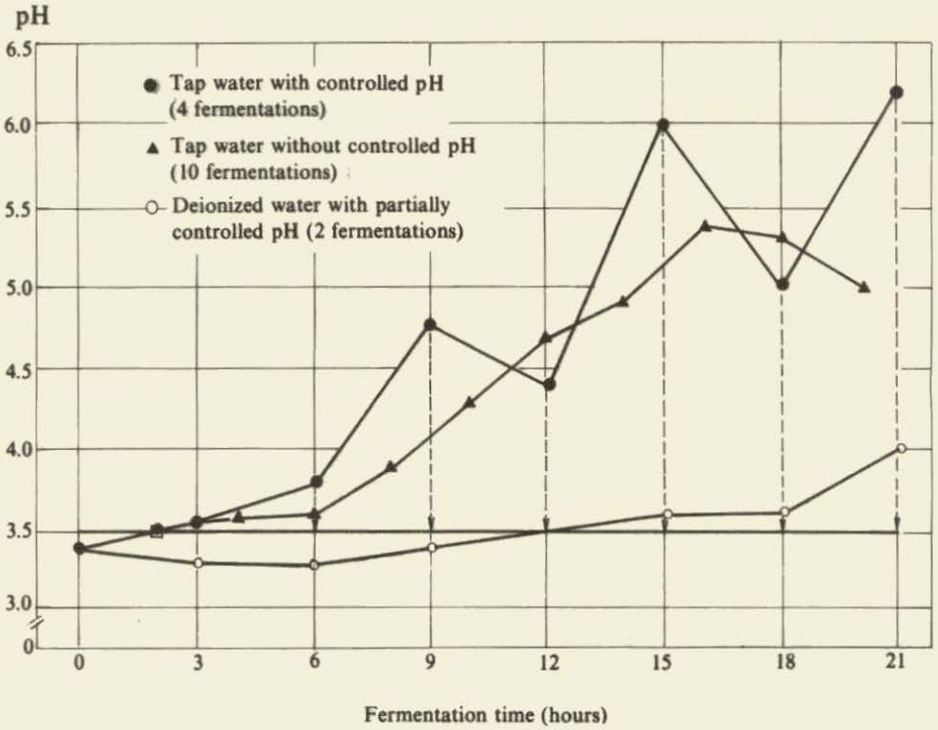

Figure 4. Change in pH during the fermentation of wole cassava media (in tap and deionized water) by *Aspergillus fumigatus* I-21A, with and without the addition of *9N* sulfuric acid

Table 9. **Crude and true protein contents obtained from growth of *Aspergillus fumigatus* mutants I-21A and ON-5 on cassava-based culture media.**

Medium	No. of fermentations	Crude Protein (%)	True Protein (%)	$\frac{TP}{CP} \times 100$
Mutant I-21A				
Fresh cassava, tap water				
without pH control	6	30.9	24.2	78
controlled pH	4	33.0	24.8	75
Fresh cassava, deionized water				
without pH control	3	31.1	24.8	80
Cassava meal, tap water				
without pH control	6	27.2	19.1[1]	70
Mutant ON-5				
Fresh cassava, tap water				
without pH control	3	27.6	20.7	75
Cassava meal, tap water				
without pH control	15	28.8	20.8	72

Table 10. **Comparison of the protein quality of casein, soybean meal and unsupplemented and methionine-supplemented fungal biomass grown on a cassava medium and fed to rats.[1].**

Parameter[2]	Total feed intake (g)	Total weight gain (g)	Feed/gain	Adjusted Protein Efficiency Ratio[3]
Control: casein	302.6a	78.2ab	3.9c	2.5a
Soybean meal	308.8a	68.2c	4.5c	2.2b
Biomass produced on:				
Fresh cassava				
Without methionine	195.6b	24.2d	8.5a	1.2
+ 0.3% methionine	296.0a	74.8bc	4.0c	2.5a
Cassava meal				
Without methionine	198.8b	29.7d	6.9b	1.5c
+ 0.3% methionine	323.7a	85.0a	3.8c	2.5a

1 Average results from 10 male rats per group; 28-day experimental period; avg initial wt 41.2 + 2.1 g.
2 Values followed by a common letter are not significantly different (P 0.05) according to Duncan's multiple range test.
3 Values adjusted to the standard value of 2.5 for casein.

fermentations and averaged 4.3, 19.2 and 4.4 percent, respectively.

Feeding Trials

Results of feeding trials with growing rats to ascertain the protein quality of dried fungal biomass from fermentations with either fresh roots or cassava meal substrates are shown in Table 10. The effect of methionine supplementation was studied in particular. Total weight gains over a 28-day period were very low for rats fed the unsupplemented biomass-based diets. Methionine supplementation significantly improved the quality of the fungal protein and produced weight gains similar to those obtained with casein and significantly better than those for the soybean meal-based diet (supplemented with 0.3 percent methionine). Rats fed the dry biomass-based diets, without methionine supplementation, consumed less feed than those fed methionine-supplemented diets. Rats fed the methionine-supplemented, fungal protein-based diet had protein efficiency rations (PER) similar to those of the control group receiving casein.

The results obtained from the production of this microbial protein are very encouraging and the process is on the way to being standardized with the 200-liter fermentator. A few fermentations per-fermentor. A few fermentations performed late in 1977 showed a significant improvement in the final crude protein content of the dried biomass with values ranging from 33 to 35 percent. The objective now is to begin operating the 3000-liter fermentor to produce enough material for nutritional and practical evaluations with swine.

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