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THE EVALUATION OF INDIGENOUS FEEDSTUFFS
FOR THE NUTRITION OF SWINE AND POULTRY
IN BELIZE, CENTRAL AMERICA

presented by

Michael A. Costa

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THE EVALUATION OF INDIGENOUS FEEDSTUFFS FOR THE NUTRITION OF SWINE AND POULTRY IN BELIZE, CENTRAL AMERICA

By

Michael A. Costa

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1981

ABSTRACT

THE EVALUATION OF INDIGENOUS FEEDSTUFFS FOR THE NUTRITION OF SWINE AND POULTRY IN BELIZE, CENTRAL AMERICA

By

Michael A. Costa

A feeds research project was organized to increase the use of local feedstuffs in livestock feeds and provide greater profit margins for farmers engaged in animal production. The project was organized into three phases that included: [1] diet formulation and testing at the research station; [2] diffusion of the most reliable and most economical feeding and management programs into the rural sector; and [3] organization of a national feeds production scheme that would provide a continuous supply of quality feeds.

Nutritional parameters of feedstuffs were determined by chemical analysis and by performance of animals on feed trials. Average daily gains (ADG), feed conversion efficiencies (G/F) and cost per unit of gain (C/G) were used to evaluate the performance of test diets. Preliminary studies were conducted to compare the performance of animals fed experimental diets to performance of animals fed commercial feeds as control diets. Least cost rations were formulated to meet the daily requirements for crude protein (or first limiting amino acid), calcium and phosphorus for swine or poultry.

Results from preliminary Phase I feed trials are presented. Three grower-finisher swine trials were conducted to determine [1] the feasibility

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of substituting a Belizean meat-and-bone meal (MBM) as an alternative protein supplement to imported soybean meal (SBM); [2] the effects of substituting wheat millrun and rice bran and polishings for corn or grain sorghum in MBM-supplemented diets; and [3] the effects of substituting blood meal or synthetic lysine in grower or finisher diets, respectively, for SBM at three levels of rice bran and polishings in corn-based, MBM-supplemented diets. Two broiler trials were conducted to determine the effects of [1] MBM as a replacement for SBM as the protein supplement in corn or grain sorghum-based diets that contained rice bran and polishings or wheat millrun; and [2] high and low levels of MBM in corn or grain sorghum-based diets.

Swine trial results showed that complete substitution of MBM for SBM resulted in a decrease ($P < 0.01$) in ADG and G/F. A low level of SBM combined with rice bran and polishings or wheat millrun improved performance and reduced the C/G of animals compared to gains of animals fed imported commercial feeds. Broiler trial results indicated that MBM could be used as the main protein supplement in starter and finisher diets, combined with corn or grain sorghum and rice bran and polishings or wheat millrun, to provide more economical eight-week gains of animals compared to gains of animals fed commercial feeds.

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ACKNOWLEDGMENTS

The author wishes to express his sincere appreciation to Dr. Robert J. Deans for his excellent guidance, counseling and patience during this long-term research and for his constructive planning efforts of the Belize Livestock Feeds Project.

First, I would like to acknowledge the planning efforts and coordination of activities of Dr. Robert J. Deans, who developed the concept of the project and sought the funding for it, and who gave much of his time to visit the project to provide guidance and direction; Dr. Duane E. Ullrey, Dr. Richard J. Aulerich, and Dr. Herbert R. Bird (University of Wisconsin) for advice and who took the time from their busy schedules to visit the project to provide on-site guidance and recommendations; and Dr. William T. Magee, for his assistance with computer programming for the statistical analysis of the feeding trials. I owe very much to Dr. Charles W. Laughlin and Dr. J. James Kielbaso, who provided assistance for me during my studies at M.S.U. and who taught me the meaning of being flexible; to Dr. Irving R. Wyeth and Dr. Kim A. Wilson, who were responsible for the administration of the grant received from MUCIA and who gave counseling to me regarding the scope of involvement in international agricultural activities; and to all of the many other people in their office, especially Pat Riley, who assisted me with typing and bureaucratic problems. The laboratory support from Dr. Pao Ku and Phyllis Whetter at M.S.U. was greatly appreciated; and assistance with typing from Kathi Mikulka and Pat Cramer was greatly appreciated.

Appreciation is expressed to Heifer Project International for their assistance with supportive allowance, livestock equipment and supplies for the project in Belize; to Dr. Jerry Cal, who offered inspiring advice for the development of agriculture in Belize; to Dr. Balmore Silva and Elias Juan, who assisted in the facilitation of establishment and functioning of the project at Central Farm; to Elaine Middleton for her interests and involvement with youth and agricultural production; to Mr. Mark Long, who directed the analysis of feedstuff items in Belize; to Dr. Ian McLeish and his assistants, who provided livestock health advice and services for the experimental animals in Belize; to the laborers at Central Farm, who altered their schedules to meet the demands of the project and who cared for the experimental animals and facilities; to the enthusiastic assistance received from the students from Michigan State University and Goshen College, and also the Peace Corps Volunteers, who assisted in the planning and implementation of project activities; to Elias Awe, who made available the resources of the Central Farm Agricultural Library; to Godsman Ellis, who assisted the project in planning of extension activities.

A special thanks is given ot the members of the Spanish Lookout Mennonite community, who cooperated with the project in its activities, including Peter Friesen for scheduling large supplies of chicks when they were needed for feeding trials, and Reimer's Feed Mill for information on feed supplies. Appreciation is also expressed to the Davis family and to Dave Miller for the use of their slaughtering facilities for obtaining data of poultry, and to Norland Farm for use of their slaughtering facilities for obtaining data of swine.

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Thanks is expressed to Santiago Gomez of the Partners of Americas Program in Belize, and to the Michigan Partners Program for their interest in and support of the project.

There are many more acknowledgments that have not been mentioned, but the list seems endless when one is involved in a project of this scope. One final and especially important acknowledgment is expressed to Mr. Rene Montero, my Belizean counterpart, for his patience and understanding during the initial phases of the project, and for the example he set as a person concerned with the progress of his country.

Finally, the author is extremely grateful to Sandra Tyacke at Washington State University for her services in the final typing of this thesis; to Joanna Gruber, Department of Dairy Science, Michigan State University for her helpful advisement on the final preparation of the thesis, to Dr. Richard Koes, Department of Animal Sciences, Washington State University, for his constructive advice in the final preparation of the thesis; and to June Lipe at Washington State University, for her excellent drafts of figures of the animal housing units.

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I. INTRODUCTION

Improvement of the Livestock Feeds Industry in Belize

Improvement and expansion of the livestock industry in any country depend upon the development of a continuous supply of good quality feedstuffs at a reasonable cost (Arnott and Lim, 1966). The use of large quantities of high-priced imported feeds has been the main obstacle in developing a viable livestock industry in the Caribbean (Mann, 1935; Gohl, 1975). This problem was also identified in other areas of the world (Arnott and Lim, 1966). Substitution of local feedstuffs for imported ingredients entails a radical departure from conventional feed formulation and feeding practices (Gohl, 1975). By-product feedstuffs, which are not normally in demand for human consumption, are available for livestock feed. In Belize, expanded crop production and increased output of processing mills and industries have increased the availability of indigenous feedstuffs.

Inconsistent methods of processing and variations in local conditions of crop production affect the nutritional composition and nutrient availability of feedstuffs. Therefore, it is important to determine the nutritional value of local feedstuffs in order to formulate feeds that will support economically efficient livestock production.

Feed prices are affected by inflation, supply, demand and production costs of the feed industry. It is to the livestock producers' advantage to obtain highest performance in terms of feed efficiency and daily gain (Sachtleben, 1975). Environmental effects, price fluctuations, availability of and storage capabilities for ingredients are variables affecting the economics

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economics of livestock production. Imported ingredients are subject to nutrient fatigue during shipping and handling. Fatigue of feed nutrients may occur [1] in storage and en route in the country of origin to the site of export; [2] during shipping from place of export to the port of entry in the receiving country; and [3] from port of entry in the receiving country to the site of storage and sales. Ingredients are susceptible to weather (humidity, rain, heat) and mechanical damage (torn bags, soiling from liquids) or insect or rodent damage. Weather damage to feed is not always noticeable (except for molding or rancidity), but may contribute to the reduced performance of livestock.

For these reasons, the amount of revenue spent per nutritional unit imported can be reduced by shipping smaller quantities of more concentrated feed supplements less frequently. (A nutritional unit is referred to here as the amount of a particular nutrient, e.g., protein, amino acid, vitamin or mineral, in a given quantity of feed.)

Belize Agricultural Production

Belize exports sugar, molasses, bananas, citrus fruits, coconuts, fish and lobster, while it imports prepared meats, rice, corn, wheat, other cereals, fresh fruits and vegetables, beans and lard (Ministry of Agriculture and Lands, 1975). Policies of the Ministry of Agriculture to assist farmers have resulted in upward trends in agricultural production since the devastation caused by hurricane Hattie in 1961 (see Table 1). Land suitable for raising cattle offers a potential production capacity of 60,000 head per year. Cayo District is the main livestock-production area, accounting for 65% of all the cattle in the country (Ministry of Trade and Industry, 1972). The present domestic livestock market is small, with 4,400 head of cattle

TABLE 1. Annual Production of Belize Livestock and Crops

Livestock Production

TABLE 1.--Annual Production of Belize Livestock and Crops.[a]

	Crop Production			Livestock Production			
Year	Sugarcane Molasses (metric tons)	Rice (metric tons)	Maize (metric tons)	Number of Beef Animals Slaughtered	Number of Hogs Slaughtered	Number of Broilers Exported	Eggs Exported (dozens)
1969	------	-----	------	-----	-----	22,107	35,932
1970	23,997	3,500	15,750	3,310	6,542	24,619	10,281
1971	20,873	4,557	15,750	4,390	8,526	46,604	31,495
1972	22,292	5,811	15,840	5,004	9,902	31,734	22,615
1973	23,754	8,182	15,975	6,886	9,439	9,317	------
1974[b]	24,584	7,545	12,690	5,670	5,795	------	------

[a]Ministry of Agriculture and Lands, 1975.

[b]Hurricane damage in 1974 caused low crop and livestock production.

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and 8,500 pigs slaughtered in 1971, yielding 680,400 kilograms (kg) of beef and 331,128 kg of pork, respectively. Export markets still have much potential, especially with Jamaica, Barbados, Trinidad and the United States. The meat-packing plant in Belize City, which meets standards of the United States Department of Agriculture, has a slaughter capacity of 12,500 head of cattle and 5,000 hogs yearly, which could be doubled (Ministry of Trade and Industry, 1972). Facilities exist, therefore, for the production of 212 metric tons[1] of meat-and-bone meal (MBM) from 12,500 head of cattle and 15 metric tons[2] from 5,000 hogs, which would provide a total of 227 metric tons of meat-and-bone meal per year. The slaughter capacity of the meat-packing plant could be doubled.

A 1975 census reported 18,000 pigs in Belize (Ministry of Agriculture and Lands, 1975). Local pork consumption was approximately 2.7 kg per capita per year, a total of 331,818 kg per year. Domestic demand for fresh pork is supplied by the national swine production, but in order to supply the demand for all imported processed pork products as well, 20,000 head of swine must be slaughtered annually (at 46 kg per head) (Ministry of Agriculture and Lands, 1975). The introduction of improved breeds and management are resulting in the production of larger swine.

Annual consumption of poultry meat in 1975 was estimated to be 1.1 million kg of which only 700,000 kg was produced locally (Ministry of Agriculture and Lands, 1975). A small portion of the local production is sold

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[1]12,500 cattle x 17 kg MBM/cattle.

[2]5,000 hogs x 3 kg MBM/hog. (Yield estimates for footnotes 1 and 2 obtained from R. Williams, Belize Beef Corporation, Belize City.)

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to Mexico or Guatemala. The Mennonite settlement at Spanish Lookout, Cayo District, produced an estimated 40% of the fresh chicken for the local market in 1976. Average sales of 3,250 birds per week, which supplied most of the districts from Belize City south, amounted to a yearly total of US $610,000 (Jenkin *et al.*, 1976). The only chick hatchery in the country is located at Spanish Lookout, which imported eggs from the United States. The hatchery sold 320,000 chicks (broiler and layer) in 1976, of which an estimated 80% were broilers. Sales of table eggs in Belize City amounted to US $70,248 in 1976 (Jenkin *et al.*, 1976).

Spanish Lookout produced 127 metric tons of livestock feed per month in 1976, using protein supplements imported from the United States and Guatemala (Jenkin *et al.*, 1976). Only 11% of this was sold to people outside of the Mennonite settlement. The increase in annual imports of animal feeds to meet the needs of an increasing animal population is presented in Table 2 (Deans, 1976).

TABLE 2.--Annual Imports of Animal Feeds in Belize.

Year	Value (US $)	Kg
1966	106,790.00	---------[a]
1967	163,416.00	---------
1968	203,594.00	---------
1969	194,652.00	---------
1970	280,254.00	2,070,954
1971	294,500.00	---------
1972	419,500.00	---------
1973	----------	---------
1974	722,362.00	3,043,318

[a]Not available.

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This indicates that there should be a demand for good quality feeds made from indigenous feedstuffs. Imported feeds consisted of commercial protein supplements, which were mixed with local grain. No by-product feed ingredients were imported on a regular basis although meat meals, fishmeal, and cottonseed meal were obtained on occasion from neighboring countries.

Feed Resources Available in Belize

Energy feeds presently available and which can be used in commercial feed production include corn, grain sorghum, rice bran and polishings and wheat millrun. Combined, these provide an estimated 29,553 metric tons of feedstuffs (Table 3), which could compose up to 90% of a swine or poultry ration. Therefore, using these feedstuffs, 32,837 metric tons (29,553 metric tons ÷ 90%) of feed could potentially be produced. These calculations do not include the use of citrus waste or molasses, which are also available commercially in large amounts and could be included in a commercial feed.

Feed production is limited, however, by inconsistent sources of protein supplements. Meat and bone meal is a major locally produced protein source. If this by-product was used on the average of 5% in rations (in addition to amino acid supplements), then this would provide for 1,060 metric tons (53 metric tons[3] ÷ 5%) of feed production. If the meat packing plant were operating at full capacity and produced 227 metric tons of MBM annually, then 4,540 metric tons (227 metric tons ÷ 5%) of feed could be produced. This is only 42% of the amount of feed needed to attain production to meet all pork and poultry consumption demands (Table 4). Clearly then, the main limitation to a successful feeds industry in Belize is the

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[3]Amount of MBM currently produced (see Table 3).

TABLE 3.--

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TABLE 3.--Annual Availability of Feedstuffs in Belize.

Item	Amount Available[a] (metric tons)	Price Range[b] (US $/metric ton)
Maize (corn)	22,724[c]	132-242
Grain sorghum	2,726[d]	88-154
Wheat millrun	3,285[e]	132
Rice bran and polishings	818[f]	110
Citrus waste	1,640[g]	165
Molasses	24,584[h]	55
Meat-and-bone meal	53[i]	253
Cohune nut meal	34[j]	165
Brewer's spent grain	545[k]	---
Soybeans	20[l]	---
Bananas (waste)	2,045[m]	---
Fish product waste (total)	171[n]	---
Lobster	46[n]	---
Conch	113[n]	---
Fish	10[n]	---
Shrimp and other	3[n]	---
Fat	78[o]	275

[a]1977 estimates (unless otherwise noted).

[b]1979 prices (items with no listed price are not sold on a commercial basis).

[c]2,079 kg/hectare (ha) x 10,931 ha (Cal, 1977).

[d]1,496 kg/ha x 1,822 ha (Cal, 1977).

[e]9 metric tons/day x 365 days (Gomez, 1977).

[f]2,429 ha x 3,368 kg/ha x 10% by-product yield (Swagerty, 1977).

[g]500,000 boxes/year x 41 kg/box x 40% waste x 20% dry matter (Jenkins, 1977).

[h]1974 figure (Ministry of Agriculture and Lands, 1975).

[i]60 cattle slaughtered/week x 17 kg MBM yield/animal x 52 weeks (Williams, 1977).

TABLE 3.--Ann

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TABLE 3.--Annual Availability of Feedstuffs in Belize (Continued)

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[j]81,818 kg of kernels processed x 41% waste as meal (Cain, 1977).

[k]2,727 metric tons/year x 20% dry matter (Bowen, 1977).

[l]674 kg/ha x 30 ha (Cal, 1977).

[m]8,182 metric tons x 25% waste banana (fresh material). 1975 estimate (Deans, 1976).

[n]Total estimated as 50% waste from 855 metric tons of exported products x 20% dry matter. Amounts for individual products also calculated using 50% waste x 20% dry matter (Ministry of Trade and Industry, 1972).

[o]60 animals/week x 500 kg/animal x 52 weeks x 5% carcass fat yield (Williams, 1977).

TABLE 4.-

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TABLE 4.--Statistical Data on Livestock Production, Demand and Feed Requirements in Belize.

Item	Production	Demand	Feed Required To Meet Demand (metric tons)
Market pigs	5,795 head[a]	20,000 head[a]	7,645[c]
Poultry:			
Broilers	0.7 million kg	1.1 million kg	2,750[d]
Layers (eggs)	175,619 dozen	--------------[b]	400[e]
Total feed requirement to meet demands:			10,795

[a]Ministry of Agriculture and Lands, 1975.

[b]Production was enough to meet demand for eggs, but no demand figure was available.

[c]Calculation: 20,000 hogs x 382 kg feed/hog (Miller *et al.*, 1975).

[d]Calculation: 1.1 million kg ÷ 1.8 kg/bird x 4.5 kg feed/8 wk bird.

[e]Calculation: 175,619 dozen ÷ 22 dozen eggs/bird x 50 kg feed/bird. (1.8 kg feed/dozen eggs x 22 dozen eggs = 40 kg feed/bird/year, plus 9 kg feed/bird for initial 23 weeks of growth = 49 kg feed per bird per year).

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amount of supplemental protein source available. To produce a sufficient amount of feed using local resources, the shortage of protein supplement must be overcome by the use of resourceful ration formulation.

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II. OVERALL PROJECT ORGANIZATION AND DESCRIPTION

Goals

This project was conceived to maximize the use of local feedstuff resources available in Belize to provide alternative ration formulations for developing a viable livestock feeds industry.

The overall goal of the Belize Livestock Feedstuffs Project (BLFP) was to minimize feed importation and use low-cost local feedstuffs in the development of livestock rations that would perform satisfactorily and that would allow farmers to engage in animal production with a greater chance of doing so profitably. Development of nutritionally and economically efficient livestock rations that are practical and acceptible to the livestock producer requires both experiment station testing and analysis, and field testing and evaluation under local conditions. This would provide confidence that rations could be recommended which offered economical benefits to livestock raisers.

Strategies Used for Attaining Project Goals

Organizational Structure of Project

The Feeds Project was supported by agencies and organizations with common interests in agricultural development. The linkages between the various agencies are summarized in the scheme shown in Figure 1.

The Belize Ministry of Agriculture and Lands valued the project as a vehicle to improve swine and poultry production and increase the income of

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Figure 1.--(

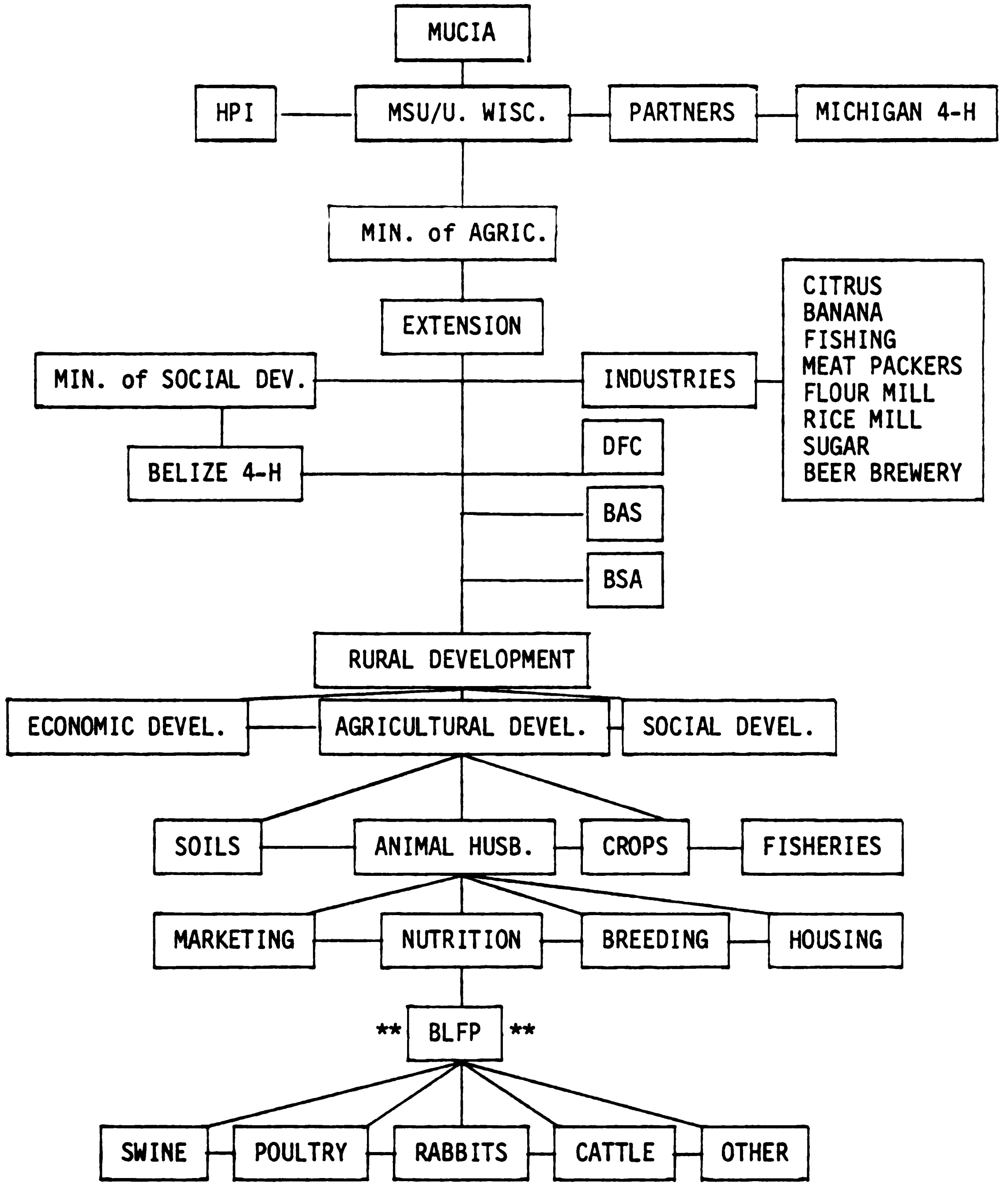

Figure 1.--Overall Scheme of Agencies Involved in Rural Development.

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the subsistence farmer. The Ministry of Social Development, Labor and Welfare expected the activities to lead to the adoption of small livestock projects (rabbits and poultry) by rural youth as a means to improve the nutrition and income in the rural family production scheme. The DFC (Development Finance Corporation) needed information concerning the economics of livestock production in order to determine the financial needs of farmers for small-scale agricultural project loans. Industries in Belize that have by-products (wheat mill, rice mill, beer brewery, sugar refinery, citrus juice producer, meat packers, and the fishing industry) needed an indication as to the extent that by-products could be used and if the processing methods could be improved. Heifer Project International (HPI), The Partners of The Americas, and other organizations needed indicators and methods of delivery for their programs. Heifer Project International recognized the difficulty that the small livestock farmer had in maintaining a profitable activity in the presence of a monopolistic feed supply system. Midwest Universities Consortium for International Activities (MUCIA) had the interests of furthering the development of international project activities. The Feeds Project provided the means to serve many of these interests through feeding trials conducted at Central Farm, in which good livestock management was demonstrated, and by applying the information to field studies with cooperator farmers.

The structure of this project involved four groups: [1] advisory groups; [2] project management personnel; [3] field workers from the extension department, DFC, BAS, and 4-H; and [4] local farmers' organizations. The advisory groups acted as mediators on such matters as priority of feedstuffs that needed to be studied and how to involve the local farmer, and recommended approaches to meet the final goals of the project. Project personnel con

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personnel conducted the daily activities of the project, were involved in planning and functioned as a communication link among the agencies supporting the project. Field workers and extension officers served to keep communications open with the farmers and provided feedback to the activities of the project, while dispersing information to the farmers. The farmers' organizations were the means by which information was disseminated and were the vectors for the development of local feeds processing and distribution and for the marketing of livestock products.

Strategies for Meeting the Goals

Results obtained from studies at the research station do not ensure the same performance at the farm level due to variations in climatic environment, location, management, housing, stock, etc. For this reason, field studies with local producers must affirm that the rations provide an income equal to or better than the feeds normally used. This is especially important when dealing with subsistence farmers, who cannot afford to try a new method with a possibility of failure. Finally, a national or local feed production system must be developed to supply a continuous volume of feed that is of constant nutritional quality.

The project was organized in three phases that involved ration formulation and testing, methods of delivery of systems to farmers, and the development of a national feeds production scheme (Figure 2).

Phase I strategies involved experiment station-based research to formulate and test least-cost rations under controlled conditions. This isolated the effects of rations on animal performance from other environmental influences. It provided a baseline against which animal performance results could be compared. Swine and poultry units of a design similar to

PHASE I —

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Figure 2.--

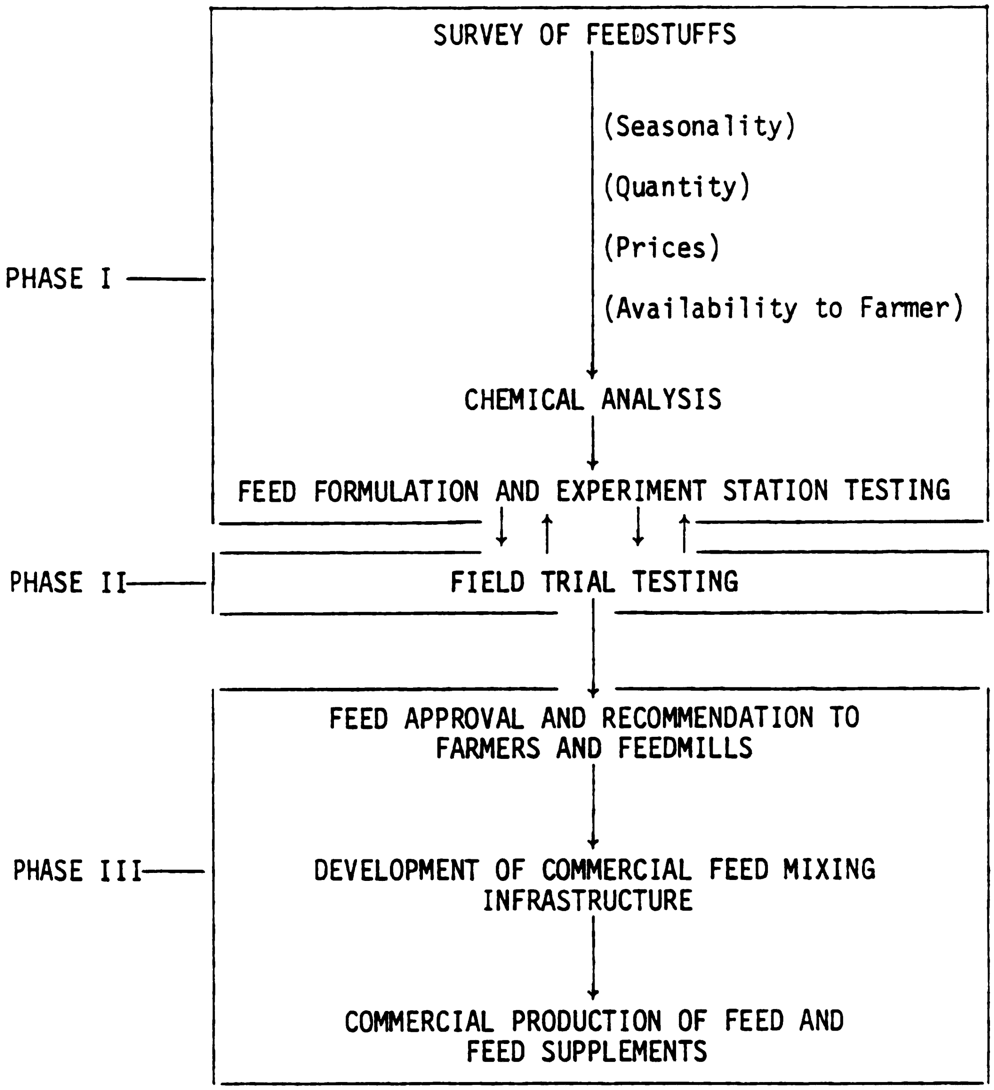

Figure 2.--Flow of Events in Ration Development.

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those used by local farmers were constructed at Central Farm to provide facilities for studying the performance of animals on test diets. Surveys of feedstuff supplies were made to determine the amounts and availabilities of ingredients. Laboratory systems for feeds analysis were developed, and the facilities for feed mixing and storage were obtained. Local farmers were visited to discuss their concerns for livestock feeds and also to observe their methods of animal husbandry. The establishment of the project was made known to the people through these farm visits, extension newsletters and radio broadcasts. A Belizean counterpart was assigned to the project to be involved in all developmental procedures. Visits to the project site were made by US advisors in order to have a better concept of the nature of the project and to determine guidelines with the on-site administrators.

Phase II involved field trials of recommended rations at local farm sites. The objective of these trials was to test extensively the rations which gave consistent economical performance in the station-based trials. The combined efforts of farmers, extension personnel, the DFC (Development Finance Corporation, which gave loans to farmers), and the BAS (Belize Agricultural Society) were involved in this aspect of the project (see Figure 3). Cooperator farmers raised two groups of animals with one group fed the test ration and the other group given the standard commercial feed normally used. Farmers who were conscientiously trying to improve their income through the use of recommended agricultural methods were selected from those suggested by DFC field workers. Good communications between the project administrators and the farmers helped to achieve the goals of the project. The feedback mechanism built into the program planning system (Figure 4). involved a scheme of iterative reciprocity (Axinn, 1978).

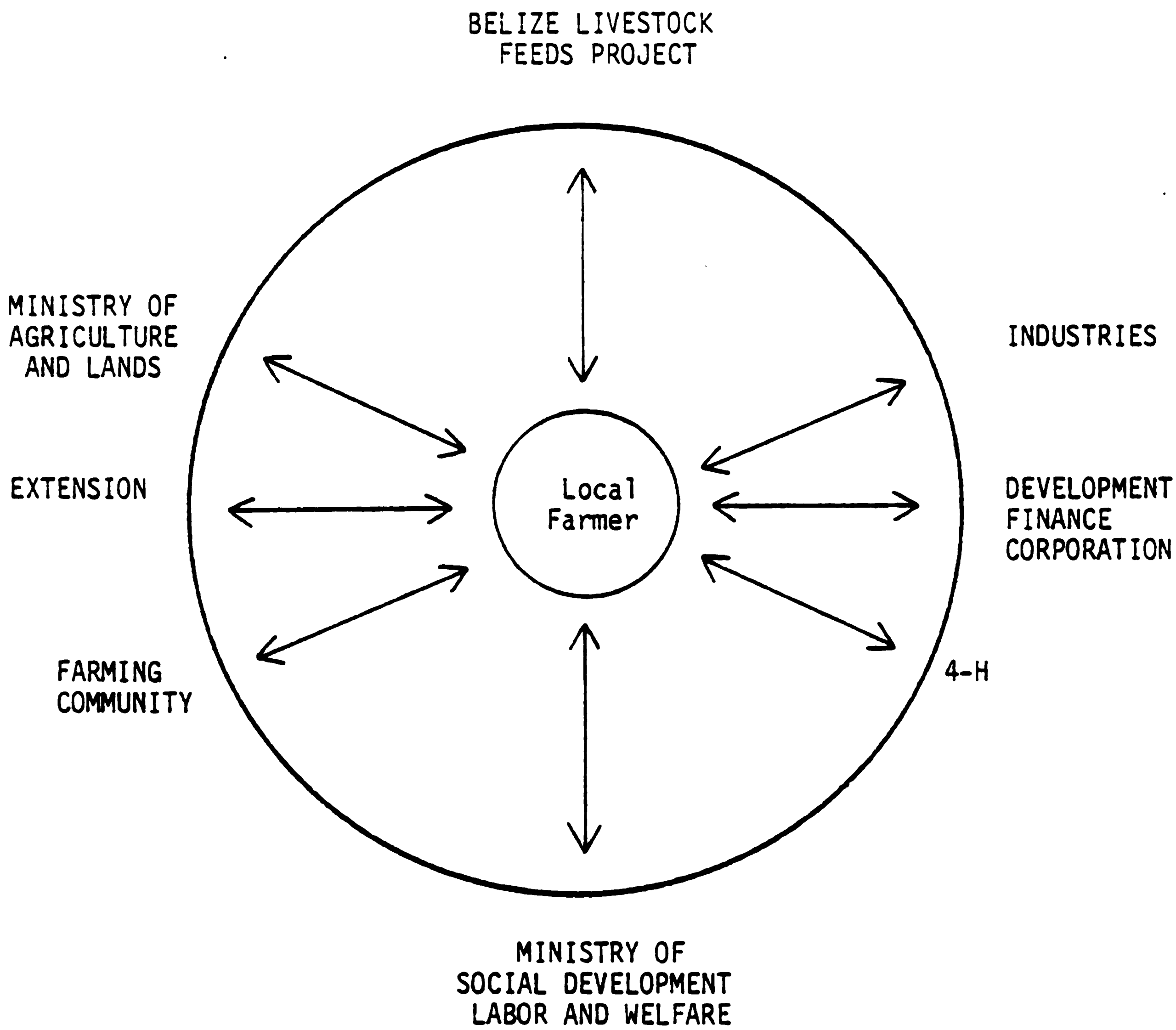

Figure 3.--Farmer-Agency Interactions.

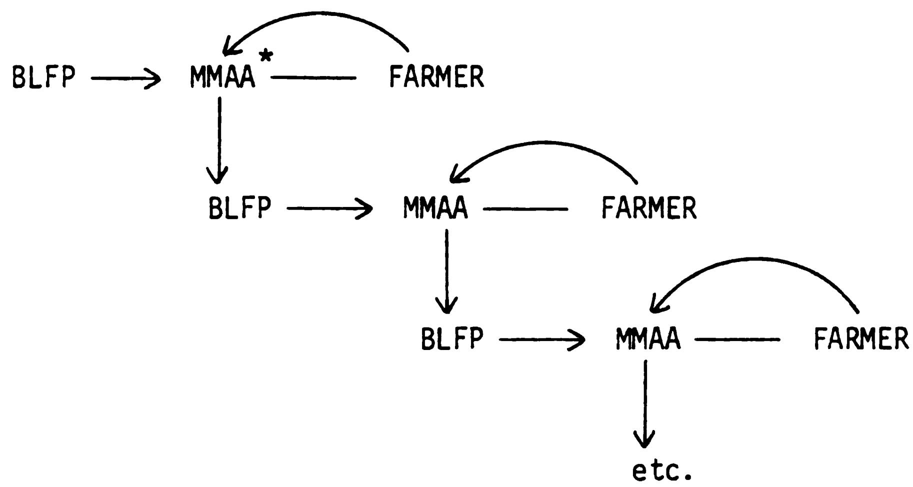

Figure 4.--Iterative Reciprocity Flow Over Time between Farmers and Feeds Project.

*Transactions between the farmers and the Feeds Project researchers (BLFP) were mediated through the Ministry of Agriculture and Lands, Ministry of Social Development Labor and Welfare, and the expatriate and local advisory committees (MMAA).

Phase III encompassed the ultimate goal of the project, which was to develop a commercial feed production, storage and distribution system for Belize. This involved the efforts of those who had interest in the development of a feeds industry, including the suppliers of feedstuffs, feed mill operators, and farmers who would use the feeds. Development of the feeds system could occur in small farming communities mediated by the Ministry of Agriculture. A model production unit scheme was suggested[4] whereby a subdivision of farmers could produce grain mainly for pig production (see Figure 5). The program would involve grain and pig production in one unit, which would include the development of a feed mill, supply shops, marketing center, and processing facilities. The models could start with groups of 25 farmers with basic infrastructures provided by the government, such as buildings, loans and technology. Farmers would first receive training at Central Farm.

This thesis is concerned with the procedures used for the establishment and organization of the feeds project, and the results of Phase I swine and poultry feed trials conducted at the research station.

Advisory Groups

The project leaders were responsible to two main cores of advisory persons (see Figure 6). Indirect leadership was provided by a faculty advisory committee consisting of four professors, one from the University of Wisconsin and three from Michigan State University. These members advised on the development of test rations for the species of animals studied and assisted with the analysis and evaluation of the results obtained from feeding trials. Direct leadership for the project came from the second advisory group. This

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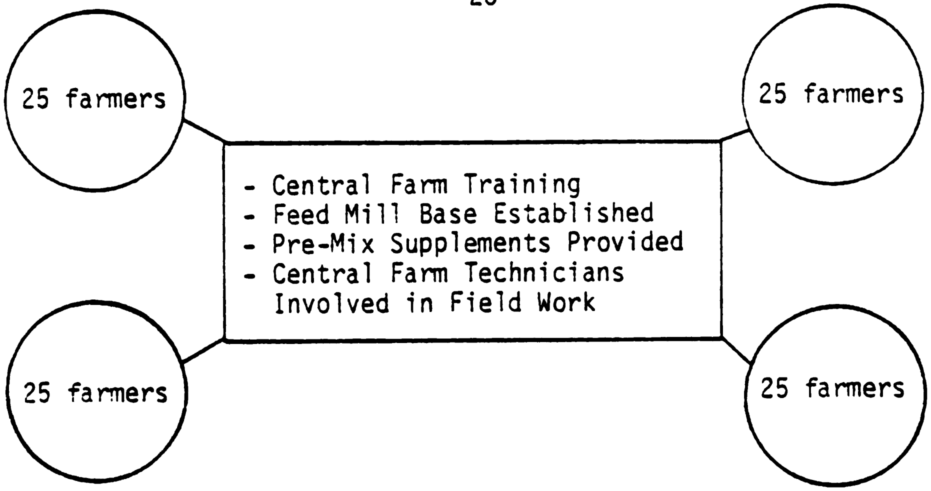
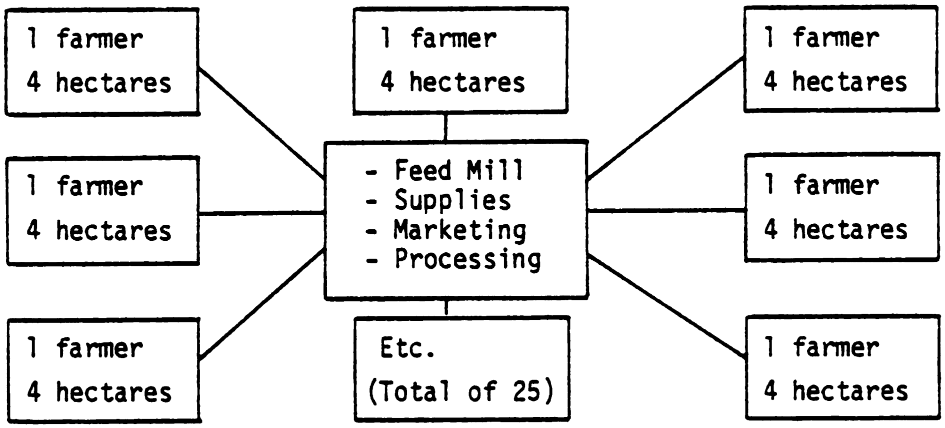
[4]Dr. J. Cal, Chief Agricultural Officer, Ministry of Agriculture, Belmopan, Belize.



Model A: Production Units Composed of Groups of 25 Farmers.



Model B: Development of a Farm Community Production Scheme.

Figure 5.--Development of a Model Production Scheme with Groups of 25 Farmers Given 4 Hectare Land Packages for Grain and Pig Production.

gure 6.--P

[a]See

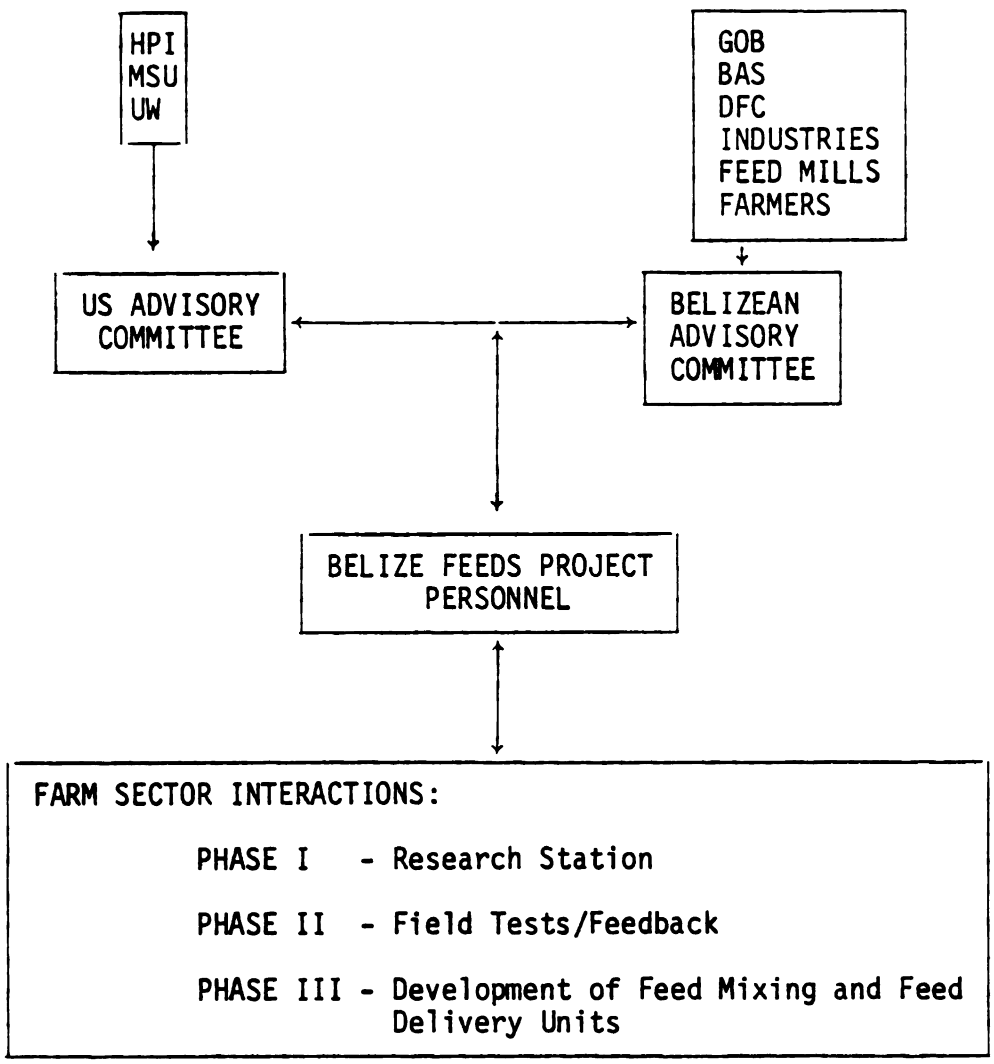


Figure 6.--Project Guidance Linkages.[a]

[a]See text for explanation of abbreviations used.

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group consisted of Belizean personnel, including [a] representatives from the Ministry of Agriculture and Lands and the Ministry of Social Development, Labor and Welfare; [b] persons from the industries that produced by-products for use as feedstuffs; operators of the two Mennonite feed mills; and [c] representative farmers from large and small operations in Belize. This group influenced and directed both the immediate and long-range objectives of the Feeds Project and determined the priorities of the research that were undertaken.

Project Linkages

Achievement of the goals of the project depended on strong communication linkages between the project staff and the advisory groups.

Extension Department personnel (in the Ministry of Agriculture and Lands) supported a strong research-extension linkage, a vital component of agricultural development.

Local leaders from the farming sectors, included in the planning, provided a two-way farmer-bureaucracy communication which allowed unimpeded feedback from the farmer.

The advisory group representatives served [1] as enabling linkages which provided the authority and essential resources for the project to operate; [2] as functional linkages that provided critical inputs and means for outputs; [3] as normative linkages which allowed for the participating organizations to share overlapping interests; and [4] as diffuse linkages for the sectors of the society that had an interest or involvement in the agricultural development of the country.

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Project Evaluation Criteria

This project was subjected to a continuous form of evaluation in its efforts to reach the subsistence farmer and to conduct studies and activities that would be to his benefit. Local participation was a critical means of evaluation as it reflected the amount of contact with and the relevance of the program of activities to the local farmers. Achievements for each of the three phases of the project were evaluated respectively by [1] the biological growth performance of animals fed the test rations and the costs of production; [2] the biological performance and cost of production of animals fed selected test rations in farm trials; and [3] the development of a feedstuffs supply and feed distribution system for livestock producers. The extent of farmer participation and their desire to try new methods of feeding provided feedback indicators for evaluation of the program.

Reference Library

Funding was provided for the development of a reference library of materials relevant to the goals of the project. Students at Michigan State University compiled reference materials for this library, which consisted of [1] a note card system; [2] filed copies of relevant articles; and [3] a bibliography. This work began one year prior to the initiation of the on-site activities of the project in Belize. The materials which were collected pertained to useful feedstuffs and animal production systems in tropical or developing countries. This was a transferable system, which could be useful to other countries as well as Belize. A copy of the reference materials remained at Michigan State University (MSU) and a copy was located at the Central Farm Library in Belize.

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Staffing

The project has been staffed by five graduate students from MSU (over a three-year period) working with three Belizean counterparts in the administration of the program. The counterparts were extension officers in the Ministry of Agriculture and Lands, who would continue to administrate the project upon completion of expatriot involvement. The plan was to have the Belizean counterparts continue their education after working with the MSU students at Central Farm and then return to administer the project. Three undergraduate students from MSU, four students from Goshen College in Indiana, and three Peace Corps volunteers also assisted with project activities in Belize. Other students contributed to the project by researching for literature and by the preparation of reports at MSU. The project was assigned seven laborers at Central Farm to assist with the care of animals on feed trials and with the preparation of feeds. These laborers cleaned the animal pens, checked the feed and water supplies, and assisted with feed preparation and mixing.

Laboratory Support

Facilities for the analysis of feeds were provided through funding from HPI and MSU. The Central Farm Agricultural Chemistry Laboratory was equpped to do a complete proximate analysis, but certain facilities, including Kjehldahl nitrogen digester units, Goldfisch ether extract apparatus and a crude fiber analysis unit, were in need of replacement. Backstopping for feeds analysis was provided by the nutrition laboratory at MSU until all facilities at Central Farm were in operation. Representative samples of feedstuffs and mixed feeds were sent to MSU for analysis of calcium, phosphorus and proximate fractions.

Specific Procedures and Strategies Used to Develop a System of Rations

Choosing Animal Species and Feedstuffs

The Belize Government has established a high priority for beef cattle research. The Ministry of Agriculture, however, determined that initial activities of the Feeds Project would focus on swine and poultry, since farmers engaged in raising these species were not earning a profit and were demanding more economical feeds.

The strategy for ration development was to use maximal amounts of local feed ingredients to produce a marketable animal and a good profit margin. Initially, local feedstuffs that were available commercially on a continuous basis were selected as the primary components of the diets. Freshly harvested, non-commercial items were fed *ad libitum* in certain trials as these items became available.

Rationale Used in Developing Feed Formulas

Swine and poultry diets were formulated on a least-cost basis to make use of indigenous feedstuff items. A number of diets were formulated with alternative feedstuff combinations in order to allow for the replacement of one ingredient for another if a particular feedstuff should become scarce or expensive. The stepwise development of diets included: [1] the use of indigenous feedstuffs in alternative least-cost combinations of energy and protein sources; [2] comparison of animal growth and economical performance on local versus imported protein supplements; [3] the use of graded levels of synthetic amino acids or blood meal in place of SBM to provide essential amino acids that were limiting in the local feedstuffs; and of supplem

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[4] supplementation of all diets with the specially formulated vitamin and trace mineral premixes.

A control diet was used as an indicator of variation in animals and environment between trials. Imported commercial feeds were initially used as control diets. These feeds provided a baseline to which the experimental feeds were compared. The imported feeds were replaced by an experimental feed as a control diet when the trial results indicated that an experimental diet resulted in animal performance with favorable growth and feed conversion efficiency. A diet was repeated in at least two trials before it was considered to be used as a control diet. Locally produced by-product feedstuffs had lower metabolizable energy levels than grains that were used in diet formulation. Poultry diets that had a lower metabolizable energy level than the NRC (1977) recommendations were formulated with an equal percent decrease in other nutrient levels to the extent that this was possible. Protein levels of the concentrate feed were increased in trials based on free-choice fresh feeds. Fresh feed materials were fed in order to determine the amount of concentrate feed that could be spared if the animals were allowed continuous access to fresh feedstuffs. Combinations of corn, grain sorghum, wheat millrun, rice bran and polishings, and MBM were tested which could be fed with fresh materials, including root crops, bananas and cohune trash. Salt, trace minerals, vitamins and supplemental amino acids, which could be made available in a lost-cost premix to farmers and which would result in improved performance, were added to experimental diets.

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Procedures and Physical Plant Used

Facility Design and Basis for Selection

Phase I facilities were provided by the Government of Belize (GOB) and HPI. The GOB allocated funds for the facilities at the Central Farm Research Station, housing for project personnel, office space, experimental livestock units and feed. Heifer Project funded expenses for expatriote staff, transport and feed mixing equipment. Support from HPI was critical as it provided the means for accurate feed weighing and processing equipment and for vehicles needed to visit farmers, obtain ingredients and transport materials and animals.

A crucial component of the project was to conduct the research using systems that a local farmer could identify with and that were available to him. Local conditions of animal management, especially the feeding practices, were considered when test rations were developed. Most farmers fed concentrates in a trough or in a hanging metal tube feeder (for poultry) and fed chopped fresh feeds in a trough. The project provided feed for birds from two hanging tube feeders per pen, allowing 5.1 cm feeding space per bird in a pen of 50 broilers. In certain trials (Trials 3 and 8, which are not discussed in this thesis), fresh ground moist feeds (cassava root, sweet potato, cohune nut kernels) were fed in separate troughs.

A locally manufactured hanging water trough system was used by farmers to supply water to poultry. This system, consisting of a float and a 123 cm long V-shaped trough, which provided 2.5 cm drinking space per bird and was accessible from both sides, was used by the Feeds Project initially. However, the floats proved to be undependable for the complex layout of pens at Central Farm. The use of one float in each of 20 broiler pens and in each of 16 layer pens required a constant demand on the labor force to check for malfunctioning floats. Other methods were explored to supply poultry with water and the most dependable was found to be hanging plastic bell-shaped waterers. These imported waterer units were less expensive than the locally made metal troughs and were also practical for farmers to use.

Swine and poultry housing units were designed and constructed from materials commonly used in Belize. The units are described in a later section. Pen sizes used for poultry trials were smaller than those used by the local farmer. Fifty birds per pen were used for broiler trials, and twenty birds per pen were used for layer trials. This number of birds per pen was used for two reasons: [1] the farmers could more readily associate their own systems with larger pen sizes, and [2] the large number of birds per pen made it feasible, if desired, to conduct exploratory treatments on a broad range of diets using only one pen per treatment. Then significant differences in performance could be further explored by conducting trials with duplicate groups (2 pens per diet) in future trials.[5] The broiler unit was constructed lengthwise in a north-south orientation in order to provide a uniform environment in all of the pens. Originally, it was planned to construct two separate rows of broiler pens so that all of the pens would be affected equally by the east and west sunlight. However, the decision to have two rows of pens contained as one unit caused environmental differences between the east and the west rows of pens. The east row of pens received only a small portion of early morning direct sunlight, while the west row of pens received the direct rays of the warmer west sunlight. The decision to

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[5]H. R. Bird, University of Wisconsin, Madison. Personal communication, 1978.

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make one building with two rows of pens was made in order to reduce the cost of construction.

Feed Mixing Facilities

Feed preparation and storage facilities were developed at Central Farm. The feed mixing center consisted of a fan scale[6] for the measurement of small quantities of ingredients, a platform scale[7] for the measurement of bulk feed quantities, two horizontal feed mixers (one 227 kg capacity and one 909 kg capacity),[8] two storage bins (150 bushel storage capacity each),[9] a pelleting machine,[10] a bag-closing machine,[11] and a vertical mixer/hammermill.[12] This equipment would be sufficient for an estimated maximum production capacity of 18 metric tons of mixed feed per day,[13] which could be doubled if twice the regular maount of man-hours were used to prepare the feed. A production capacity of 9,396 metric tons per year could be achieved using these facilities (employing only the two horizontal mixers),[14] which could nearly supply the estimated total feed required to support the

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[6]Toledo Computagram Scale Model No. 3710, with a sensitivity of 1 gram. Toledo Scales Co., Toledo, Ohio.

[7]Toledo Platform Scale Model No. 2181, with a 277 kg capacity and a 114 gram sensitivity. Toledo Scales Co., Toledo, Ohio.

[8]H. C. Davis and Sons Manufacturing Co., Inc., Bonner Springs, Kansas.

[9]Brock Bins Co. (Hendrickson Distributers, Inc., Wabash, Indiana).

[10]R. A. Lister and Co., Ltd., Dursley, Glouchestershire, England (distributed in the U.S. by Daffin Co., Lancaster, Pennsylvania).

[11]Dave Fischbein Co., Minneapolis, Minnesota.

[12]Gehl Company, West Bend, Wisconsin.

[13]((909 + 227 kg)/batch) x (16 man-hours/day) ÷ 2 man-hours preparation time/batch.

[14]36 metric tons/day x 261 work days per year.

production of swine and poultry in Belize (see Table 4). However, it would be necessary to increase the limited storage capabilities for raw materials and mixed feeds.

The procedure for mixing feeds for trials was as follows: bulk ingredients, which composed the majority of the ration, were first added to the mixer, with a portion saved out to mix with the small amounts of supplemental ingredients. Protein supplements were added second, and the vitamins, minerals and other ingredients used in small quantities were added third (after mixing with the portion of bulk ingredient that was held out). Finally, molasses was dripped into the mixer, if it was included in the ration.[15] Feeds were mixed for 10 to 20 minutes, depending on the amount of molasses added.

Feeds were mixed weekly in batches of 91 to 227 kg and were stored in 23 or 45.4 kg quantities in polypropylene feed bags. Homogeneous lots of feed ingredients for each trial were stored in 45.4 kg quantities in polypropylene or burlap bags prior to mixing. (Fresh shipments of bulk energy sources [wheat millrun and rice bran and polishings] were obtained bimonthly.) Imported feed ingredients (vitamin and trace mineral premixes, soybean meal, alfalfa meal, blood meal, lysine and methionine) were stored in an air-conditioned room at a temperature of 18°C.

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[15]Molasses was dripped into the mixer as follows: a 36 cm diameter flat-bottomed pan (containing 75 drilled holes of 1 cm diameter in the botton) was placed on top of the grid at one end of the mixer. This diameter of hole allowed a constant, thin stream of molasses to flow into the feed as it was mixed.

Poultry Facilities

Broilers

Broiler birds were raised on a deep litter floor system using hardwood tree shavings. The open-air building was constructed from local wood posts and wood frame. Hardware cloth (0.64 cm mesh) was used for the sides and for pen divisions. Dimensions of the building were 21.2 m x 7.3 m, oriented in a lengthwise north-south direction in order to minimize variation in the amounts of sunlight and radiation affecting the birds in each pen. (An east-west orientation would have provided a cooler environment in the middle pens, with an adverse effect on the end pens.) In this way, one set of replicates on the east side received radiation from the morning sun and one set of replicates on the west side received radiation from the afternoon sun. The 1.2 m overhang provided by the thatched roof[16] was insufficient to prevent direct sunlight from entering the pens. This caused the west pens to be subjected to a more extreme heat exposure (4 to 6°C higher)[17] for a short period of time as the sun set (approximately 3:00 to 4:00 p.m.). The unit consisted of two rows of ten pens each, divided by a 2.4 meter wide alleyway (see Figures 7 and 9). Dimensions of each pen were 2.4 m deep x 2.1 m wide x 1.8 m high. This allowed 0.1 sq m per bird with 50 birds housed per pen.

The building was located in an open field with crops planted 30 meters to the east and a swine unit 10 meters to the west. There were no shade trees in the immediate vicinity of the building.

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[16]Made from bay plam tree leaves.

[17]A two-point thermograph was used to record temperatures simultaneously in the east and west pens continuously for 24-hour periods.

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Layers

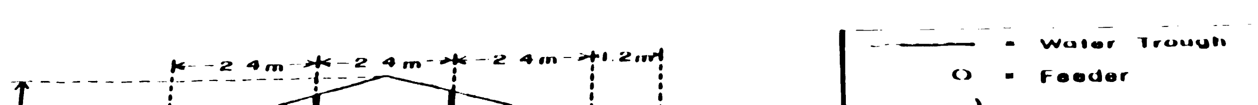
Conditions of management for the layer birds were similar to those for the broilers, except for a few minor differences. Two units of open-air pens, containing eight pens per unit, were constructed in a lengthwise north-south direction, leaving an open field space of 9 m between the two units (Figures 8 and 10). This allowed all pens to receive equal amounts of the east sun and the west sun with minimal interference of shadows. This was important to provide equal sunlight exposure to both units of pens. Materials used to construct the units were similar to the broiler units, with 0.64 cm mesh hardware cloth sides, a thatched bay palm leaf roof, and wood shavings on the floor. Each unit, comprising a single row of eight pens, was 18.3 m long x 21.3 m wide. Individual pen measurements were 3 m deep x 1.8 m wide x 1.8 m high, which allowed 5.4 sq m for 20 birds or 0.3 sq m per bird. Feeding, watering, and brooding systems were similar to those used in the broiler studies.

Swine Facilities

The swine grower-finisher unit was constructed using 15 cm wide wood slat sides spaced horizontally with 10 cm gaps (see Figures 11 and 13). A solid concrete floor with a slope of 4.3 cm per meter directed animal wastes away from both sides of a 0.9 m alleyway located between two rows of eight pens each. The unit was oriented lengthwise in an east-west direction and was covered by a galvanized tin roof. Each pen was 2.4 m deep x 2.1 m wide, providing 5 sq m per pig with 5 pigs per pen. One hog nipple waterer per pen allowed for an *ad libitum* supply of water. A single 1.2 m long wooden self-feeder per pen allowed for *ad libitum* feeding (see Figure 12).

Figure 7.--Broiler Housing Unit.

Figure 8.--Layer Housing Units.


2 4m
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1.2m
= Water Trough
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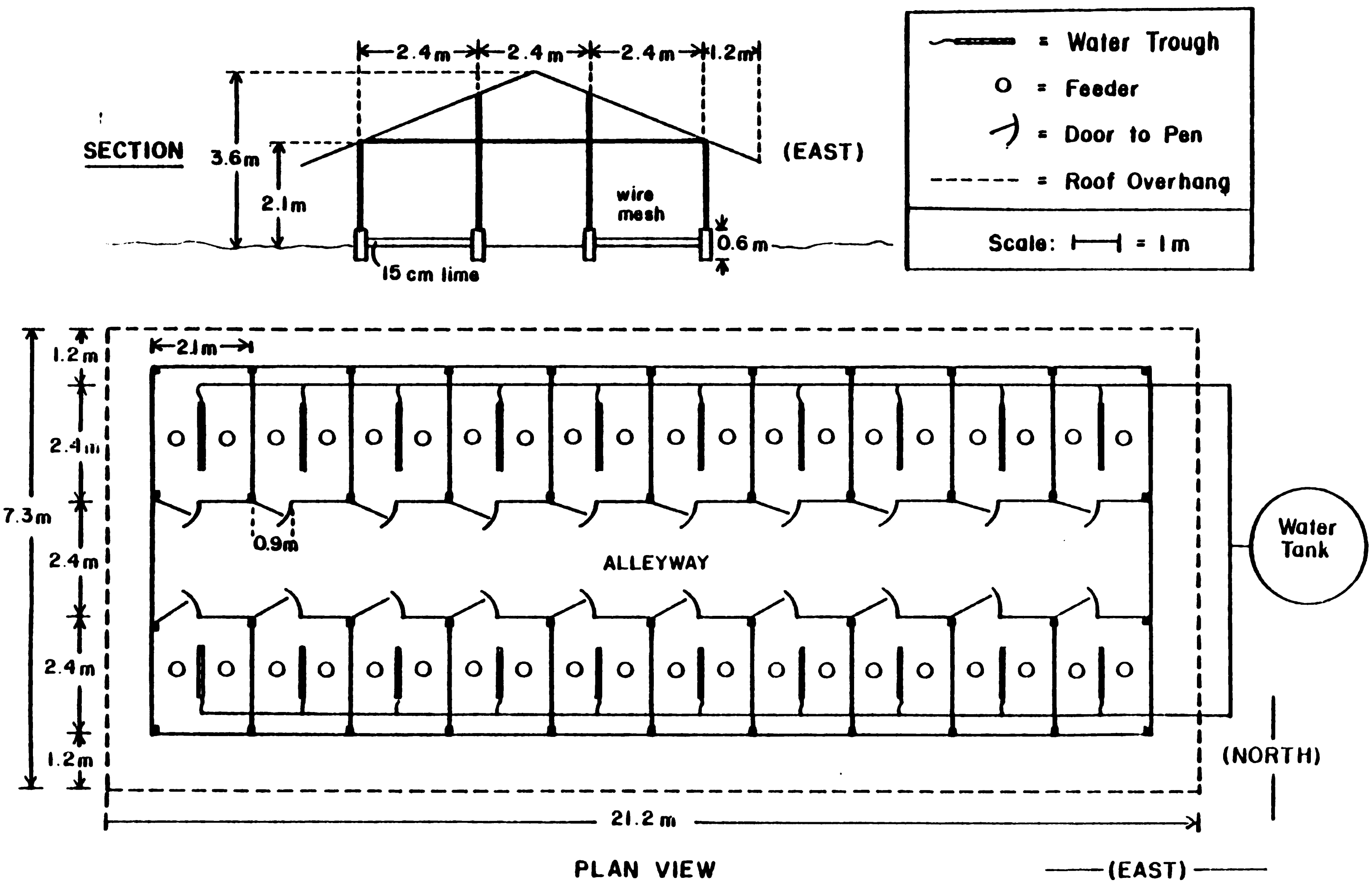

Figure 9.--Broiler Housing Unit Floor Plan.


Water Trough

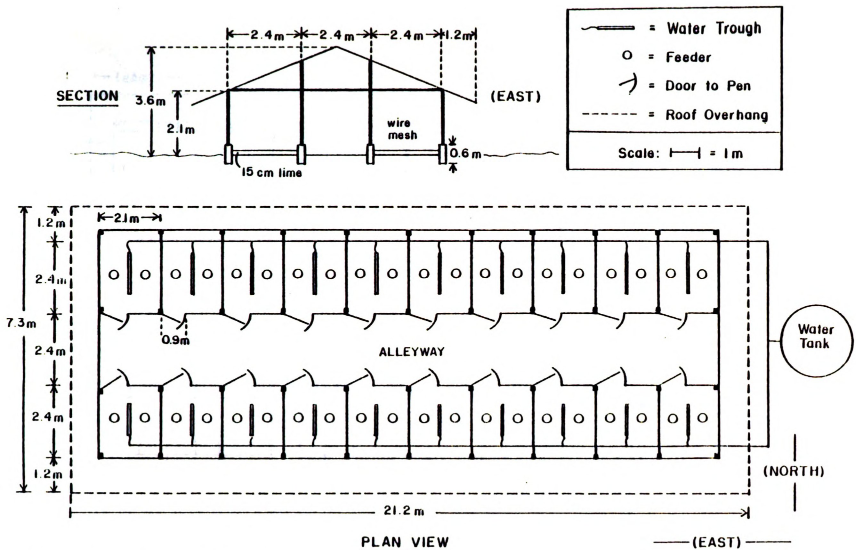

Figure 9.--Broiler Housing Unit Floor Plan.

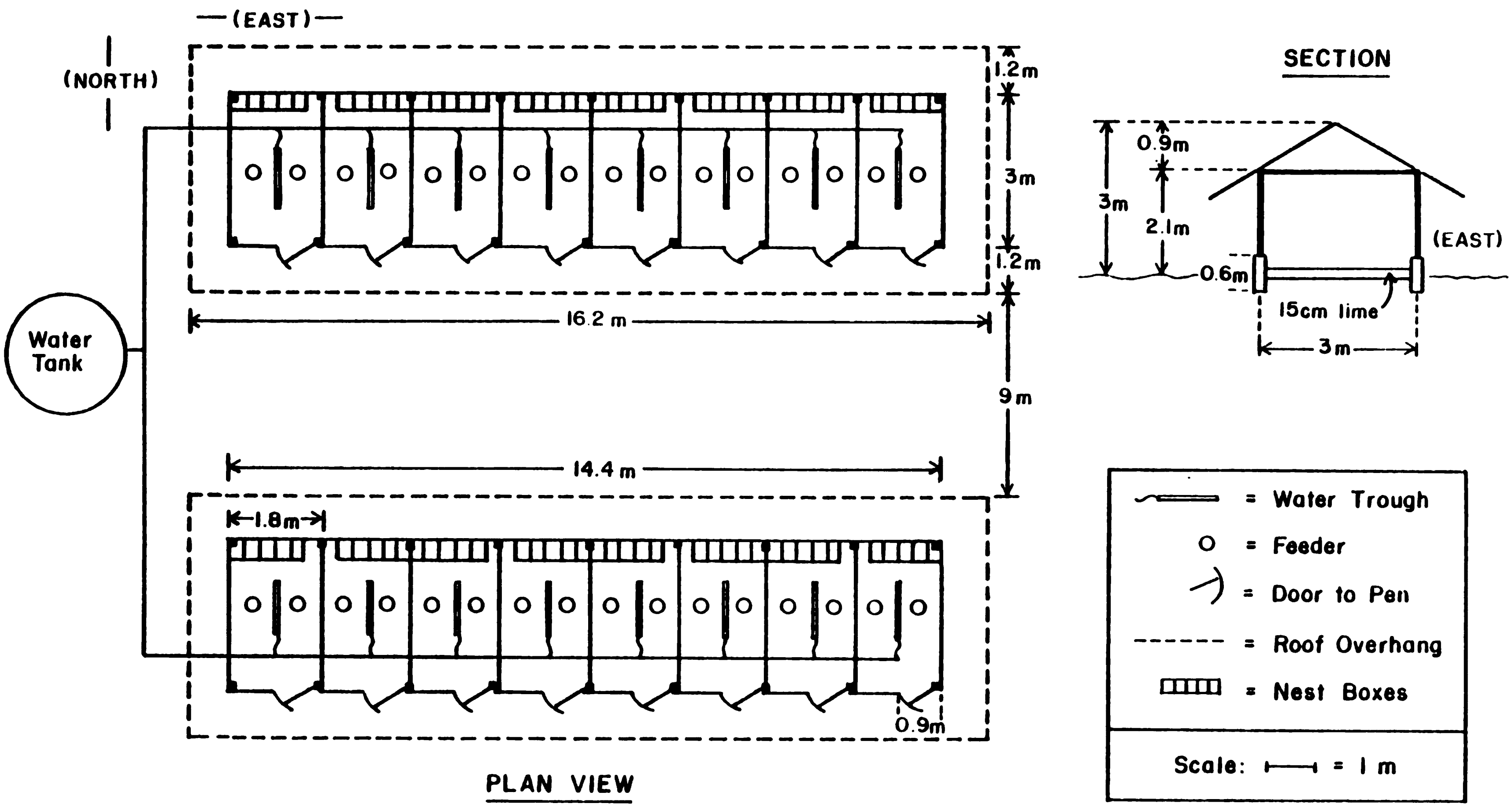

Figure 10.--Layer Housing Unit Floor Plan.

Figure 11.--Grower-Finisher Swine Housing Unit.

Figure 12.--Grower-Finisher Swine Housing Unit--Self-Feeder.

Figure 13.--Grower-Finisher Swine Housing Unit Floor Plan.


Water Nipple Unit
SECTION

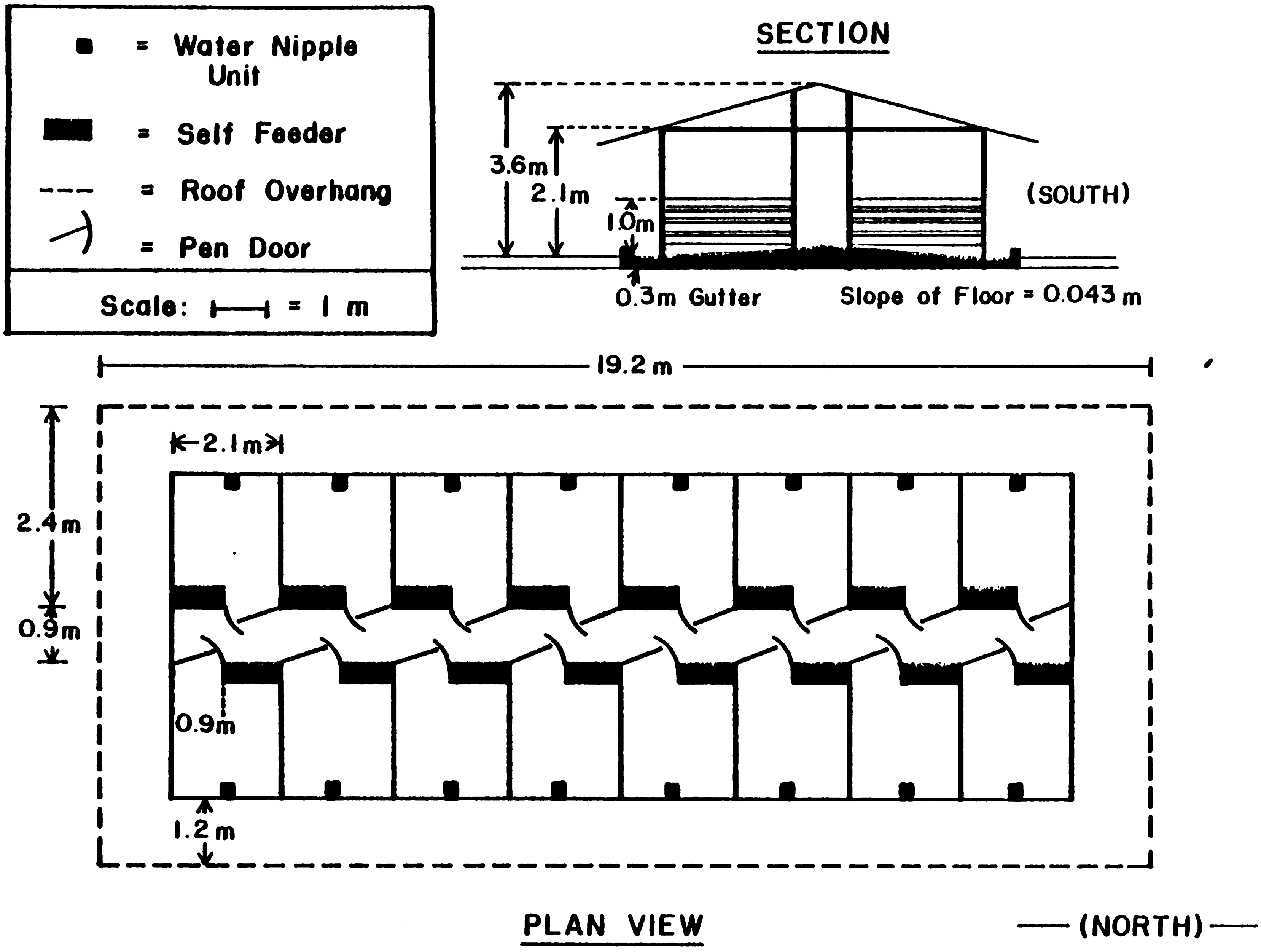
■ = Water Nipple Unit
= Self Feeder
--- = Roof Overhang
= Pen Door
Scale: = 1 m
SECTION
3.6m
2.1m
1.0m
(SOUTH)
0.3m Gutter
Slope of Floor = 0.043 m
19.2 m
2.1m
2.4m
0.9m
0.9m
1.2 m
PLAN VIEW
(NORTH)

Figure 13

To minimize the effects of environmental interactions and provide cooler surroundings for the pigs, the roof was painted white on the top to reflect radiation from above, and black on the underside to absorb radiation from below. East and west end pens were not used in order to reduce effects of radiation from direct sunlight on pig performance. Also, the groups of pigs were rotated in a figure-8 fashion during each two-week weigh period to further reduce the effects of pen environment on animal performance.

Materials and Methods Used in Conducting Swine and Poultry Feeding Trials

Feedstuffs Studied and Evaluated

Feedstuffs Used

Indigenous Belizean feedstuffs that were used in test diets included MBM, bone meal, yellow corn, grain sorghum, rice bran and polishings, citrus pulp pellets, molasses, cassava and sweet potato tubers, cohune nut kernels and cohune nut meal, limestone, bone ash, *Cajanus cajan* leaf meal, *Desmodium leonii* leaf meal, and *Leucaena leucocephala* leaf meal. Wheat millrun and dried brewers spent grains (DBSG) originated from grains imported from the United States, but the by-products were produced by the industries in Belize.

Meat-and-bone meal was the only commercially available indigenous protein supplement.[18] The meal was dry-rendered at 160°C and 176 kg/sq cm of pressure for four hours.[19] The MBM, produced from beef cattle and swine slaughter wastes, contained large pieces of bone, hoof and hair owing to a

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[18]Produced by Belize Beef and Cattle, Ltd., Belize City, Belize.

[19]Normal processing conditions for good quality MBM are 2 hr at 130°C at atmospheric temperature (Herbert and Norgate, 1971).

worn hammermill screen. Laboratory analysis of the MBM showed that it contained a higher content of calcium and phosphorus and a lower level of protein than a standard US MBM product. A standard US MBM contains 50% protein, 8% fat, 10% calcium and 5% phosphorus. (Processing conditions in the US have varied according to the type of by-product. Batch or continuous rendering have been used, depending on the freshness of the product. Also, different processes have been used depending on the fat content of the carcass. In general, an attempt was made to obtain 8% residual fat in the meal. A crumbly sample of feed indicated that enough oil had been removed and the batch was done. If the MBM contained 50% crude protein, then the phosphorus level was usually good.)[20]

Yellow corn (*Zea mays* L.) used in the feed trials was a locally-grown Mexican Synthetic Variety VS 550A. Corn was grown throughout Belize, with greatest production in the Cayo District. Most was sold through the Marketing Board, but some farmers retained portions for their own needs. Due to lack of storage space and lack of proper feed mixing knowledge, the small farmers bought mixed commercial feed containing corn at a higher price than if they had used their own corn.

The grain sorghum (*Sorghum vulgare*) variety used was Northrup King 222 (non bird-resistant), which is a hetero yellow-red hybrid.

The rice bran and polishings used in these trials was produced from rice (*Oryza sativa* L.) grown at Big Falls Ranch in the Belize District, Belize. The Costa Rican variety CR 11-13 was the most common type of rice grown. Rice was stored and polished throughout the year, providing a continuous supply of rice bran and polishings. Rice was polished at the mill

[20]Information obtained from Tom Foltz, Armour Co., Phoenix, Arizona.

in three steps and was not separated into the three polishings. The combined by-product was sold as "rice bran." Analysis of the three polishings is given in Table 5. The final mixture of rice bran and polishings consisted of the three polishings in a ratio of 20:30:50 for the 1st, 2nd and 3rd polishings, respectively. Daily output from the mill (9 hours) yielded approximately 2,045 kg of the final mixed by-product, which sold at US $11.00/100 kg. Kester and Jones (1950) estimated that milled rice yielded 10% bran. Zwankhuisen (1961) listed the fractions from average rice milling as follows: 63.5% milled rice, 15.1% husk (hulls), 17.1% coarse bran, and 4.3% fine bran and polishings. The rice bran and polishings produced in Belize contained no rice hulls. The volume of this feedstuff could be extended if it were adulterated with rice hulls. Scott and Noland (1959) used 20 to 40% ground rice hulls in a 15% corn-SBM-alfalfa diet for swine and obtained growth performance that was not significantly different from a control diet which contained no hulls.

In studies at Central Farm, a high level (30%) of rice bran and polishings included in the feed caused caking, which prevented a continuous flow of feed in the self-feeders. This could affect animal gains by causing a reduced feed availability and decreased consumption. The rice bran and polishings had a high oil content and a higher protein level than corn or grain sorghum. The oil present in rice bran is subject to oxidative rancidity (Scott *et al.*, 1976), which results in a less palatable feed. This can also result in destruction of essential fatty acids, reactions with amino acid groups of proteins to cause protein degradation,and the formation of toxic compounds (Cockerell *et al.*, 1971). Heating the bran was one method suggested to destroy the lipolytic enzymes and possible trypsin inhibitors that some workers believed were present in the by-product (Kratzer *et al.*, 1974). The by-product used in the present studies appeared to become rancid upon storage

TABLE 5.--Analysis of Rice Bran and Polishings, Wheat Millrun, Corn and Grain Sorghum.[a]

Item	DM	CP	Ca	P
	---------------% (As Fed Basis)--------------			
Rice, 1st polish	89.7	14.8	0.06	0.96
Rice, 2nd polish	89.3	16.2	0.03	1.43
Rice, 3rd polish	89.0	11.9	0.02	1.42
Rice bran and polishings	88.3	12.6	0.03	1.37
Wheat bran	89.0	13.9	0.10	0.95
Wheat shorts and middlings	88.5	14.3	0.08	0.76
Wheat screanings	89.3	14.4	0.17	0.49
Wheat millrun	87.6	15.1	0.16	0.88
Corn, yellow	88.7	8.2	0.03	0.28
Sorghum, grain	89.5	9.4	----	----

[a]Chemical analysis performed at Animal Husbandry Nutrition Laboratory, Michigan State University, East Lansing, Michigan. DM = dry matter; CP = crude protein; Ca = calcium; P = phosphorus.

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for one to two weeks, as was observed by a change in color of the meal from light to dark, and a change in the odor and flavor.

Wheat millrun was a by-product from wheat milled to produce flour at Belize Flour Limited, in Belize City, Belize. Wheat (*Triticum aestivum* L.) was imported from Texas and neighboring areas in the United States. The grain contained impurities of corn, soybeans, broken wheat grains, and other miscellaneous seeds. These impurities were removed in the first milling process and were sold as a broken grains by-product on an irregular basis. This was not normally fed in routine livestock feeding programs, because it was not a constantly available product and also because the composition varied as the impurities varied. Approximately 682 kg of the broken grains feedstuff was produced per week and was sold for US $8.80/100 kg. In the next process, the whole wheat grains were screened and cleaned prior to polishing, which produced the by-product termed screenings. About 909 kg/day of screenings were produced which sold for US $6.60/100 kg. Finally, the wheat was polished to remove the outer bran coat. The next polishing produced the shorts, and a final polishing produced the middlings (which contained some flour). The polishings could be separated from the bran, but this was not done because of the low market for the bran alone. The wheat millrun mixed feed (which was sold in Belize as "wheat bran") consisted of approximately 50% bran, 30% shorts and 20% middlings (see Table 5 for analysis). Forty-five metric tons per week of the mixed feedstuff were sold commercially at US $13.00/100 kg.

Majors (1950) stated that wheat yielded 28% of the crop as by-products, which were useful as animal feeds. In the feeding trials at Central Farm, poultry diets containing a high level of wheat millrun (30%) were wasted as the birds billed out the finer particles, while the larger bran flakes dropped to the floor. Wind currents in the open-air pens also contributed to waste of the larg

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the larger flakes as it belw them out of the feeders. Pigs, however, did not appear to waste the rations containing high levels of wheat millrun.

Citrus pellets were a by-product of the Salada Company, Pomona Valley, Stan Creek District, Belize, which processed grapefruit (*Citrus paradisi* Macf.) and oranges (*Citrus sinensis* Pers.) for the production of juices. The pulp and rinds (minus the seeds) were pelletized into large pellets, which were exported to the US (Florida) as feed for beef feedlot operations. The pellets could be purchased locally, but commanded a price of US $16.50/100 kg, which was not an economical value compared to the other more nutritional feedstuffs available to the Belizean livestock producer. (The pellets, after being ground in a hammermill, were included as an ingredient in a layer bird and a rabbit feeding trial, which are not discussed in this thesis.) The flavor of the pellets was sweet, but bitter.

Molasses, a by-product of Belize Sugar Industry, Ltd., in Corozal, Belize, was used at low levels in the diets (4 to 5%) as this was a recommended level that mixed readily in the mashes without causing too much of a laxative effect (Scott, 1976; Bird, 1975). It was used to improve the texture of the bulky, highly fibrous mashes and as a cheap source of energy. The B-grade refinery sugarcane molasses was available in large amounts and sold for US $110/metric ton. Special transport, such as a tank truck, was needed to obtain this product, which made it difficult for some farmers to obtain molasses.

Brewers' spent grains, obtained in a fresh, moist form, were sun and forced-air dried to 10 to 12% moisture (from an initial 80%). This by-product, from Beliken Beer Brewery, Belize City, Belize, was available at no cost after each brewing, which was on the average of three times per week. Farmers were encourage

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encouraged to remove the spent grains by the truckload. This feedstuff contained much fiber, due to the hulls on the grains, but it was palatable and useful as a protein and energy source.

Cohune nut meal, a by-product from the cohune oil industry, was produced by Belize International, Limited, Belize City, Belize, and also from local village processing of cohune nuts. The two processing methods resulted in an end product which varied considerably in nutritional composition and physical form. The oil was valuable for cooking and other manufactured products and commanded a good price in the international market. The cohune nuts grew in large clusters on palm trees (*Orbignya cohune* [Mart] Dahlgren) in Belize. These were harvested by hand and shelled at the location of harvesting. The nuts contained solid, highly fibrous oil-saturated kernels enclosed in an extremely hard outer shell. The commercially-processed kernels were ground through a 0.3 cm hammermill screen and were steam-cooked at a temperature of 100°C for 20 to 35 minutes. The oil was pressed out, leaving the by-product meal, which still contained a high percentage of oil and protein (see analysis, Appendix II).

Cohune oil extraction methods in the village were somewhat different. Kernels were ground in a small-sized hammermill and boiled in a large drum filled with water. Oil was skimmed off the top after approximately four hours of boiling and then the watery meal was transferred to a drum that had holes in it. Excess water escaped through the holes, leaving a high-moisture by-product, which was termed cohune trash, which still contained approximately 54% of ether extract (see analysis, Appendix II). Comparison of the ether extract values of cohune trash with values obtained from the whole kernels showed that the village processing method did not remove the major portion of

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the oil. (The low ether extract value obtained from the Central Farm analysis of the cohune nut kernels was apparently due to difficulties in extracting the large amounts of oil from the kernels.) The cohune trash was scooped out and fed fresh to chickens or pigs.

In one trial (Broiler Trial 8), whole cohune nut kernels were ground daily in a hand-grinding mill and were fed free-choice with a concentrate mixture. Cohune nut meal became rancid within a few days, turning brown and acquiring a soap-like flavor. This rancid meal, when fed alone, was not eaten by pigs, but it was readily consumed by broilers.

Local leaf meals were produced from legume crops that were planted for use as feedstuffs. The most promising forage crops, with regards to production rates of foliage and ease of harvesting and drying, were *Cajanus cajan*, *Leucaena leucocephala* and *Desmodium leonii*. These crops were planted at Central Farm and were harvested after six months to one year of growth. The hand-harvested leaves were forced-air dried at ambient temperature to approximately a 10% moisture level and were ground and stored in burlap bags for use in feed trials. The leaf meals were used mainly for rabbit feed trials, but low levels were used in some broiler diets as a source of protein, vitamins and minerals.

Cassava (*Manihot esculenta*) (sweet Bluebird variety) and sweet potato (*Ipomoea batatas*) tubers, obtained fresh on a daily basis, were fed free-choice to broilers (Broiler Trial 3) after the birds were two weeks of age. The cassava was washed, peeled and ground before feeding. The supply was too limited at the time of the trial to allow continuous feeding. During the root crop harvesting season, these crops commanded high market prices for use in human consumption. However, the feeding trials were valuable because information was needed on the feeding value of surplus or unmarketable root crops.

Bone ash was prepared from bones obtained from Norland Farm, a local slaughtering facility in San Miguel, Cayo District, Belize. The bones were burned on a heavy metal sheet over a wood fire until they were completely charred. The charred bones were then hand-ground into a powder and stored for use. This provided an inexpensive, locally produced phosphorus supplement that could replace imported defluorinated rock phosphate or other phosphate compounds. Limestone, obtained from local cliff deposits along Chicabul Road in Georgeville, Cayo District, Belize, was ground and used as a calcium supplement. This provided an inexpensive, local source of the mineral to replace imported oyster shell.

Imported feed ingredients used in feed trials included soybean meal (44%),[21] flash ring-dried blood meal,[22] alfalfa meal (17%),[23] deflourinated rock phosphate,[24] vitamin and trace mineral premixes,[25] 98% L-lysine monohydrochloride,[26] 98% DL-methionine,[27] and coccidiostat. One shipment of SMB was dehulled (49%). One shipment of blood meal that was received was labeled

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[21]44% crude protein, solvent extracted. Shipments obtained from: Buckeye Cellulose Corporation, Cincinnati, Ohio; Carnation Co., Los Angeles, California; and Michigan Farm Bureau Services, Inc., Lansing, Michigan.

[22]Purchased from H. J. Baker and Bro., Inc., New York, New York.

[23]Purchased from Blanton Alfalfa Mills, Inc., Hughes, Arkansas.

[24]Produced by International Mineral and Chemical Corp., Mundelein, Illinois.

[25]Prepared by Henwood Feed Additives, Lewisburg, Ohio.

[26]Provided 78% L-lysine. The first batch, used in Broiler Trial 5, was obtained from Dow Chemical Co., Midland, Michigan. The second batch, used in all following trials, was donated by Fermentaciones Mexicanas, SA de CV, Homero 418, Mexico 5 D.F., Mexico City, Mexico.

[27]Obtained from Dow Chemical Co., Midland, Michigan.

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Animal Protein Supplement[28] and the diets that contained blood meal were reformulated to include this new ingredient. Alfalfa meal was included in broiler diets in Trials 1 and 3 to determine the effect of this forage meal in poultry rations. The vitamin and trace mineral premixes were developed to meet the requirements for swine and poultry, so that only one premix source would be needed for all species studied. Premixes were stored separately in air-tight containers for not longer than 90 days (as was recommended by the manufacturer). The premixes in the first shipment were added to diets in the same concentration in which they were received. Future shipments contained five times the required levels of nutrients and were diluted with rice bran and polishings or fine wheat middlings prior to use in diets. Copper, included in the original formulation, was erroneously omitted from the premix. Therefore, the diets did not contain supplemental copper.

Commercial feed preparations[29] were used as control diets to compare the gains and cost per unit of gain of animals fed the test diets.

Vitamin and Trace Mineral Supplemental Premixes

Concentrated vitamin and trace mineral premixes and amino acids were imported to use for supplementation of test diets (Tables 6 and 7).

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[28]Propak Fish and Animal Protein Concentrate, H. J. Baker and Bro., Inc., New York, New York. Contained the following ingredients: fish meals (Anchovy, Herring, Tuna, Menhaden), condensed fish solubles, poultry by-products, fish and animal fat, meat-and-bone meal, low fluorine rock phosphate, DL-methionine, L-lysine, stabilized with ethoxyquin. Package analysis of composition: crude protein, 60% or more; crude fat, 6% or more; crude fiber, 2% or less, calcium, 5-6%; phosphorus, 3% or more; ash, 20% or less.

[29]Purchased from Reimer's or Kornelson's Feed Mills, Spanish Lookout, Cayo. These mills imported the feed from Ralston Purina Co., St. Louis, Missouri, or from Aliansa Feeds, Guatemala City, Guatemala.

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TABLE 6.--Belize Vitamin Premix.[a]

Ingredient	Original Mixture	Concentrated 5 Times
Vitamin A (USP units)	727,300	3,636,500
Vitamin D_3 (IC units)	90,910	454,500
Vitamin E (Int. units)	454.5	2,272.5
Vitamin K (MSBC) (milligrams)	577	2,885
d-Pantothenic Acid (milligrams)	1,090.0	5,454.5
Niacin (milligrams)	2,727.3	13,636.5
Riboflavin (milligrams)	363.6	1,818
BHT (pounds)	0.0091	0.0455
Vitamin B_{12} (milligrams)	1.8182	9.091
Choline Chloride (milligrams)	27,273	136,365

[a]Guaranteed analysis per pound of premix. Ingredients: Vitamin A acetate in gelatin, d-activated animal sterol (source of Vitamin D_3), Vitamin E supplement, menadione sodium bisulfite complex (source of Vitamin K activity), d-calcium pantothenate, niacin, riboflavin supplement, BHT (a preservative), Vitamin B_{12} supplement, choline chloride and corn fermentation solubles.

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TABLE 7.--Belize Trace Mineral Premix.[a]

Ingredient	Original Mixture	Concentrated 5 Times
Manganese (minimum %)	1.00	5.00
Zinc (minimum %)	1.40	7.00
Iron (minimum %)	1.00	5.00
Iodine (minimum %)	0.005	0.025
Selenium (milligrams)	9.091	45.455

[a]Guaranteed analysis per pound. Ingredients: manganous oxide, zinc oxide, iron sulfate, ethylene diamine dihydroiodide, sodium selenite and corn fermentation solubles.

This reduced shipping and storage costs compared to the importation of bulkier diluted concentrate mixes, and provided a fresh source of these nutrients for the animal feeds. Importation of these concentrated supplements allowed for the use of indigenous feedstuffs as fillers or extenders rather than importing these fillers as part of a more dilute premix. Vitamin and trace mineral premixes in the first imported shipment were each included at a level of 0.5% of the diet in the same concentrated form in which they were received. This amounted to a total of 1.0% of the diet (not including the salt) or 10 kg per 1,000 kg of feed that was of imported origin. Premixes in the second shipment were 5 times as concentrated as the original formulations. These were diluted in Belize prior to adding them to the test diets. The diluted premixes, each included at a level of 0.5% in the diets, then contributed a total amount of only 0.2% of imported ingredient to the animal feed (2 kg of imported ingredient per 1,000 kg of mixed feed). The total value of these added premixes was US $1.11 per 1,000 kg of mixed feed [($0.68/kg vitamin x 1 kg) + ($0.43/kg trace mineral x 1 kg)]. Consumption of 291 kg feed per grower-finisher pig[30] x $1.11 worth of premix per 1,000 kg cost US $0.32 compared to 73 kg of commercial protein concentrate[31] consumed at US $0.88 per kg for a total of $64.00 (see Table 8). Similarly, broilers consumed, on the average, 406 kg feed per 100 birds marketed (Hubbard, 1977), including a total of US $0.45 worth of premix ($1.11/1,000 kg x 406 kg of feed) compared to US $143.00 worth of imported commercial protein concentrate ($0.88/kg x 162 kg feed[32]) (Table 8). The imported premixes

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[30](2.0 kg/day x 56 days grower) + (3.2 kg/day x 56 days finisher) = 291 kg (Miller *et al.*, 1975).

[31](33% x grower feed calculated in footnote 30) + (20% x finisher feed) = 73 kg.

[32]40% x 406 kg feed = 162 kg.

TABLE 8.--Comparison of Feed Consumption and Meat Production of Pigs and Broiler Birds.

TABLE 8.--Comparison of Feed Consumption and Meat Production of Pigs and Broiler Birds.

Item	Feed Consumed (kg)	Number of Weeks	Total Premix Consumed (kg)	Total Premix (US $)	Total CPC[a] (kg)	Total CPC Cost (US $)	Dressed Meat Produced Per Week (kg)
1 Grower-finisher Pig	291	16	2.91	0.32	73	64.00	4.2[c]
72 Broiler birds	291[b]	8	2.91	0.32	116	102.00	12.2[d]
100 Broiler birds	406[b]	8	4.06	0.45	162	143.00	16.9[e]

[a]CPC = Commercial Protein Concentrate (imported).

[b]406 kg/100 birds/8 week period (Hubbard, 1977).

[c]Pig: 90 kg pig x 75% dress = 67.5 kg meat in a 16-week growth period. 67.5 ÷ 4.2 kg/week.

[d]72 broilers: 291 kg feed ÷ 4 kg feed/bird = 72 birds that would consume this amount of feed. 72 x 1.8 kg wt/bird - 130 kg. 130 kg x 75% dress = 97.5 kg meat. 97.5 ÷ 8 weeks = 12.2 kg meat/week.

[e]100 broilers: 100 x 1.8 kg/bird = 180 kg. 180 kg x 75% dress = 135 kg meat/8 weeks = 16.9 kg/week.

could be formulated to be 10 times or more as concentrated as the original mixture, which would result in only 1% or less of imported premix being added to local feeds (1 kg per 1,000 kg). However, the Feeds Project did not focus on this aspect at the present time.

Table 8 also shows that for the same amount of feed consumed in half the time period, broiler birds produced a greater amount of dressed meat. This may make the broiler bird appear to be a more economical unit of production, but the fact must be considered that the broiler industry depended on imported eggs, while the swine industry was self-supporting.

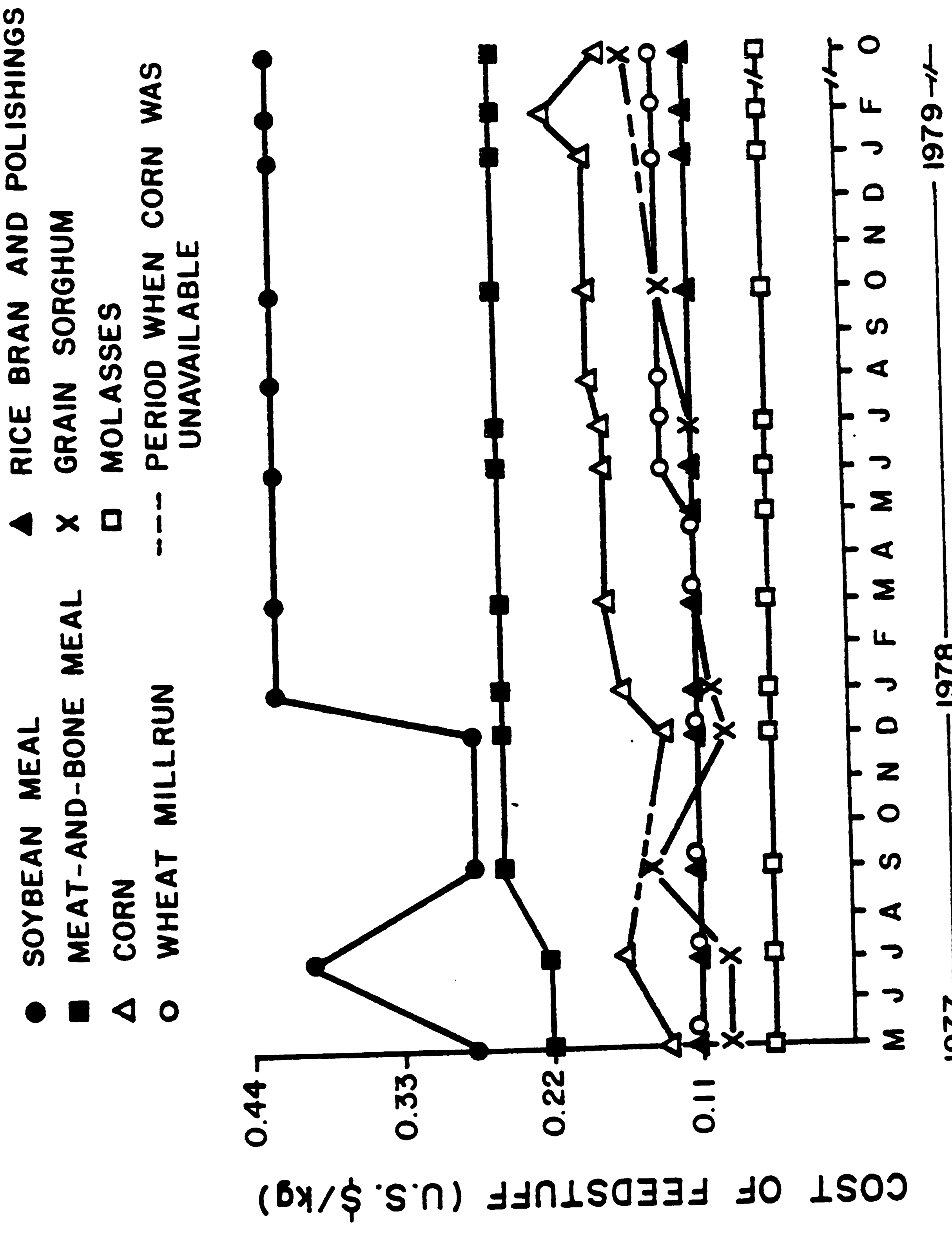
Price Fluctuations of Feedstuffs

Corn and grain sorghum prices in Belize fluctuated greatly throughout the year. However, most of the by-products (MBM, rice bran and polishings, wheat millrun and molasses) had a narrow range of price variation (Figure 14). This was a result of the limited storage facilities in Belize for corn or grain sorghum. The limited grain storage space was used with a priority for corn storage, which discouraged farmers from growing grain sorghum. The limited corn storage capacity forced the government to export corn that would be needed in the future. As corn became scarce, the small amount of grain sorghum that was grown was in great demand, causing the price of this grain to increase.

Feedstuffs that had a narrow price fluctuation were those for which storage space was not a problem, becuase of the smaller volumes of these materials produced at any one time. The private industries that produced the wheat millrun and the rice bran and polishings had sufficient storage facilities for the wheat or rice grains for a constant output of flour or rice, respectively, and the by-products were sold continuously as they were

Figure 14.--Variation in Costs of Feedstuffs in Belize.

● SOYBEAN MEAL
■ MEAT-AND-BONE MEAL
▲ RICE BRAN AND POLISHINGS
× GRAIN SORGHUM


SOYBEAN MEAL
MEAT-AND-BONE MEAL
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RICE BRAN AND POLISHINGS
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Figure 14 shows that, over the three-year period, the price of corn had a large fluctuation, depending on its availability. Grain sorghum prices paralled those of corn and were generally lower. The price of sorghum rose rapidly when corn was not available. Rice bran and polishings and wheat millrun did not vary in price, over the three-year period, except for a slight increase in the price of wheat millrun. The price of meat-and-bone meal was constant, with only a slight rise, whereas, imported soybean meal prices had considerable variation, depending on the market prices in the United States. Molasses remained at a constant, low price.

Cost of Imported Feedstuffs

The cost per unit of nutrient had a basic effect on the economics of production. The most important parameters were the cost per unit of protein and the cost per unit of limiting essential amino acid. For example, the level of lysine was a limiting nutrient in the swine diets tested. Synthetic L-lysine monohydrochloride cost US $4.71 per kg and contained 78% L-lysine per kg, which amounted to US $6.03 per kg actual L-lysine.[33] Soybean meal, on the other hand, cost US $0.40 per kg and contained 2.8% lysine per kg, which amounted to US $14.28 per kg of actual lysine.[34] When the reduction in transportation cost and storage space required per unit of lysine were considered, and also the more uniform quality of the lysine, the advantages of the crystalline amino acid became readily apparent.

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[33] $4.71 per 0.78 kg lysine = $6.02 per kg.

[34] $0.40 per 0.028 kg lysine = $14.28 per kg.

Diet Formulation

Swine

Diets for Swine Trial 1 were formulated to meet the minimum dietary requirements for essential amino acids (especially lysine), phosphorus and calcium. Diets were formulated to compare the performance of pigs fed the local MBM in place of SBM as the protein supplement.

Diets used in Swine Trial 2 treatments were formulated with wheat millrun and rice bran and polishings with a synthetic lysine source to improve the amino acid balance. Diets were formulated to meet the minimum dietary requirements for tryptophan and lysine, which are the first and second limiting amino acids, respectively, for a growing-finishing pig fed a diet based on MBM as the protein supplement.

Swine Trial 3 included blood meal as an alternative to SBM, and synthetic lysine as a supplementary source of lysine to the MBM.

Broiler

Broiler Trial 1 was designed to compare a wide range of combinations of the feedstuffs available. In addition, the stepwise replacement of MBM for SBM was compared.

Broiler Trial 2 was designed to compare low versus high levels of MBM with low or high levels of SBM to determine whether lower mineral levels, as a result of the decreased MBM levels, would compensate for the sub-optimal protein levels. This was of interest because it was felt that the high mineral contents of the MBM may be detrimental to animal performance. Subsequent trials were designed to compare low levels of MBM with different combinations of by-product feedstuffs and synthetic amino acid supplementation.

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All diets were formulated on a least-cost basis to meet the dietary requirements of the swine or poultry.

Laboratory Analytical Methods of Feedstuffs and Diets

Proximate fractions were determined for feedstuffs and mixed diets according to AOAC (1975) methods. Calcium and phosphorus analysis involved atomic absorption or spectrophotometric methods, respectively, according to the procedures of the MSU feeds analysis laboratory (Schoepke and Covert, 1975). Representative portions of mixed feed samples were taken randomly from bags of feedstuffs from each shipment and from the mixed diets. Feed samples were also obtained from the animal feeders. Fresh feeds (cassava, sweet potato and cohune nut kernels) were sampled as they were prepared for feeding and the samples were stored at -5°C for the duration of the feed trial. The individual samples for each ingredient were combined before the analysis was performed. An analysis of feedstuffs is presented in Appendix II.

Statistical Analysis of Feeding Trials

The nutritional composition of feedstuffs was determined by laboratory analysis. Nutritional value was determined by the growth performance and feed conversion efficiencies of the swine and poultry. Feed cost per unit of gain was the indicator used to compare the economics of animal performance on local versus imported feeds. Treatment effects were analyzed to compare average daily gain, average daily feed consumption, feed conversion efficiency and cost per unit of gain. The swine trials, with equal numbers of animals per pen, were analyzed by two-way analysis of variance (ANOVA), with the two factors being diet and weight blocks. A FORTRAN program with

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an SPSS package was used in the Cyber 750 Computer at MSU for analysis of the data (see Appendix V). Significance of treatment means was determined using Tukey's HSD (Honestly Significant Difference) test for all pair-wise comparisons of means (Gill, 1978). Broiler studies were analyzed by Least Squares methods (Gill, 1978) to determine the effects of treatment, sex and location (east versus west). (The location effect was isolated because of interest in the east-west location differences in feed consumption rates and final weights.)

Broiler trials were analyzed on an unequal numbers basis. Significances among treatment means and sex or location were determined using Bonferroni's t-test (Gill, 1978) for specified non-orthogonal contrasts and Tukey's HSD test for all pair-wise comparisons of means. Death losses which occurred during the trials were handled as missing values. Feed consumption was determined for the number of bird-days that had accumulated until the nearest two-week weigh period.

Procedures Used in Feeding Trials

Swine and poultry were weighed every two weeks and the feed weigh-back was recorded at that time. Animals were allowed access to feed and water at all times. During weigh periods, fecal samples were collected and later checked for parasites. Pigs were wormed on a monthly basis,[35] while broilers were wormed at one month of age, if the fecal samples indicated heavy worm burdens. A coccidiostat[36] was added to broiler starter diets

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[35]Pigs were wormed with Atgard pig wormer pellets mixed into the feed.

[36]The coccidiostat used was Amprolium, produced by Merck and Co., Inc., Rahway, New Jersey, or Coban (monensin sodium, equivalent to 242 grams monensic acid activity/kg Coban), prepared by ELANCO Products Co., Indianapolis, Indiana.

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(the first 6 weeks), but was removed during the finisher period. (No coccidiostat was used in the first broiler trial.) No antibiotics or other feed additives were used in the swine or poultry diets.

Swine Trials

Swine grower and finisher studies were conducted with F_1 or F_2 offspring of purebred Duroc, Large White, Hampshire and Spotted Poland China parental stock that were imported from the United States. The breeds were crossed to produce F_1 offspring for Swine Trials 1 and 2, which were crossed to a third breed to produce the F_2 offspring for Swine Trial 3. Purebred offspring were used when the numbers of crossbreds were not sufficient for balanced replicates.

Pigs at Central Farm were weaned at 8 weeks of age, since a 6-week weaning age was not suited for the management levels in Belize. Piglets showed improved gains when left with the sow for the additional two weeks, because good quality creep and starter feeds were not available or were imported and, therefore, not economical to use.

The breeding schedule of sows was planned to have farrowings occur within a two-week period to provide a sufficient number of pigs for each study. In some cases, this two-week limit was exceeded by a few days. Male piglets were castrated at two weeks of age.

Each pig was weighed after it was weaned and separate lists were made of barrows and gilts, according to increasing weight, from the lightest to the heaviest pig. This list was divided at the median to provide a light and heavy group of pigs. The pigs in each group (light and heavy barrows and light and heavy gilts), were alloted in a stratified randomization experimental design to form an equal number of light and heavy replicates with an ecual ra

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equal ratio of barrows to gilts in each group. All groups of pigs were fed a commercially prepared feed[37] during an adjustment period of 7 to 10 days. Pigs were put on feeding trials at 10 weeks of age. Pigs were weighed bi-monthly from 8 a.m. to 12 noon using a mobile hog scale.[38] They had access to feed and water up to the time of weighing. Animals from the first two trials were slaughtered at the meat packing plant in Belize City and carcass information was obtained. Pigs from Swine Trial 3 had to be slaughtered at a local market over a five-week period due to difficulties at the meat packing plant; therefore, carcass information was not obtained on this group.

Broiler Trials

Chicks for the trials were obtained on the day of hatching from the Friesen Hatchery at Spanish Lookout in Cayo District.[39] Broilers were a result of the Hubbard Breeder Pullet mated with the Hubbard White Mountain Breeder Cockerel, producing the autosexing Hubbard Broiler. This bird was an all-white broiler, which was claimed to be an efficient converter of feed to high quality broiler meat (Hubbard Farms, 1978). Average performance data for these birds, as determined by Hubbard Farms (1978) are presented in Table 9. The birds were debeaked by the hatchery and were delivered to Central Farm in cardboard chick cartons with approximately 100 chicks per carton. The cartons with chicks were weighed upon receiving them, chicks

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[37] Prepared by Reimer's Feed Mill in Spanish Lookout, Cayo. The feed consisted of imported Ralston Purina 40% Concentrate mixed with locally-grown grains.

[38] The scale had a 0.45 kg sensitivity. Purchased from Wadler Mfg. Co., Galena, Kansas.

[39] This hatchery imported eggs from CWT Farms, International, Gainesville, Georgia.

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TABLE 9.--Hubbard Broiler Performance Standards.[a]

Age (Weeks)	Average Weight (Grams)	Feed Conversion Efficiency (Cumulative) (Feed/Gain)
6	1355	1.73
8	2010	2.14

[a]Averages of straight-run (males and females mixed). Hubbard, 1977.

were counted and randomly allocated to pens, and the empty cartons were re-weighed. The difference in weight between the empty carton and carton with chicks, divided by the total number of chicks per carton, gave the average initial weight per chick for each trial. (Broilers were a mixture of cockerels and pullets. No attempt was made to sex them until the six or eight-week weigh period, at which time a note was made next to the bird's weight whether it was a male or female.)

One hundred chicks were brooded in each of ten west-side pens. Brooders consisted of a 46 cm high metal circular enclosure and a metal hanging square hover, which contained a 40-watt light bulb. Plastic water founts were used to provide drinking water, and feed was placed on cardboard egg trays for the first few days, after which time small feed troughs were used. Chicks were vaccinated at 2 days of age against fowl pox (except for the chicks in Trials 1 and 2). Brooders were removed by 7 to 10 days of age, depending on the weather conditions. At 2 weeks of age, the birds were weighed in groups of 25, and an overall average weight per bird was calculated. Each pen of 100 birds was divided into two replicates, with half of the birds

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the birds remaining in the original pen on the west side and half randomly assigned to an east-side pen. Birds were wing-banded at 2 weeks of age and individual weights were obtained for each bird at four, six and eight weeks of age. Weighing took place from 6:00 a.m. to 12:00 noon. Starter diets were fed for the first 6 weeks and finisher diets for the last 2 weeks (except for certain trials, which compared the effects of changing from starter to finisher at an earlier time).

Birds had access to feed until the time they were weighed. They were marketed on the morning following the eight-week weigh period and carcass dressed weights were obtained during that morning on a random sample.[40] Dressed weight included the carcass plus feet, liver, heart and gizzard.

Layer Trials

Harco sex-link, layer birds, produced by Arbor Acres Farm, Inc., in Glastonbury, Connecticut, were used in layer studies. The birds were brown feathered and produced brown eggs, and were developed to produce a large number of commercial eggs efficiently through consistent high rate of lay, efficient feed conversion, strong livability, premium egg size and outstanding shell quality (Arbor Acres, 1978). These were the desired characteristics of an economical laying-type hen.

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[40] Dressed weights were obtained at the Millers' slaughtering facility in Red Creek, Cayo. A Single Dial Autopsy Scale SS was used (10 gm sensitivity). Scientific Products, Romulus, Michigan. Samples of 10-20 birds per group were determined to be sufficient.

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III. DESCRIPTION OF SWINE AND POULTRY FEEDING TRIALS

Swine Trials--Review of Literature

Meat-and-bone meal is a protein supplement of variable nutritional value due to the variation in composition (Sathe *et al.*, 1964; Beames and Sewell, 1969; Meade, 1975) and/or methods of processing (Atkinson and Carpenter, 1970; Conrad, 1974; Gohl, 1975). Gohl (1975) defined MBM as having greater than 4.4% phosphorus and a crude protein content less than 55%. Reduced growth and feed efficiencies of swine have been demonstrated when MBM was used as the only supplemental protein source in corn or grain sorghum-based diets (Peo and Hudman, 1962; Atkinson and Carpenter, 1970; Lynch *et al.*, 1970). Decreased performance of the animals was attributed to the poor protein quality of the meal (Todd and Daniels, 1965; Wilson and Holder, 1967), which was particularly limiting in tryptophan (Bloss *et al.*, 1953; Henson *et al.*, 1954). Tanksley and Baker (1977) attributed the reduced palatability of MBM-supplemented diets to the high mineral level of the MBM, which they concluded caused a decrease in feed consumption and body weight gains. They also mentioned that MBM was limiting in both tryptophan and lysine. Babatunde *et al.* (1975) observed depressed body weight gains, feed consumption and feed conversion efficiencies of growing-finishing pigs fed indigenous sources of MBM in the tropics.

Eckert and Allee (1974) and Cohen and Tanksley (1976) determined that lysine and threonine were the first and second limiting amino acids, respectively, in the protein of grain sorghum for the growing pig, while isoleucine

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isoleucine was possibley third limiting. Copelin *et al.* (1978) determined lysine, threonine and tryptophan to be the first three limiting amino acids in a grain sorghum-SBM diet.

Wheat millrun and rice bran and polishings are available in large quantities in Belize at a cost equal to or less than corn or grain sorghum. Compared to these grains, the analysis of wheat millrun and rice bran and polishings showed higher levels of tryptophan and lysine (NRC, 1973; Miller *et al.*, 1975). These by-products have produced favorable body weight gains and feed conversion efficiencies in swine (Thrasher *et al.*, 1965; Brooks and Lumanta, 1975; Campabadel *et al.*, 1976; Erickson *et al.*, 1977). Campabadel *et al.* (1976) observed an inflammation and ulceration of the gastrointestinal tract and loose faeces in growing pigs fed a 30% rice bran level in the diet, but growth of the pigs was not affected.

Blood meal was found to be an important source of essential amino acids, particularly lysine (Squibb and Braham, 1976; Wahlstrom and Libal, 1977), when prepared by new methods of drying blood at a lower temperature (Doty, 1973). Blood meal could be used to extend the limited supply of MBM and provide an alternative source of protein to replace imported protein sources such as SBM. Flash ring dried blood meal used in swine studies had a lysine availability of 70% for the growing pig (Miller *et al.*, 1976a) and a conservative value of 7.0% was suggested for the lysine content of this product (Miller *et al.*, 1976b). Wahlstrom and Libal (1977) recommended that not more than 2 to 3% of dried blood meal should be used in swine grower-finisher diets. Blood meal combined with synthetic lysine and rice bran and polishings or wheat millrun may serve to reduce the deficiencies of tryptophan and lysine that occur when MBM is used as the main protein supplement in corn-based diets.

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Swine Trial 1

The objectives of Swine Trial 1 were to evaluate the nutritional value of local MBM as a protein supplement in swine grower-finisher diets and to determine the maximum level that could be substituted for SBM in fortified corn and/or grain sorghum-based diets in order to decrease the cost per unit of gain. To one diet, which contained 100% MBM as the protein source, zinc sulfate was added to prevent a possible zinc deficiency due to high mineral levels present in the MBM. Analytical values used for the calculation of diets are given in Table 10.

Sixty purebred or single-cross pigs of Duroc, Large White or Hampshire breed, averaging 12.1 kg, were randomly assigned to 12 lots of 5 pigs each.

The control diet consisted of yellow dent corn and imported soybean meal in proportions which provided a calculated level of 16% or 12% crude protein in the grower and finisher diets, respectively (Tables 11 and 12). Other nutrient concentrations met NRC (1973) requirements for 15 kg or 65 kg pigs for the grower or finisher diets, respectively. MBM was incorporated into this diet, replacing SBM in 50% increments, to make diets in which the protein source was 0, 50, or 100% MBM (Tables 11 and 12). Also, grain sorghum was incorporated into the control diet, replacing corn in 50% increments, to make diets in which the energy source was 0, 50, or 100% grain sorghum at the 50% MBM level. The 16-week trial was conducted from July 13 to November 2, 1977.[41]

[41]Subtropical, humid climate. Mean daily maximum temperature = 31.4°C; mean daily minimum temperature = 21.6°C; mean daily relative humidity = 83.2%; average maximum and 74.6% average minimum for the period of this study (July through November) (Jenkin *et al.*, 1976).

TABLE 10.--Swine Trial 1: Nutritional Values and Costs of Ingredients Used in Formulation of Diets.

Ingredient	DE Kcal/kg[a]	DM[b]	CP[b]	Ca[b]	P[b]	Lys[a]	Met +Cys[a]	Trp[a]	Cost/kg[c] (US $)
		---% (As Fed Basis)---							
Corn, yellow[d]	3593	88.7	8.6	0.02	0.28	0.25	0.35	0.07	0.15
Sorghum, grain[d]	3417	89.5	10.0	0.02	0.30	0.20	0.25	0.09	0.11
Soybean meal, solvent	3307	89.6	45.0	0.25	0.60	2.80	1.30	0.63	0.40
Meat-and-bone meal[d]	2056[e]	93.3	39.2	11.18	5.45	2.04[g]	0.70[g]	0.20[g]	0.22
Bone meal[d]	2699[f]	95.5	31.7	14.02	6.91	1.65[h]	0.57[h]	0.16[h]	0.22
Limestone[d]	----	----	-----	32.00	-----	----	----	----	0.11
Defluorinated phosphate	----	----	-----	32.00	18.00	----	----	----	0.28
Commercial supplement	----	----	-----	-----	----	----	----	----	0.44
Salt	----	----	-----	-----	----	----	----	----	0.13
Vitamin premix	----	----	-----	-----	----	----	----	----	0.68
Trace mineral premix	----	----	-----	-----	----	----	----	----	0.43

[a]Values obtained from Miller *et al.*, 1975. DE = Digestible Energy; Lys = lysine; Met = methionine; Cys = cysteine; Trp = tryptophan.

[b]Chemical analysis. DM = Dry Matter; CP = Crude Protein; Ca = Calcium; P = Phosphorus.

[c]Exchange ratio of Belize $ to US $ = 2:1. Free on board prices are given for all of the imported ingredients.

[d]Local feedstuffs grown or produced in Belize.

[e]Value estimated by the following calculation: (5.65 kcal/g protein x 60% digestibility x 39.2% protein) + (9.4 kcal/kg fat x 90% digestibility x 8.6% ether extract) = 2.056 kcal/g.

[f]Value estimated by the following calculation: (5.65 kcal/g protein x 60% digestibility x 31.7% protein) + (9.4 kcal/g fat x 90% digestibility x 19.2% ether extract) = 2.699 kcal/g.

TABLE 10.--(Continued)

TABLE 10.--(Continued)

[g]Values are expressed as percent of the protein content, according to the following calculation: (% protein in chemical analysis) ÷ (% protein listed in NRC (1979) reference) x (% amino acid listed in NRC (1979) reference). For example, lysine: (39.2% ÷ 50.0%) x (2.60%) = 2.04% lysine as the estimated value for the MBM used in this study.

[h]Calculated as described in footnote "g".

TABLE 11.--Swine Trial 1: Composition of Grower Diets.

TABLE 11.--Swine Trial 1: Composition of Grower Diets.

Ingredient	International Feed Number	Diet Number 11	12	13	14	15	16
		Percent MBM of Total Protein Supplement					
			0	50	50	50	100
Corn, yellow	4-02-935	76.4	74.1	76.0	38.0	-------	73.9
Sorghum, grain	4-04-444	-----	-------	-------	38.0	76.0	-------
Commercial supplement[a]		23.6	-------	-------	-------	-------	-------
Soybean meal, solvent	5-04-604	-----	21.4	11.3	11.3	11.3	-------
Meat-and-bone meal	5-09-322	-----	-------	11.2	11.2	11.2	24.6
Bone meal		-----	2.3	-------	-------	-------	-------
Limestone, min. 32% Ca		-----	0.7	-------	-------	-------	-------
Salt		-----	0.5	0.5	0.5	0.5	0.5
Vitamin premix[b]		-----	0.5	0.5	0.5	0.5	0.5
Trace mineral premix[c]		-----	0.5	0.5	0.5	0.5	0.5
$ZnSO_4$		-----	-------	-------	-------	-------	0.025
Calculated analysis:[d]							
DE, Kcal/kg		-----[f]	3417	3334	3267	3201	3161
CP, %		16.0	16.7	16.0	16.5	17.1	16.0
Lys, %		-----[f]	0.82	0.74	0.72	0.70	0.68
Met & Cys, %		-----[f]	0.55	0.49	0.46	0.42	0.43
Trp, %		-----[f]	0.19	0.14	0.15	0.16	0.10
Ca, %		0.89	0.65	1.30	1.30	1.30	2.76
P, %		0.62	0.50	0.89	0.89	0.89	1.55
Cost, US $/100 kg[e]		22.46	20.88	19.00	16.72	15.96	17.48

[a]Ralston Purina Farmblend Hog Chow.

TABLE 11.--(Continued)

...kilogram of diet: Vitamin A, 8000 IU; Vitamin D_3, 1000

TABLE 11.--(Continued)

[b]Supplying the following vitamins per kilogram of diet: Vitamin A, 8000 IU; Vitamin D_3, 1000 ICU; Vitamin E, 5 IU; menadione sodium bisulfite, 6 mg; riboflavin, 4 mg; niacin, 30 mg; d-pantothenic acid, 12 mg; choline choloride, 301 mg; Vitamin B12, 20 micrograms, BHT, 100 grams.

[c]Supplying the following trace elements per kilogram of diet: zinc, 70 mg; manganese, 50 mg; iodine, 0.25 mg; iron, 50 mg; selenium, 0.10 mg.

[d]DE = Digestible Energy, CP = Crude Protein, Lys = Lysine, Met = Methionine, Cys = Cysteine, Trp = Tryptophan, Ca = Calcium, P = Phosphorus.

[e]Determined on the basis of ingredient costs in Table 10 (no overhead added to cost).

[f]No analysis available.

TABLE II.--(Continued)

TABLE 11.--(Continued)

[b]Supplying the following vitamins per kilogram of diet: Vitamin A, 8000 IU; Vitamin D_3, 1000 ICU; Vitamin E, 5 IU; menadione sodium bisulfite, 6 mg; riboflavin, 4 mg; niacin, 30 mg; d-pantothenic acid, 12 mg; choline choloride, 301 mg; Vitamin B12, 20 micrograms, BHT, 100 grams.

[c]Supplying the following trace elements per kilogram of diet: zinc, 70 mg; manganese, 50 mg; iodine, 0.25 mg; iron, 50 mg; selenium, 0.10 mg.

[d]DE = Digestible Energy, CP = Crude Protein, Lys = Lysine, Met = Methionine, Cys = Cysteine, Trp = Tryptophan, Ca = Calcium, P = Phosphorus.

[e]Determined on the basis of ingredient costs in Table 10 (no overhead added to cost).

[f]No analysis available.

TABLE 12.--Swine Trial 1: Composition of Finisher Diets.

Ingredient	International Feed Number	Diet Number 11	12	13	14	15	16
		Percent MBM of Total Protein Supplement					
			0	50	50	50	100
Corn, yellow	4-02-935	89.2	86.5	87.6	43.8	-------	87.0
Sorghum, grain	4-04-444	----	-------	-------	43.8	87.6	-------
Commercial supplement[a]		10.8	-------	-------	-------	-------	-------
Soybean meal, solvent	5-04-604	----	10.5	5.2	5.2	5.2	-------
Meat-and-bone meal	5-09-322	----	-------	5.3	5.3	5.3	11.5
Limestone, min 32% Ca	6-01-069	----	0.7	0.4	0.4	0.4	-------
Defluorinated phosphate	6-01-780	----	0.8	-------	-------	-------	-------
Salt		----	0.5	0.5	0.5	0.5	0.5
Vitamin premix[b]		----	0.5	0.5	0.5	0.5	0.5
Trace mineral premix[c]		----	0.5	0.5	0.5	0.5	0.5
Calculated analysis:[d]							
DE, Kcal/kg		----[f]	3455	3428	3351	3274	3371
CP, %		12.0	12.2	12.0	12.5	13.0	12.0
Lys, %		----[f]	0.51	0.47	0.45	0.43	0.46
Met & Cys, %		----[f]	0.44	0.41	0.37	0.32	0.39
Trp, %		----[f]	0.13	0.11	0.12	0.12	0.08
Ca, %		0.42	0.55	0.77	0.77	0.77	1.29
P, %		0.43	0.45	0.57	0.57	0.57	0.87
Cost, US $/100 kg[e]		18.13	18.10	17.05	15.30	13.52	16.20

[a]See footnote "a", Table 11, for source of commercial supplement.

[b]See footnote "b", Table 11, for premix formula.

TABLE 12.--(Continued)

TABLE 12.--(Continued)

[c]See footnote "c", Table 11, for premix formula.

[d]See footnote "d", Table 11, for explanation of abbreviations.

[e]See footnote "e", Table 11, for calculation of cost.

[f]No analysis available.

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Swine Trial 2

In this trial, wheat millrun and rice bran and polishings were substituted for corn or grain sorghum in grower and finisher diets containing synthetic lysine and supplemented with MBM. Limestone was included in two of the finisher diets to increase calcium levels. Analytical values used for the calculation of diets are given in Table 13.

Forty pigs of Duroc, Large White or Hampshire single crosses, averaging 23.1 kg, were randomly assigned to ten groups of four pigs each. The control diet for the grower period (Diet 21) consisted of yellow dent corn supplemented with SBM and MBM protein sources to provide a calculated crude protein level of 16.8% (Table 14). The control diet for the finisher period contained grain sorghum as a replacement for corn and provided a calculated crude protein level of 15.0% (Table 15). Other nutrient concentrations met NRC (1973) requirements of 25 or 65 kg pigs for the grower or finisher diets, respectively. Wheat millrun and rice bran and polishings were incorporated into the test diets. The diets were formulated on a least-cost basis and calculated to meet the grower or finisher pig requirement for tryptophan, the first limiting amino acid in corn or grain sorghum diets supplemented with MBM (Bloss *et al.*, 1953; Meade, 1975). Synthetic lysine was included in diets to meet the pig's requirement for this amino acid. Effects of fixed levels of 20% wheat millrun or 20% rice bran and polishings (Diets 26 and 27, respectively), fixed levels of MBM (11.5 and 5.3% in grower and finisher diets, respectively), 20% wheat millrun (Diet 23), and no fixed levels of any of the ingredients (Diet 25) were compared. In the control diet (Diet 21), the MBM level was fixed (11.2 and 5.3% in grower and finisher diets, respectively) and no synthetic lysine was allowed. The grower diets were formulated based on corn, but corn was replaced by grain sorghum in the

TABLE 13.-- Swine Trial 2: Nutritional Values and Costs of Ingredients Used in Formulation of Diets.

TABLE 13.-- Swine Trial 2: Nutritional Values and Costs of Ingredients Used in Formulation of Diets.

Ingredient	DE[a] kcal/kg	DM[b]	CP[b]	Ca[b]	P[b]	Lys[a]	Met +Cys[a]	Trp[a]	Cost/kg[c] (US $)
		% (As Fed Basis)							
Corn, yellow[d]	3593	88.7	8.8	0.02	0.26	0.25	0.35	0.07	0.15
Sorghum, grain[d]	3417	89.5	10.0	0.05	0.27	0.20	0.25	0.09	0.11
Rice bran and polishings[d]	3792[f]	88.3	11.6	0.08	0.87	0.57[f]	0.30[f]	0.13[f]	0.11
Wheat millrun[d]	2748[g]	87.6	15.5	0.10	0.98	0.68[g]	0.50[f]	0.26[g]	0.13
Soybean meal	3307	89.6	45.0	0.25	0.60	2.80	1.30	0.63	0.40
Meat-and-bone meal[d]	2205	93.3	45.0	8.00	4.00	2.34[h]	0.81[h]	0.22[h]	0.22
Lysine[e]	----	----	----	----	----	78.00	----	----	4.71
Limestone[d]	----	----	----	38.10	----	----	----	----	0.11
Salt	----	----	----	----	----	----	----	----	0.13
Vitamin premix	----	----	----	----	----	----	----	----	0.68
Trace mineral premix	----	----	----	----	----	----	----	----	0.43

[a]Miller *et al.*, 1975. DE = Digestible energy; Lys = Lysine; Met = Methionine; Cys = Cysteine; Trp = Tryptophan.

[b]Chemical analysis. DM = Dry matter; CP = Crude protein; Ca = Calcium; P = Phosphorus.

[c]Exchange ratio of Belize $ to US $ = 2:1. Free on board prices are given for all the imported ingredients.

[d]Local feedstuffs grown or produced in Belize.

[e]98% L-lysine HCl. Produced and generously donated by Fermentaciones Mexicans, SA de CV, Homero 418, Mexico 5 DF, Mexico City, Mexico.

[f]NRC, 1979.

[g]Millers' National Federation, 1972.

TABLE 13.--(Continued)

[h]Calculated as follows:

$$\frac{(\%\ \text{Protein in Chemical Analysis})}{(\%\ \text{Protein in NRC (1979) Reference})} \times (\text{Value Listed in NRC (1979) Reference for the Amino Acid})$$

For example, lysine:

$$\frac{(45\%)}{(50\%)} \times (2.60\%) = 2.34\% \text{ for Lysine}$$

TABLE 14.--Swine Trial 2: Composition of Grower Diets.

Ingredient	International Feed Number	Diet Number				
		21	23	25	26	27
Corn, yellow	4-02-935	76.0	66.8	83.0	67.2	63.5
Rice bran and polishings[a]	4-03-943	-------	-------	-------	-------	20.0
Wheat millrun[b]	4-05-206	-------	20.0	-------	20.0	-------
Soybean meal, solvent	5-04-604	11.3	-------	5.3	1.2	5.0
Meat-and-bone meal	5-09-322	11.2	11.5	10.0	9.9	9.9
Lysine (98% L-Lysine HCl)		-------	0.2	0.2	0.2	0.1
Salt		0.5	0.5	0.5	0.5	0.5
Vitamin premix[c]		0.5	0.5	0.5	0.5	0.5
Trace mineral premix[d]		0.5	0.5	0.5	0.5	0.5
Calculated analysis:[e]						
DE, kcal/kg		3351	3203	3378	3222	3424
CP, %		16.8	14.2	14.2	14.0	14.6
Lys, %		0.77	0.73	0.74	0.73	0.71
Met + Cys, %		0.50	0.43	0.44	0.43	0.42
Trp, %		0.15	0.13	0.12	0.13	0.13
Ca, %		0.94	0.95	0.83	0.83	0.83
P, %		0.71	0.83	0.65	0.77	0.76
Cost, US $/100 kg[f]		19.00	16.71	18.33	16.90	16.99

[a]Mixture of bran and two polishings in a 2:3:5 ratio, respectively.

[b]Mixture of wheat bran, shorts and middlings in a 5:3:2 ratio, respectively.

[c]See footnote "b", Table 11, for premix formula.

[d]See footnote "c", Table 11, for premix formula.

[e]See footnote "d", Table 11, for explanation of abbreviations.

[f]Determined on the basis of ingredient costs in Table 13 (no overhead added to cost).

TABLE 15.--Swine Trial 2: Composition of Finisher Diets.

Ingredient	International Feed Number	Diet Number				
		21	23	25	26	27
Sorghum, grain	4-04-444	84.5	72.7	75.6	71.23	65.15
Rice bran and polishings[a]	4-03-943	-------	-------	-------	-------	20.0
Wheat millrun[b]	4-05-206	-------	20.0	12.8	20.0	3.3
Soybean meal, solvent	5-04-604	8.7	-------	-------	-------	-------
Meat-and-bone meal	5-09-322	5.3	5.3	10.0	6.3	10.0
Lysine (98% L-Lysine HCl)		-------	0.2	0.1	0.17	0.05
Limestone, min 32% Ca		-------	0.3	-------	0.8	-------
Salt		0.5	0.5	0.5	0.5	0.5
Vitamin premix[c]		0.5	0.5	0.5	0.5	0.5
Trace mineral premix[d]		0.5	0.5	0.5	0.5	0.5
Calculated analysis:[e]						
DE, kcal/kg		3292	3150	3156	3122	3295
CP, %		15.0	12.7	14.0	13.0	13.8
Lys, %		0.54	0.55	0.55	0.56	0.54
Met + Cys, %		0.36	0.32	0.33	0.32	0.31
Trp, %		0.14	0.13	0.12	0.13	0.12
Ca, %		0.49	0.59	0.85	0.86	0.85
P, %		0.49	0.60	0.73	0.64	0.78
Cost, US $/100 kg[f]		14.56	13.35	13.27	13.32	12.85

[a]See footnote "a", Table 14, for description.

[b]See footnote "b", Table 14, for description.

[c]See footnote "b", Table 11, for premix formula.

[d]See footnote "c", Table 11, for premix formula.

[e]See footnote "d", Table 11, for explanation of abbreviations.

[f]See footnote "f", Table 14, for calculation of cost of feed.

finisher diets due to a greater availability and lower cost of grain sorghum at the time when pigs were changed to finisher diets. Since grain sorghum and corn have similar nutritional values, when used in swine diets (Miller *et al.*, 1975), replacement of one grain for the other should not influence the results obtained. The 12-week trial was conducted from January 11 to April 5, 1978.[42]

Swine Trial 3

Swine Trial 3 was designed to study the effects of replacing SBM with blood meal as a supplemental source of lysine in grower diets, and to study the effects of adding lysine with graded levels of rice bran and polishings in MBM-supplemented finisher diets. Both the grower and finisher diets were formulated to compare the effects of three levels of rice bran and polishings, and were supplemented with synthetic lysine. Diets were formulated using the analytical values given in Table 16.

Sixty pigs of Duroc, Large White, Hampshire, or Spotted Poland China single or two-way crosses, averaging 14.8 kg, were alloted randomly to 12 groups of 5 pigs each.

The control diet for the grower period (Diet 34) consisted of yellow dent corn and rice bran and polishings, supplemented with SBM, MBM and lysine to provide a calculated dietary lysine level of 0.72% (Table 17). In a previous trial (Table 14, Diet 27), pigs fed this diet had body weight gains at a lower cost per unit of gain compared to a control diet. The control diet for the finisher period (Diet 34) contained no SBM and provided a calculated lysine level of 0.54% (Table 18). Other nutrient concentrations met NRC (1973)

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[42]Subtropical, humid climate. Mean daily maximum temperature = 31.4°C; mean daily minimum temperature = 21.6°C; mean daily relative humidity = 85.8% maximum and 64.5% minimum during the period of this study (January through March) (Jenkin *et al.*, 1976).

TABLE 16.--Swine Trial 3: Nutritional Values and Costs of Ingredients Used in Formulation of Diets.

Ingredient	DE[a] kcal/kg	DM[b]	CP[b]	Ca[b]	P[b]	Lys[c]	Met +Cys[c]	Trp[c]	Cost/kg[d] (US $)
		---------------------	------% (As Fed	Basis)------	------	------	------	------	
Corn, yellow[e]	3593	88.7	8.6	0.02	0.28	0.25	0.35	0.07	0.15
Rice bran and polishings[e]	3792	88.3	11.6	0.03	1.37	0.57[a]	0.30[a]	0.13[a]	0.11
Soybean meal	3307	89.6	45.0	0.25	0.60	2.80	1.30	0.63	0.40
Meat-and-bone meal[e]	2205	93.3	45.0	8.00	3.98	2.34[g]	0.81[g]	0.22[g]	0.22
Blood meal	2690	89.8	80.0	0.28	0. 22	8.10[a]	3.00	1.10	0.77
Lysine[f]	----	----	----	----	----	78.00	----	----	4.71
Salt	----	----	----	----	----	----	----	----	0.13
Vitamin premix	----	----	----	----	----	----	----	----	0.68
Trace mineral premix	----	----	----	----	----	----	----	----	0.43

[a]NRC, 1979. DE = Digestible Energy for swine.

[b]Chemical analysis. DM = Dry Matter; CP = Crude Protein; Ca = Calcium; P = Phosphorus.

[c]Miller *et al.*, 1975. Lys = Lysine; Met = Methionine; Cys = Cysteine; Trp = Tryptophan.

[d]Exchange ratio of Belize $ to US $ = 2:1. Free on board prices are given for imported ingredients.

[e]Local feedstuffs grown or produced in Belize.

[f]98% L-lysine HCl. See footnote "e", Table 13, for source of this product.

[g]Calculated based on % protein compared to NRC (1979) reference analysis. Example: lysine: (45% ÷ 50.0%) x 2.60% lysine = 2.34% lysine in this MBM sample.

TABLE 17.--Swine Trial 3: Composition of Grower Diets.

		Diet Number					
		31	32	33	34	35	36
		2.5% Blood Meal			5% Soybean Meal		
		Percent Rice Bran and Polishings					
Ingredient	International Feed Number	20	25	30	20	25	30
Corn, yellow	4-02-935	64.9	60.9	56.9	63.5	59.4	55.4
Rice bran and polishings[a]	4-03-943	20.0	25.0	30.0	20.0	25.0	30.0
Soybean meal, solvent	5-04-604	-------	-------	-------	5.0	5.0	5.0
Meat-and-bone meal	5-09-322	11.0	10.0	9.0	9.9	9.0	8.0
Blood meal	5-00-381	2.5	2.5	2.5	-------	-------	-------
Lysine (98% L-lysine HCl)		0.1	0.1	0.1	0.1	0.1	0.1
Salt		0.5	0.5	0.5	0.5	0.5	0.5
Vitamin premix[b]		0.5	0.5	0.5	0.5	0.5	0.5
Trace mineral premix[c]		0.5	0.5	0.5	0.5	0.5	0.5
Calculated analysis:[d]							
DE, kcal/kg		3400	3424	3448	3424	3446	3470
CP, %		14.8	14.6	14.4	14.5	14.3	14.1
Lys, %		0.81	0.81	0.81	0.72	0.72	0.72
Met + Cys, %		0.45	0.44	0.43	0.43	0.42	0.41
Trp, %		0.13	0.13	0.13	0.13	0.13	0.13
Ca, %		0.90	0.83	0.75	0.82	0.75	0.67
P, %		0.90	0.92	0.93	0.88	0.90	0.91
Cost, US $/100 kg[e]		17.37	17.10	16.84	16.99	16.73	16.46

TABLE 17.--(Continued)

[a]See footnote "a", Table 14, for description.

[b]See footnote "b", Table 11, for premix formula.

[c]See footnote "c", Table 11, for premix formula.

[d]See footnote "d", Table 11, for explanation of abbreviations.

[e]Determined on the basis of ingredient costs in Table 16 (no overhead added to cost).

TABLE 18.--Swine Trial 3: Composition of Finisher Diets.

Ingredient	International Feed Number	Diet Number					
		31	32	33	34	35	36
		0.05% L-Lysine			No L-Lysine Added		
		Percent Rice Bran and Polishings					
		20	25	30	20	25	30
Corn, yellow	4-02-935	68.45	64.45	60.45	67.5	63.5	59.0
Rice bran and polishings[a]	4-03-943	20.0	25.0	30.0	20.0	25.0	30.0
Meat-and-bone meal	5-09-322	10.0	9.0	8.0	11.0	10.0	9.5
Lysine (98% L-lysine HCl)		0.05	0.05	0.05	-------	-------	-------
Salt		0.5	0.5	0.5	0.5	0.5	0.5
Vitamin premix[b]		0.5	0.5	0.5	0.5	0.5	0.5
Trace mineral premix[c]		0.5	0.5	0.5	0.5	0.5	0.5
Calculated analysis:[d]							
DE, kcal/kg		3438	3462	3486	3426	3450	3467
CP, %		12.7	12.5	12.3	13.1	12.9	12.8
Lys, %		0.55	0.56	0.55	0.54	0.53	0.54
Met + Cys, %		0.38	0.37	0.36	0.39	0.38	0.37
Trp, %		0.10	0.10	0.10	0.10	0.10	0.10
Ca, %		0.82	0.74	0.66	0.90	0.82	0.78
P, %		0.86	0.88	0.90	0.90	0.92	0.95
Cost, US $/100 kg[e]		15.53	15.26	14.99	15.36	15.10	14.86

TABLE 18.--(Continued)

[a]See footnote "a", Table 14, for description.

[b]See footnote "b", Table 11, for premix formula.

[c]See footnote "c", Table 11, for premix formula.

[d]See footnote "d", Table 11, for explanation of abbreviations.

[e]Determined on the basis of ingredient costs in Table 16 (no overhead added to cost).

requirements of 25 or 65 kg pigs for the grower or finisher diets, respectively. Diets were formulated on a least-cost basis and were calculated to meet the grower or finisher requirements of pigs for tryptophan and lysine.

Blood meal or SBM were combined with lysine in experimental diets to meet the requirements for this amino acid, and rice bran and polishings was included at increasing levels to maintain the tryptophan content of the diets, while decreasing the amount of protein supplement used. The experimental diets were formulated to compare the effects of increasing levels of rice bran and polishings at fixed levels of blood meal or SBM combined with synthetic lysine in the grower period. In the finisher period, the effects of increasing levels of rice bran and polishings at a fixed level of supplemental lysine versus no supplemental lysine were compared. The 16-week trial was conducted from July 12 to October 31, 1978.[43]

Broiler Trials--Review of Literature

Broiler production in Belize is not a very profitable venture, due to the use of expensive imported commercial protein supplements for use in feed. Feeds composed of the local MBM supplement combined with indigenous energy sources could reduce the cost of feeds and increase the use of local feedstuff items.

Studies have shown MBM to be inferior to SBM in supporting growth rates of chickens (Lynch *et al.*, 1970). However, Runnels (1968) included MBM in broiler diets at moderate levels without causing a reduction in animal performance. In a review of the nutritional evaluation of meat meals for

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[43]Subtropical humid climate. Mean daily maximum temperature = 31.4°C; mean daily minimum temperature = 21.6°C; mean daily relative humidity = 83.2% maximum and 74.6% minimum during the period of this study (July through October) (Jenkin *et al.*, 1976).

poultry, Skurray (1974) stated that body weight gains of animals fed meat meal-based diets were particularly sensitive to both the amount of meat meal in the diet and the type of cereal that the diet was based on. This would be expected to occur when feeding MBM-based diets, which differ from meat meal mainly in protein and mineral levels. Chemical analysis showed that the MBM produced in Belize contained high levels of minerals and a low crude protein level (see Appendix II). Scott *et al.* (1976) advised limiting the use of MBM to 7.5-10.0% of the diet, due to the variable nutritional quality and the high phosphorus content of this feedstuff.

Few studies have compared the growth rates of broiler birds fed MBM in combination with rice bran and polishings, wheat millrun and leaf meals. Rice bran (Rathore and Chaturvedi, 1970; Maust *et al.*, 1971) and wheat bran (Kratzer *et al.*, 1974) were fed to poultry at levels up to 40% without affecting performance.

Tannins in grain sorghum appeared to reduce chick body weight gains in studies conducted by Armstrong *et al.* (1974), but Sykes (1970) and Ali *et al.* (1974) observed no differences in performance in chicks fed grain sorghum or corn.

The purpose of Broiler Trial 1 was to determine the performance of broilers fed MBM, in stepwise replacement of SBM, as a protein supplement combined with locally available energy sources and with alfalfa meal. The objective of Broiler Trial 2 was to determine whether lower, more reasonable mineral levels, obtained by using lower levels of MBM combined with either high or low levels of SBM, would be to a great enough advantage to overcome the disadvantage of sub-optimal protein levels in corn or grain sorghum-based broiler diets.

Broiler Trial 1

This trial was conducted to evaluate the stepwise replacement of imported SBM by Belizean MBM in broiler starter and finisher diets. Wheat millrun or rice bran and polishings supplied approximately one-half of the energy source component of the experimental diets. Alfalfa meal was incorporated into the basal diet to replace portions of the grain and protein supplements. Analytical values used for the calculation of the diets are given in Table 19.

One-thousand-and-forty-one newly-hatched broiler chicks, with an average weight of 43 grams, were alloted to pens according to the methods described on page 61.

The basal diet consisted of grain sorghum, wheat millrun, SBM and MBM in proportions which provided a calculated level of 21% crude protein in the starter diet (Table 20, Diet 11). No SBM was used in the basal finisher diet, which was calculated to provide a crude protein level of 16.5% (Table 21, Diet 11). Calcium and phosphorus levels in diets increased with the use of increasing levels of MBM. Alfalfa meal was incorporated into the basal diet at a level of 10%, replacing a portion of the grain and SBM. MBM was then incorporated into the basal diet, which contained alfalfa meal, replacing SBM in approximately 50% increments to provide starter diets in which the protein source was approximately 50, 75 and 100% MBM.

Grain sorghum replaced MBM in three diets in 6% increments to determine if a lowered protein level, and consequently, lowered mineral levels, obtained by decreasing the MBM level, would have a beneficial effect on performance. In a parallel series of diets, rice bran and polishings replaced all of the wheat millrun. Finally, in one diet, all of the grain sorghum in the basal diet was replaced by corn.

TABLE 19.--*Broiler Trial 1: Nutritional Values and Costs of Ingredients Used* in Formulation of Diets.

Ingredient	ME[a] (kcal/kg)	DM[b]	CP[b]	Ca[b]	P[b]	Lys[c]	Met +Cys[c]	Trp[c]	Cost/kg[d] (US $)
		--------	--------	--------	% (As Fed Basis)	--------	--------	--------	
Wheat millrun[e]	1672[f]	87.6	15.5	0.10	0.98	0.68[f]	0.50	0.26[f]	0.13
Rice bran and polishings[e]	2360	88.3	11.6	0.03	1.37	0.57	0.30	0.13	0.11
Sorghum, grain[e]	3370	89.5	10.0	0.02	0.30	0.20	0.30	0.09	0.11
Corn, yellow[e]	3430	88.7	8.6	0.02	0.28	0.24	0.40	0.05	0.15
Soybean meal	2230	89.6	45.0	0.25	0.60	2.93	1.40	0.62	0.40
Meat-and-bone meal[e]	1960	93.3	39.2	11.18	5.45	2.04[g]	0.70[g]	0.20[g]	0.22
Molasses[e]	1960	73.7[c]	2.9[c]	0.82[c]	0.08[c]	----	----	----	0.06
Alfalfa meal	1370	90.6	17.0	1.44[c]	0.22[c]	0.73	0.40	0.28	0.33
Salt	----	----	----	----	----	----	----	----	0.13
Vitamin premix	----	----	----	----	----	----	----	----	0.68
Trace mineral premix	----	----	----	----	----	----	----	----	0.43

[a]NRC, 1977 (unless otherwise noted). ME = Metabolizable Energy.

[b]Chemical analysis. DM = Dry Matter; CP = Crude Protein; Ca = Calcium; P = Phosphorus.

[c]NRC, 1979 (unless otherwise noted). Lys = Lysine; Met = Methionine; Cys = Cysteine; Trp = Tryptophan.

[d]Exchange ratio of Belize $ to US $ = 2:1. Free on board prices are given for all of the imported ingredients.

[e]Local feedstuffs grown or produced in Belize.

[f]Millers' National Federation, 1972.

[g]Values derived from following calculation: $\frac{\text{\% Protein in Chemical Analysis}}{\text{\% Protein in NRC (1977) Reference}}$ x (Listed value for amino acid from NRC (1977) reference). For example, Lysine: $\frac{39.2\%}{50.0\%}$ x 2.60% = 2.04% for lysine.

TABLE 20.--Broiler Trial I: Composition of Starter Diets.

Ingredients	International Feed Number	Diet Number 10[a]	11	12	13	14	15	16	17	18	19
Wheat millrun[b]	4-05-206	-----	30.0	30.0	30.0	30.0	-------	-------	-------	-------	30.0
Rice bran and polishings[c]	4-03-943	-----	-------	-------	-------	-------	32.5	32.5	32.5	32.5	-------
Sorghum, grain	4-04-383	----	34.5	26.5	26.5	25.5	30.0	22.0	21.0	20.0	-------
Corn, yellow	4-02-935	----	-------	-------	-------	-------	-------	-------	-------	-------	32.5
Soybean meal, solvent	5-04-604	----	15.0	12.0	7.0	-------	17.0	15.0	10.0	-------	15.0
Meat-and-bone meal	5-09-322	----	15.0	16.0	21.0	29.0	15.0	15.0	21.0	32.0	16.0
Molasses	4-04-696	----	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0
Alfalfa meal	1-00-023	----	-------	10.0	10.0	10.0	-------	10.0	10.0	10.0	-------
Salt		----	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Vitamin mix[d]		----	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Trace mineral mix[e]		----	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Calculated analysis:[f]											
ME, Kcal/kg		----[h]	2371	2191	2178	2145	2530	2352	2325	2284	2343
CP, %		23.0	21.0	20.8	20.5	20.4	20.4	20.4	20.4	20.1	20.6
Ca, %		----[h]	1.78	2.03	2.58	3.45	1.77	1.90	2.56	3.77	1.90
P, %		----[h]	1.31	1.34	1.58	1.98	1.46	1.44	1.74	2.27	1.35
Lys, %		----[h]	1.02	1.01	0.96	0.92	1.05	1.05	1.02	0.95	1.05
Met & Cys, %		----[h]	0.57	0.55	0.51	0.47	0.53	0.52	0.49	0.42	0.60
Trp, %		----[h]	0.23	0.24	0.22	0.19	0.20	0.21	0.19	0.15	0.22
Cost, US $/100 kg[g]		24.20	17.86	19.30	18.40	17.24	17.84	19.46	18.66	16.98	19.16

[a]Commercial feed (Reimer's 23% Broiler Starter. A mixture of Ralston Purina Broiler Chowder with grain sorghum). Purchased at Reimer's Feed Mill, Spanish Lookout, Cayo, Belize.

[b]See footnote "b", Table 14, for description of this feedstuff.

[c]See footnote "a", Table 14, for description of this feedstuff.

[d]See footnote "b", Table 11, for premix formula.

[e]See footnote "c", Table 11, for premix formula.

[f]ME = Metabolizable Energy. See footnote "d", Table 11, for explanation of other abbreviations.

[g]Cost of experimental diets (Diets 11-19) was calculated from prices of ingredients given in Table 19. Cost given for the commercial feed = purchase price minus an estimated overhead cost of $3.85/100 kg.

[h]No analysis available.

TABLE 21.--Broiler Trial 1: Composition of Finisher Diets.

Ingredient	International Feed Number	Diet Number 10[a]	11	12	13	14	15	16	17	18	19
Wheat millrun[b]	4-05-206	----	30.0	30.0	30.0	30.0	-------	-------	-------	-------	30.0
Rice bran and polishings[c]	4-03-943	----	-------	-------	-------	-------	32.5	32.5	32.5	32.5	-------
Grain sorghum	4-04-383	----	46.5	38.5	44.5	32.5	41.0	33.0	39.0	27.0	-------
Corn, yellow	4-02-935	----	-------	-------	-------	-------	-------	-------	-------	-------	38.5
Meat-and-bone meal	5-09-322	----	18.0	16.0	10.0	22.0	21.0	19.0	13.0	25.0	26.0
Molasses	4-04-696	----	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0
Alfalfa meal	1-00-023	----	-------	10.0	10.0	10.0	-------	10.0	10.0	10.0	-------
Salt		----	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Vitamin mix[d]		----	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Trace mineral mix[e]		----	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Calculated analysis:[f]											
ME, Kcal/kg		----[h]	2500	2328	2413	2243	2639	2467	2552	2382	2410
CP, %		19.0	16.5	16.6	14.8	18.3	16.2	16.3	14.6	18.1	18.3
Ca, %		----[h]	2.08	2.00	1.33	2.67	2.40	2.32	1.65	2.99	2.98
P, %		----[h]	1.41	1.31	1.00	1.62	1.72	1.60	1.30	1.91	1.82
Lys, %		----[h]	0.66	0.68	0.57	0.79	0.70	0.71	0.60	0.82	0.83
Met + Cys, %		----[h]	0.42	0.42	0.39	0.44	0.37	0.37	0.34	0.39	0.40
Trp, %		----[h]	0.16	0.17	0.17	0.18	0.12	0.14	0.13	0.14	0.15
Cost, US $/100 kg[g]		21.56	13.84	15.82	15.16	16.48	13.56	15.54	14.88	16.20	16.26

[a]Commercial feed (Reimer's 19% Broiler Finisher. A mixture of Ralston Purina Broiler Chowder with grain sorghum.) Purchased at Reimer's Feed Mill, Spanish Lookout, Cayo, Belize.

[b]See footnote "b", Table 14, for description of this feedstuff.

[c]See footnote "a", Table 14, for description of this feedstuff.

[d]See footnote "b", Table 11, for premix formula.

[e]See footnote "c", Table 11, for premix formula.

[f]ME = Metabolizable Energy. See footnote "d", Table 11, for explanation of other abbreviations.

[g]See footnote "g", Table 20, for calculation of cost.

[h]No analysis available.

Due to a delayed arrival of the imported ingredient supplies, the experimental starter diets were fed for only the first two weeks of age. From two to six weeks of age, all of the groups of birds were fed the commercial feed (Diet 10). The ten experimental finisher diets were then fed from six to eights weeks of age. Body weights were recorded at two, six and eights weeks of age. The eight-week trial was conducted from May 16 to July 11, 1977.[44] Four non-orthogonal contrasts were used to compare diets containing [1] alfalfa meal versus those with no alfalfa meal; [2] rice bran and polishings versus wheat millrun; [3] corn versus grain sorghum; and [4] SBM versus no SBM (or low versus high level of MBM in the case of the finisher diets).

Broiler Trial 2

This trial was conducted to evaluate the effects of including high versus low levels of MBM in the diet, which provided high or low mineral and protein levels, in combination with SBM and corn or grain sorghum in broiler starter and finisher diets. A low level of alfalfa meal was included in the diets. Two different commercial feeds were used as comparative control diets. Analytical values used for calculation of the diets are given in Table 22.

Nine-hundred-and-ninety-six newly-hatched broiler chicks with an average weight of 39 grams were alloted to pens according to the methods described on page 61.

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[44]Subtropical, humid climate. The warm, rainy season prevailed for the period of this study, with mean daily maximum temperature = 32.6°C; mean daily minimum temperature = 21.6°C; mean daily relative humidity maximum and minimum were 79.1% and 71.0%, respectively (Jenkin *et al.*, 1976).

TABLE 22.--Broiler Trial 2: Nutritional Values and Costs of Ingredients Used in Formulation of Diets.

Ingredient	ME[a] (kcal/kg)	DM[b]	CP[b]	Ca[b]	P[b]	Lys[c]	Met +Cys[c]	Trp[c]	Cost/kg[d] (US $)
		---	---	---	% (As Fed Basis)	---	---	---	
Corn, yellow[e]	3430	88.7	8.0	0.02	0.28	0.24	0.40	0.05	0.15
Sorghum, grain[e]	3370	89.5	10.0	0.02	0.30	0.20	0.30	0.09	0.11
Soybean meal	2230	89.6	44.0	0.25	0.60	2.93	1.40	0.62	0.40
Meat-and-bone meal[e]	1960	93.3	45.0	8.00	4.00	2.34[f]	0.81[f]	0.22[f]	0.22
Alfalfa meal	1370	90.6	17.0	1.44[c]	0.22[c]	0.73	0.40	0.28	0.33
Molasses[e]	1960	73.7[c]	2.9[c]	0.82[c]	0.08[c]	----	----	----	0.06
Salt	----	----	----	----	----	----	----	----	0.13
Vitamin premix	----	----	----	----	----	----	----	----	0.68
Trace mineral premix	----	----	----	----	----	----	----	----	0.43

[a]NRC, 1977. ME = Metabolizable Energy.

[b]Chemical analysis. DM = Dry Matter; CP = Crude Protein; Ca = Calcium; P = Phosphorus.

[c]NRC, 1979 (unless otherwise noted). Lys = Lysine; Met = Methionine; Cys = Cysteine; Trp = Tryptophan.

[d]Exchange ratio of Belize $ to US $ = 2:1. Free on board prices are given for all of the imported ingredients.

[e]Local feedstuffs grown or produced in Belize.

[f]Values derived from the following calculation: $\frac{\text{\% Protein in Chemical Analysis}}{\text{\% Protein in NRC (1977) Reference}}$ x (Listed Value for Amino Acid in NRC (1977) Reference). For example, Lysine: $\frac{45.0\%}{50.0\%} \times 2.60\% = 2.34\%$.

The basal diet consisted of yellow corn, SBM and MBM in proportions which provided a calculated level of 20.9 or 18.0% crude protein in the starter and finisher diets, respectively (Tables 23 and 24, Diet 21). The SBM and MBM were present in equal levels, while other feedstuff levels varied. Meat-and-bone meal was incorporated into this diet at higher and lower levels, either replacing one-third of the SBM, or being replaced by one-third with grain, while the SBM level remained constant. The purpose of these formulations was to determine the effects of mineral levels contributed by the MBM on bird performance. These diets compared either high or low mineral levels at both high and low protein levels. A fourth diet replaced one-third of the SBM with corn, while the MBM level remained nearly constant. Four diets repeated this series, replacing the corn completely with grain sorghum, while maintaining protein and mineral levels similar to the levels in the corn diets. The eight-week trial was conducted from July 18 to September 12, 1977.[45] Three designed non-orthogonal contrasts were used to compare performance and birds fed corn versus grain sorghum-based diets, high versus low local protein supplement (MBM) levels, and high versus low SBM levels.

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[45]Subtropical, humid environment. The warm, rainy season prevailed for the period of this study, with mean daily maximum and minimum temperatures being 31.5°C and 21.8°C, respectively, and mean daily maximum and minimum relative humidity being 83.2 and 76.0%, respectively (Jenkin *et al.*, 1976).

TABLE 23.--Broiler Trial 2: Composition of Starter Diets.[a]

Ingredient	International Feed Number	Diet Number 21	22	23	24	25	26	27	28	29[b]	30[c]
Corn, yellow	4-02-935	57.5	57.0	63.5	63.0	-------	-------	-------	-------	-----	-----
Sorghum, grain	4-04-444	-------	-------	-------	-------	60.5	60.0	66.5	66.0	-----	-----
Soybean meal, solvent	5-04-604	18	13.5	18	13.5	15	10.5	15	10.5	-----	-----
Meat-and-bone meal	5-09-322	18	23	12	17	18	23	12	17	-----	-----
Alfalfa meal	1-00-023	1	1	1	1	1	1	1	1	-----	-----
Molasses	4-04-696	4	4	4	4	4	4	4	4	-----	-----
Salt		0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	-----	-----
Vitamin mix[d]		0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	-----	-----
Trace mineral mix[e]		0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	-----	-----
Calculated analysis:[f]											
ME, kcal/kg		2818	2799	2907	2887	2818	2799	2903	2884	-----[h]	----[h]
CP, %		20.9	21.1	18.7	18.9	21.0	21.2	18.9	19.2	23.0	23.0
Ca, %		1.54	1.93	1.06	1.45	1.54	1.93	1.06	1.45	-----[h]	----[h]
P, %		0.99	1.17	0.77	0.94	1.00	1.17	0.77	0.95	-----[h]	----[h]
Lys, %		1.09	1.08	0.97	0.95	0.99	0.97	0.86	0.84	-----[h]	----[h]
Met & Cys, %		0.63	0.61	0.61	0.58	0.54	0.52	0.51	0.49	-----[h]	----[h]
Trp, %		0.18	0.16	0.17	0.16	0.19	0.17	0.18	0.16	-----[h]	----[h]
Cost, US $/100 kg[g]		20.98	20.20	20.56	19.78	17.80	17.05	17.14	16.39	25.02	24.20

[a]All diets contained 0.025% Coban coccidiostat (except for the commercial diets, which contained amprolium).

[b]Commercial feed. Kornelson's 23% Broiler Starter Mash. A mixture of Aliansa Broiler 42% Concentrate (produced in Guatemala) with corn. Purchased at Kornelson's Feed Mill, Spanish Lookout, Cayo, Belize.

[c]Commercial feed. Reimer's 23% Broiler Starter. A mixture of Ralston Purina Broiler Chowder with a 50/50 mixture of corn and grain sorghum. Purchased at Reimer's Feed Mill, Spanish Lookout, Cayo, Belize.

[d]See footnote "b", Table 11, for premix formula.

[e]See footnote "c", Table 11, for premix formula.

[f]ME = Metabolizable Energy. See footnote "d", Table 11, for explanation of other abbreviations.

[g]Costs of experimental diets (Diets 21-28) were calculated from prices of ingredients given in Table 22. Costs given for the commercial feeds = purchase price minus an estimated overhead cost of $3.85/100 kg.

[h]No analysis available.

TABLE 24.--Broiler Trial 2: Composition of Finisher Diets.[a]

Ingredient	International Feed Number	Diet Number									
		21	22	23	24	25	26	27	28	29[b]	30[c]
Corn, yellow	4-02-935	63.0	62.5	69.5	68.5	-------	-------	-------	-------	-----	-----
Sorghum, grain	4-04-444	-------	-------	-------	-------	66.5	66.5	73.0	73.5	-----	-----
Soybean meal, solvent	5-04-604	15.0	9.5	15.0	9.5	12.0	7.0	12.0	7.0	-----	-----
Meat-and-bone meal	5-09-322	15.5	21.5	9.0	15.5	15.0	20.0	8.5	13.0	-----	-----
Alfalfa meal	1-00-023	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	-----	-----
Molasses	4-04-696	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	-----	-----
Salt		0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	-----	-----
Vitamin mix[d]		0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	-----	-----
Trace mineral mix[e]		0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	-----	-----
Calculated analysis:[f]											
ME, kcal/kg		2891	2869	2987	2957	2895	2881	2986	2980	-----[h]	----[h]
CP, %		18.9	19.1	16.5	16.9	19.0	19.0	16.7	16.6	20.0[h]	19.0[h]
Ca, %		1.34	1.80	0.83	1.32	1.29	1.68	0.77	1.12	-----[h]	----[h]
P, %		0.89	1.10	0.65	0,87	0.88	1.05	0.64	0.79	-----[h]	----[h]
Lys, %		0.96	0.94	0.82	0.81	0.84	0.81	0.70	0.66	-----[h]	----[h]
Met & Cys, %		0.59	0.56	0.56	0.54	0.49	0.46	0.46	0.43	-----[h]	----[h]
Trp, %		0.16	0.14	0.15	0.13	0.17	0.15	0.16	0.14	-----[h]	----[h]
Cost, US $/100 kg[g]		20.05	19.10	19.60	18.68	16.60	15.70	15.89	14.94	22.77	21.56

[a]See footnote "a", Table 23, for coccidiostat added to diets.

[b]See footnote "b", Table 23, for source of commercial feed. Kornelson's 20% Broiler Finisher Mash with corn.

[c]See footnote "c", Table 23, for source of commercial feed. Reimer's 19% Broiler Finisher with 50/50 mixture of corn and grain sorghum.

[d]See footnote "b", Table 11, for premix formula.

[e]See footnote "c", Table 11, for premix formula.

[f]ME = Metabolizable Energy. See footnote "d", Table 11, for explanation of other abbreviations.

[g]See footnote "g", Table 23, for calculation of cost.

[h]No analysis available.

IV. RESULTS OF SWINE AND POULTRY FEEDING TRIALS

Swine Trials

Swine Trial 1

The results of this trial are shown in Table 25 for the grower and finisher periods. Pigs fed diets containing 100% of the total protein supplement as MBM had decreased body weight gains ($P < 0.01$) compared to pigs fed diets containing either 0% or 50% MBM as the protein supplement. The greatest body weight gains achieved in this trial were in pigs fed the diet containing 50% MBM as the protein supplement (Diet 14). This may be due to levels of amino acids, energy or minerals. Studies by Bloss *et al.* (1953) showed that the amino acid profile of MBM in combination with SBM was superior to that of MBM alone. Also, it has been noted that the mineral and energy levels of MBM plus SBM were more favorable than those of SBM alone (Meade, 1975), since the MBM contained a greater amount of energy than the SBM, while the SBM contained lower levels of calcium and phosphorus.

Based on the inferior amino acid profile of MBM (Meade, 1975), pig performance might be expected to decrease as the dietary level of MBM is increased. Many studies have found that the complete replacement of SBM with MBM resulted in depressed body weight gains in animals (Peo and Hudson, 1962; Beames and Sewell, 1970; Meade, 1975). Meade (1975) suggested that one-third to one-half of the SBM as a source of supplemental protein can be replaced by MBM without exerting a deleterious effect on the rate of body

TABLE 25.--Swine Trial 1: Effect of Meat-and-Bone Meal on Performance of Growing and Finishing Pigs Fed Corn and/or Grain Sorghum Diets.

Item	Diet Number						± SDM[b]	T x R[c] (P <)
	11[a]	12	13	14	15	16		
	Percent Meat-and-Bone Meal in Total Protein Supplement							
		0	50	50	50	100		
	Percent Grain Sorghum in Total Grain Portion							
		0	0	50	100	0		
Grower period (10-18 weeks)								
Number of pigs	10	10	10	10	10	10		
Avg initial wt, kg	12.2	12.1	12.3	12.4	12.0	11.4	2.33	0.82
Avg final wt, kg	40.4	44.2	47.1	46.4	45.4	20.8 **	13.57	0.25
Avg daily gain, kg	0.50	0.57	0.62	0.61	0.60	0.17**	0.21	0.15
Avg daily feed intake, kg	1.47	1.46	1.56	1.58	1.59	0.69	0.42	
Feed/gain	2.9	2.6	2.5	2.6	2.6	4.0		
Feed cost/100 kg gain US $	65.13	54.29	47.50	43.47	41.50	69.92		
Finisher period (18-26 weeks)								
Number of pigs	10	10	10	10	10	10		
Avg final wt, kg	67.8	76.2	76.9	85.5	78.8	31.6 **	24.68	0.21
Avg daily gain, kg	0.49	0.57	0.53	0.70*	0.60	0.19**	0.21	0.13
Avg daily feed intake, kg	2.23	2.48	2.41	2.84	2.37	1.02	0.65	
Feed/gain	4.6	4.4	4.0	4.0	4.0	5.4		
Feed cost/100 kg gain, US $	83.40	79.64	68.20	61.20	54.08	87.48		
Overall (10-26 weeks age)								
Number of pigs	10	10	10	10	10	10		
Avg daily gain, kg	0.50	0.57	0.58	0.65	0.60	0.18**	0.20	0.17
Avg daily feed intake, kg	1.88	1.97	1.85	2.21	1.98	0.85	0.51	
Feed/gain	3.8	3.4	3.2	3.4	3.3	4.7		
Feed cost/100 kg gain, US $[d]	74.26	66.96	57.85	52.34	47.79	78.70		

TABLE 25.--(Continued)

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*Value is greater than ($P < 0.05$) control diet.

**Value is less than ($P < 0.01$) control diet (Diet 11).

[a]Purina concentrate (40% crude protein), mixed with locally grown corn.

[b]SDM = Standard Deviation of the Means.

[c]T x R = significance of treatment x replicate interaction.

[d]Overall feed cost/100 kg gain was calculated by a sum of 50% of the value for the grower period plus 50% of the value for the finisher period. For example, in Diet 11: [($65.13/100 kg gain) x 50%] + [($83.40/100 kg gain) x 50%] = $74.26/100 kg gain.

weight gain or feed conversion efficiency. Bloss *et al.* (1953) found that grower pigs fed a corn-based diet in which half of the SBM was replaced by MBM had body weight gains equal to those of pigs fed a corn-SBM diet. In other trials, protein and mineral levels were found to vary with different sources of MBM (Lynch *et al.*, 1970; Meade, 1975). Palatability, mineral imbalances, and amino acid imbalances may have affected dietary intake and protein utilization when MBM was fed as 100% of the protein supplement.

Complete replacement of SBM by MBM reduced the calculated dietary tryptophan level (Tables 11 and 12), which may have caused an amino acid imbalance due to an insufficient amount of this first limiting amino acid. Replacement of SBM by MBM may have resulted in a change in the first limiting amino acid from lysine to tryptophan. The greated body weight gains were obtained when one-half of the SBM was replaced by MBM as a source of supplemental protein, which agreed with the observations made by Meade (1975). Body weight gains were reduced in both the grower and finisher diets when MBM was used as 100% of the protein supplement. The decreased feed intake indicated that palatability was reduced, which may have been due to high mineral levels contributed by the MBM.

In the finisher period, replacement of 50% of the corn with grain sorghum (in a diet that contained 50% of the protein supplement as MBM) improved body weight gains compared to those of pigs fed corn as 100% of the grain source ($P < 0.05$). However, feed conversion efficiencies were the same in both groups. This diet (Diet 14) gave the highest overall performance compared to any of the other diets, especially in the finishing period. This may have been due to the slightly superior amino acid balance of the grain sorghum when combined with MBM as 50% of the protein supplement.

The cost per unit of gain was lowest when MBM composed 50% of the protein supplement in the diets. Replacement of the corn with lower costing grain sorghum reduced the cost per unit of gain in both the grower and finisher periods.

This study demonstrated that MBM could replace 50% of the SBM in a swine grower or finisher diet without causing a reduction in body weight gains. When used as 50% of the supplement protein source, MBM reduced the cost per unit of gain by 13% of 28%, when combined with corn or grain sorghum, respectively, compared to a commercial feed control diet.

Swine Trial 2

The results of this trial are presented in Table 26 for the grower and finisher periods. Experimental diets resulted in lesser body weight gains than the control diet in both grower and finisher periods. Feed conversion efficiencies of animals fed experimental diets were equal to or less than those fed the control diet in the grower period, while in the finisher period the feed efficiencies of animals fed the test diets were equal to or greater than those fed the control diet.

Reduced body weight gains in animals fed the test diets may have been caused by lower tryptophan and overall crude protein levels in experimental diets compared to the control diets, due to the reduced amounts of SBM used as a protein supplement.

In the finisher period, feed efficiency improved (Diet 27), when rice bran and polishings was substituted for 20% of the corn (Diet 25) in a MBM, lysine supplemented, low-SBM diet. This was probably due to the higher digestible energy content of diets containing rice bran and polishings compared to diets containing corn (Tables 14 and 15). The experimental diet

TABLE 26.--Swine Trial 2: Effect of Rice Bran and Polishings and Wheat Millrun on Performance of Growing and Finishing Pigs Fed Meat-and-Bone Meal--Soybean Meal--Lysine Supplemented Diets.

Item	Diet Number 21	23	25	26	27	± SDM[b]	T x R[c]
	Restrictions						
	11.3% MBM[a] No Lysine	11.5% MBM 20% WMR[a]	None Fixed	20% WMR	20% RBP[a]	± SDM[b]	T x R[c] (P <)
Grower period (12-20 weeks)							
Number of pigs	(8)[d]	8	8	8	8		
Avg initial wt, kg	22.8	22.9	22.9	24.0	23.1	5.97	0.91
Avg final wt, kg	65.8	60.1	56.8	59.6	63.2	12.78	0.45
Avg daily gain, kg	0.77	0.66	0.60*	0.64	0.72	0.14	0.23
Avg daily feed intake, kg	2.11	2.01	1.88	2.07	1.97	0.30	
Feed/gain	2.7	3.0	3.1	3.2	2.7		
Feed cost/100 kg gain, US $	51.30	50.13	56.82	54.08	45.87		
Finisher period (20-24 weeks)							
Number of pigs	7	8	8	8	8		
Avg final wt, kg	91.8	83.2	77.8	85.2	88.1	15.63	0.63
Avg daily gain, kg	1.08	0.96	0.87	1.07	1.04	0.18	0.09
Avg daily feed intake, kg	2.88	2.61	2.20	2.70	2.31	0.37	
Feed/gain	2.7	2.7	2.5	2.5	2.2		
Feed cost/100 kg gain, US $	39.31	36.04	33.18	33.30	28.27		
Overall (12-24 weeks)							
Number of pigs	(8)[d]	8	8	8	8		
Avg daily gain, kg	0.86	0.75	0.69*	0.76	0.81	0.13	0.43
Avg daily feed intake, kg	2.37	2.21	1.98	2.28	2.08	0.28	
Feed/gain	2.8	2.9	2.9	3.0	2.6		
Feed cost/100 kg gain, US $[e]	47.34	45.48	49.02	47.22	40.06		

TABLE 26.--(Continued)

[*]Value is less than ($P < 0.05$) the control diet (Diet 21).

[a]MBM = Meat-and-Bone Meal; WMR = Wheat Millrun; RBP = Rice Bran and Polishings.

[b]SDM = Standard Deviation of the Means.

[c]T x R = significance of treatment x replicate interaction.

[d]A pig from the heavy replicate of Diet 21 became ill and was removed four weeks after the trial had begun.

[e]Overall feed cost/100 kg gain was calculated by a sum of 67% of the value for the grower period plus 33% of the value for the finisher period. For example, in Diet 21: [($51.30/100 kg gain) x 67%] + [($39.31/100 kg gain) x 33%] = $47.34/100 kg gain.

containing 20% rice bran and polishings resulted in reduced body weight gains compared to the control diet (Diet 21) in the grower period, but the feed conversion efficiency was not decreased. In the finisher period, body weight gains of animals fed this diet approached those of the animals fed the control diet, and the feed conversion efficiency of the animals was improved compared to animals fed the control diet.

The use of rice bran and polishings in the diet reduced the levels of protein supplement and synthetic lysine needed in the diet to meet the dietary requirement for this nutrient, and resulted in the production of animals with less cost per unit of gain compared to animals fed the control diet.

The experimental diet containing 20% rice bran and polishings (Diet 27) resulted in improved body weight gains and feed conversion efficiencies of animals compared to animals fed a diet containing 20% wheat millrun (Diet 26) in the grower period, while in the finisher period, body weight gains of animals fed these diets were nearly equal. Improved feed conversion efficiencies of animals fed diets containing rice bran and polishings, in both the grower and finisher periods, resulted in lower cost per unit of gain. This may have been due to the increased energy content of the rice bran and polishings compared to wheat millrun or corn (Table 13). Body weight gains of animals fed the diet containing 20% wheat millrun (Diet 26) were less compared to those of animals fed the control diet (Diet 21), with a greater difference occurring in the grower period than in the finisher period. Feed conversion efficiencies of animals fed diets containing 20% wheat millrun were improved compared to those of animals fed the control diet in the finisher period, but not in the grower period. Performance of animals fed diets containing wheat millrun improved in the grower period when the levels of MBM and wheat millrun were fixed in the formulation of the diet (Diet 23), but this did not have the same effect in the finisher period.

Replacement of SBM and part of the corn grain (Diet 25) with 20% wheat millrun (Diets 23 and 26) resulted in improved body weight gains in the grower and finisher periods. In the grower period, replacement of corn (Diet 25) with wheat millrun (Diet 23) and elimination of the SBM improved the cost per unit of gain, due to the fact that wheat millrun was less expensive than the corn. In the finisher period, where wheat millrun replaced the less expensive grain sorghum, the cost per unit of gain was not improved. Diets containing wheat millrun and little or no SBM (Diets 23 and 26) resulted in increased body weight gains of animals compared to those of animals fed the corn diet containing MBM and a greater amount of SBM (Diet 25). This effect may have been due to an increased level of tryptophan, since the calculated level of tryptophan in the corn-based diet (Diet 25) was slightly lower than the level in the diets containing wheat millrun (Diets 23 and 26). The improved body weight gains of animals fed the wheat millrun diets may also have been due to an increased level of a third limiting amino acid.

Concentrations of B-vitamins, minerals, and crude protein were higher in mill by-products than in whole grains (Morrison, 1961; Bistoyong *et al.*, 1968; USNRC, 1968). The use of mill by-products in experimental diets may have increased the levels of these nutrients and thereby may have contributed to the improved performance of animals fed these diets. The tryptophan requirement of the growing and finishing pig was found to be 0.13% and 0.09% of the diet, respectively (Miller *et al.*, 1975). The calculated tryptophan levels of the diets used for this study met these requirements, except for one grower diet (Diet 25), which resulted in the production of animals with least body weight gains and decreased feed conversion efficiencies.

Brooks and Lumanta (1975) fed growing pigs levels of rice bran up to 40% with no depression in body weight gains, and only a slight depression in body weight gains when 60% rice bran replaced corn in a corn-SBM diet. Contrary to this, Thrasher and Mullins (1965) observed a significant reduction in body weight gain when 20% and 30% rice bran levels replaced corn and SBM. However, they replaced a greater portion of the SBM with rice bran to keep the protein levels of the diets constant. A further study conducted by Thrasher *et al.* (1965), in which they replaced only corn with rice bran, showed that a maximum level of 20% rice bran could be included in the diet to produce rapid, economical gains. Duran (1959) stated that no more than 30% rice bran should be used in a ration for fattening pigs.

In the present study, a significant decrease in body weight gains did not occur when rice bran and polishings replaced corn and part of the protein supplement. This may have been due to the addition of lysine to the diet, and also due to the high quality of the rice bran and polishings used. Erickson *et al.* (1977) obtained optimum pig performance when 20% of the corn in a corn-SBM diet was replaced by wheat middlings.

The present study has demonstrated that wheat millrun and rice bran and polishings can be included in swine grower and finisher diets, which are supplemented with lysine, and produce animals with acceptable body weight gains at a reduced cost. In terms of gain, feed efficiency and cost per unit of gain, rice bran and polishings gave more favorable results than wheat millrun, with a more extreme difference in animal performance resulting from the use of the two by-products in the grower period than in the finisher period. A corn-based diet, supplemented with lysine and containing a reduced level of SBM, resulted in decreased body weight gains in animals compared to those fed a control diet containing higher levels of SBM and MBM. It can be concluded that when rice bran and polishings are in short supply, and the prices of this feedstuff and wheat millrun are the same, it is economically advantageous to use the rice bran and polishings in grower diets and use the wheat millrun in finisher diets for swine.

Swine Trial 3

A summary of the results of Swine Trail 3 is presented in Table 27. There were no statistically significant differences in average daily body weight gains, feed consumption or feed conversion efficiencies among treatment groups for the overall experimental period. In the grower period, however, pigs fed Diet 32, in which 5% SBM (Diet 35) was replaced by 2.5% blood meal, and which contained 25% rice bran and polishings, had superior body weight gains and improved feed intakes and feed conversion efficiencies. Blood meal, included at a level of 2.5% of the diet, supplied 25% more lysine than did the 5% SBM (Table 17). The cost per unit of gain was reduced by 8% by the use of blood meal (Diet 32) compared to the SBM (Diet 35). Overall crude protein and calculated lysine levels were higher in the diets containing blood meal (Diets 31, 32, 33) compared to the SBM diets (Diets 34, 35, 36). The improved performance of pigs fed the diets containing blood meal could be due to an increased level of a third limiting amino acid. Parsons *et al.* (1979) demonstrated that 3% flash drum dried blood meal, when used in pig starter diets, provided a higher metabolizable energy value than did a corn-SBM diet. An earlier study showed that the use of up to 3% ring processed blood meal in corn-SBM rations resulted in a higher biological value of the dietary protein (Parsons *et al.*, 1975). Wahlstrom and Libal (1977) reported that pigs receiving 4% blood meal, which replaced an equivalent amount of protein from SBM, gained more slowly and required

TABLE 27.--Swine Trial 3: Effect of Blood Meal, Soybean Meal and L-Lysine on Performance of Growing and Finishing Pigs Fed Rice Bran and Polishing--Corn--Meat-and-Bone Meal Diets.

Item	Diet Number 31	32	33	34	35	36	± SDM[a]	T x R[b] (P <)
	Percent of Rice Bran and Polishings in Diet							
	20	25	30	20	25	30		
Grower period (10-20 weeks)	2.5% Blood Meal			5% Soybean Meal				
Number of pigs	10	10	10	10	10	10		
Avg initial wt, kg	13.7	15.2	15.2	15.4	15.0	14.4	2.70	0.19
Avg final wt, kg	48.3	55.1	50.8	51.7	48.5	49.9	8.76	0.46
Avg daily gain, kg	0.49	0.57	0.51	0.52	0.48	0.51	0.o0	0.64
Avg daily feed intake, kg	1.43	1.64	1.57	1.70	1.54	1.57	0.15	
Feed/gain	2.9	2.9	3.1	3.3	3.2	3.1		
Feed cost/100 kg gain, US $	50.37	49.59	52.20	56.07	53.54	51.03		
Finisher period (20-26 weeks)	0.05% L-Lysine			No L-Lysine Added				
Number of pigs	10	10	10	10	10	10		
Avg final wt, kg	72.1	79.1	77.5	80.8	71.7	72.4	11.64	0.49
Avg daily gain, kg	0.57*	0.57*	0.64	0.69	0.55*	0.54**	0.11	0.01
Avg daily feed intake, kg	2.09	2.23	2.17	2.58	2.08	2.18	0.25	
Feed/gain	3.7	3.9	3.4	3.7	3.8	4.0		
Feed cost/100 kg gain, US $	56.83	58.89	50.52	57.46	57.99	59.96		
Overall (10-26 Weeks)								
Avg daily gain, kg	0.52	0.57	0.56	0.58	0.51	0.52	0.09	0.53
Avg daily feed intake, kg	1.68	1.86	1.80	2.02	1.74	1.80	0.16	
Feed/gain	3.2	3.3	3.2	3.5	3.4	3.5		
Feed cost/100 kg gain, US $	52.82	53.12	51.56	56.60	55.23	54.42		

*Value is less than ($P < 0.05$) control diet (Diet 34).

**Value is less than ($P < 0.01$) control diet (Diet 34).

[a]SDM = Standard Deviation of the Means.

[b]T x R = significance of treatment x replicate interaction.

[c]Overall feed cost/100 kg gain was calculated by a sum of 62% of thé value for the grower period plus 38% of the value for the finisher period. For example, in Diet 31: [($50.37/100 kg gain) x 62%] + [($56.83/100 kg gain) x 38%] = $52.82/100 kg gain.

more feed per unit of gain during the grower period. However, supplementation of the diet with 0.1% L-lysine improved performance of pigs compared to pigs fed a corn-SBM control diet.

Results from feeding the three increasing levels of rice bran and polishings showed no consistent trends, which suggested the occurrence of an interaction of factors other than lysine or tryptophan levels. Critical levels of other essential amino acids, energy or minerals could have caused the variation in performance. Pond and Maner (1974) stated that blood meal was extremely deficient in isoleucine. Others claimed that it was inferior to other packing-house by-products as a general protein supplement, due to a poor balance of essential amino acids and poor palatability (Squibb and Braham, 1976; Wahlstrom and Libal, 1977). The blood meal was an effective source of protein when included at low levels in meat-meal supplemented diets, and it improved the total amino acid balance of certain diets (Pond and Maner, 1974).

In the present study, animal performance was similar when either blood meal or SBM was used in diets containing 30% rice bran and polishings. Feed intake was depressed when blood meal was used in diets containing 20% rice bran and polishings, although body weight gains were similar, resulting in an improved feed conversion efficiency and cost per unit of gain. The results indicated that a diet based on corn, MBM and rice bran and polishings, containing 2.5% blood meal and 0.1% synthetic lysine, resulted in the improved performance of growing swine compared to the performance of swine fed a diet containing 5% SBM replacing the blood meal and lysine. These results were in agreement with those of Hillier *et al.* (1955, 1956), who observed no effects in performance of animals fed diets in which 2% blood meal replaced a portion of the SBM.

Meade and Teter (1957) reported that the use of blood meal as a replacement for one-half of the protein provided by MBM resulted in significantly improved performance of growing pigs. Wahlstrom and Libal (1977) found that levels of blood meal higher than this resulted in decreased growth of animals. Blood meal contained a high level of leucine, which may have increased the dietary requirements for isoleucine, causing a deficiency of this amino acid (Oestemer *et al.*, 1973). Diets in which 10 or 20% blood meal was added at the expense of corn resulted in increased body weight gains of pigs and also prevented zinc deficiency symptoms, due either to a greater availability of zinc in the blood meal compared to zinc availability in the corn, or due to the high histidine content of blood meal (Dahmer *et al.*, 1972).

In the finisher period, increasing levels of rice bran and polishings from 20 to 30% resulted in increased body weight gains, feed intakes, and feed conversion efficiencies, when 0.5% L-lysine was included in the diet. The highest level (30%) of rice bran and polishings included in the diet resulted in optimum performance for lysine-supplemented diets. Body weight gains in animals fed this diet were greater ($P < 0.05$) than those of animals fed diets with no lysine supplement at 25 and 30% levels of rice bran and polishings. Diets containing no lysine supplement (Diets 34-36) resulted in decreased animal performance as dietary levels of rice bran and polishings increased from 20 to 30%. The lowest level of rice bran and polishings (20%), without lysine supplementation, resulted in increased body weight gains ($P < 0.01$) of animals compared to body weight gains of animals fed the diet containing 30% rice bran and polishings without lysine supplement. Also, the diet containing the 20% level of rice bran and polishings, without lysine supplement added, resulted in animals having increased body weight gains compared to those fed any of the lysine-supplemented diets.

Finisher diets, which were not supplemented with L-lysine, contained slightly higher levels of MBM (Table 18). If a borderline deficiency of tryptophan was present, the non-lysine supplemented diets, with a low level of rice bran and polishings, could have approached the requirement for this amino acid, resulting in the improved gains. As the levels of rice bran and polishings increased in L-lysine supplemented finisher diets, however, the increased content of lysine may have been antagonistic to the already limiting levels of tryptophan, which could have caused the reduction in animal performance.

This study indicated that flash ring dried blood meal, used at a level of 2.5% as a replacement for SBM in diets based on MBM, corn, and rice bran and polishings, did not cause a reduction in animal performance. Also, MBM, used as the only supplemental protein source in finisher diets containing rice bran and polishings, resulted in the production of animals having acceptable body weight gains and feed conversion efficiencies. The addition of supplemental L-lysine improved the performance of animals fed diets containing the higher level of rice bran and polishings.

Broiler Trials

Broiler Trial 1

The results of Broiler Trial 1 showed that diets without alfalfa meal resulted in improved performance (Table 28). Statistical analysis of results using Bonferroni's t-test indicated a difference ($P < 0.01$) when the contrast was made between all diets containing 10% alfalfa meal versus all diets with no alfalfa meal. There were no significant differences shown by

TABLE 28.--Broiler Trial 1: Effects of Meat-and-Bone Meal with Wheat Millrun or Rice Bran and Polishings in Birds Fed Corn or Grain Sorghum Diets.

Item	Diet Number 10	11	12	13	14	15	16	17	18	19	± SDM[a]	T x L[b] (P <)
		30% Wheat Millrun				32.5% Rice Bran and Polishings				Corn		
		Percent MBM of Total Protein Supplement in Starter Diets										
		50	57	75	100	47	50	68	100	52		
Starter period (0-2 weeks)												
Number of birds	100	103	102	100	99	101	103	101	102	99		
Avg 2-week wt, g	260	230	190	190	160	220	210	200	180	240		
Starter period (2-6 weeks)												
Number of birds	100	101	102	100	98	101	103	101	102	99		
Avg 6-week wt, g	1381	1297*	1226**	1190**	1241**	1250**	1271**	1190**	1197**	1338	188	0.22
Avg daily gain, g	32	30	28	27	28	29	29	27	28	31	4.5	0.22
Avg daily feed intake, g	65	64	62	63	60*	63	63	61*	62	64		
Feed/gain	2.0	2.1	2.2	2.3	2.1	2.2	2.2	2.2	2.3	2.1		
Finisher period (6-8 weeks)												
Number of birds	100	101	100	100	97	101	102	100	101	100		
Avg 8-week wt, g	1952	1846	1685**	1687**	1747**	1797**	1722**	1648**	1675**	1875	268	0.01
Avg daily gain, g	41	39	33	36	36	39	32	33	34	38		
Avg daily feed intake, g	117	140	136	140	118	115	132	114	132	136		
Feed/gain	2.9	3.6	4.2	3.9	3.3	2.9	4.1	3.5	3.8	3.6		
Feed cost/100 kg gain, US $	62.52	49.82	66.44	59.12	54.38	39.32	63.71	52.08	61.56	58.54		
Overall (0-8 weeks)												
Number of birds	100	101	101	100	98	101	102	100	102	100		
Avg daily gain, g	34	32	29	29	30	31	30	29	29	33	4.8	0.01
Avg daily feed intake, g	78	83	80	82	75	76	80	74	80	82		
Feed/gain	2.3	2.6	2.7	2.8	2.5	2.4	2.7	2.6	2.7	2.5		
Dress percentages	80	77	80	82	79	78	79	82	80	78		

*Value is less than ($P < 0.05$) control diet (Diet 10).

**Value is less than ($P < 0.01$) control diet (Diet 10).

[a]SDM = Standard Deviation of the Means.

[b]T x L = Significance of treatment x location interaction.

comparison of the other three contrasts, indicating that [1] the use of corn had no advantage in performance results compared to the use of grain sorghum; [2] wheat millrun or rice bran and polishings in the diet resulted in similar animal performance; and [3] combinations of varying levels of MBM and SBM did not affect performance consistently.

A comparison of all paired means using Tukey's test showed that the commercial feed (Diet 10) sustained an increase in body weight gains ($P < 0.01$) compared to any of the experimental diets in the starter period, except for Diet 11, which contained the lowest level of MBM and no alfalfa meal, and Diet 19, which was similar to Diet 11, but contained corn in place of grain sorghum. Body weight gains of birds fed the commercial feed were greater ($P < 0.05$) than body weight gains of those fed any of the other diets, except Diet 19, which contained a low level of MBM with no alfalfa meal and corn replacing grain sorghum. Diets with higher levels of MBM (Diets 13, 17, 18) resulted in reduced body weight gains of birds ($P < 0.01$) compared to gains of birds fed the basal diet. Diet 14 was an exception to this, which contained no SBM and 10% alfalfa meal combined with wheat millrun and a high level of MBM (29%). Substitution of corn (Diet 19) for grain sorghum in the basal diet (Diet 11) improved body weight gains of birds, but not significantly.

In the finisher period, the greatest body weight gains were observed in birds fed the commercial feed, but these body weight gains were not significantly greater than body weight gains observed in birds fed the basal experimental diet. Birds fed a diet containing 10% alfalfa meal (Diet 14) showed body weight gains which were not significantly different from those of birds fed the basal diet. Body weight gains improved slightly when corn replaced grain sorghum in the basal diet. The least body weight gains were observed in birds fed the rice bran and polishings-based diets containing alfalfa meal and high levels of MBM (Diets 12-14 and 16-18). Performance of birds fed Diet 14, which contained a high level of MBM, was more favorable than anticipated. The high levels of minerals contributed by the MBM were expected to result in decreased body weight gains. There were no consistent trends towards decreased body weight gains as the level of MBM was increased.

Scott *et al.* (1976) showed that MBM meal was valuable as a source of phosphorus of high biological availability as well as a source of protein and amino acids. Large differences in growth-promoting ability of MBM were attributed to variations in the nature of the raw materials and the conditions used in processing (Atkinson and Carpenter, 1970a). The high calcium content of MBM may be a cuase of depressed growth. In the present study, the calculated calcium levels of diets containing MBM and rice bran and polishings were higher than calcium levels in diets containing MBM and wheat millrun, due to the higher levels of MBM used in the diets containing rice bran and polishings. This could have been one factor causing the reduced performance of birds fed diets containing rice bran and polishings. The calculated methionine and tryptophan levels in diets based on rice bran and polishings were lower than in diets based on wheat millrun. Deficiencies of these amino acids could also have resulted in the depressed body weight gains of birds fed rice bran and polishings-based diets. According to Atkinson and Carpenter (1970b), the limiting amino acids in a cereal plus meat meal diet are determined by the type of cereal used. Although the amino acid balance of the MBM product was slightly different from a meat meal product, the type of cereal used in combination with it would also be expected to influence the limiting amino acids. Skurray (1974) suggested that the cereal masked the amino acid deficiency in meal meal when the meat meal contributed approximately 6% of the protein in a diet. However, when the meat meal contributed 10% or more of the protein to the diet, the amino acids deficient in meat meal were also limiting in the diet.

Kondos and McClymont (1972) found that the availability of certain amino acids, especially lysine, histidine and methionine, decreased by 37 and 56%, when meat meals were processed at 140°C and 160°C, respectively, thereby reducing the growth-promoting abilities of the meals. Herbert and Norgate (1971) stated that the normal time and temperature for meat meal processing was two hours at 130°C. The MBM product used in the present study was processed at a higher temperature than this and for a longer period of time (160°C for four hours), which may have decreased the availability of essential amino acids, especially lysine.

Lynch *et al.* (1970) reported that the best MBM product was significantly inferior to SBM in supporting the growth rates of chickens. Runnels (1968) found that at least 10% MBM could be used in least-cost formulated broiler diets that gave maximum body weight gains and feed conversion efficiency of birds. Gartner and Burton (1965) found a tendency for body weight gains to decrease and the feed conversion efficiencies to decrease as the percentage of bone contained in the MBM increased. Ash levels did not appear to be the major causes of differences in performance of animals fed high and low quality meals in a study conducted by Sathe *et al.* (1964).

Skurray and Cumming (1974) observed an improved feed conversion efficiency in animals fed meat meal diets based on wheat and corn compared to those fed diets based on grain sorghum. In the present study, the corn-based diet resulted in improved feed conversion efficiencies of animals compared to grain sorghum-based diets. The grain sorghum used in the present study was a non-bird-resistant variety and, therefore, should not have had any adverse effects on bird performance. Studies with grain sorghum have shown that high levels of bird-resistant varieties depressed chick performance (Conner *et al.*, 1969) due to the presence of high levels of tannin (Armstrong *et al.*, 1974; Featherston and Roger, 1975). Nelson *et al.* (1975) found that the metabolizable energy and amino acid availability increased as the tannin content of grain sorghum decreased. No attempt was made in the present study to determine the tannin content of the grain sorghum used. Damron *et al.* (1968) observed no depression in chick body weight gains or feed consumption when half of the corn in a 21.7% protein corn-SBM diet was substituted with either bird-resistant or non-bird-resistant grain sorghum. Sykes (1970) reported that grain sorghum can replace corn directly as an energy and protein source in broiler diets. Ali *et al.* (1974) completely replaced 60% of the corn in a diet with grain sorghum and observed no effects on bird performance. The most critical period when grain sorghum might have affected chick body weight gains was in the early starter phase, because grain sorghum most probably did not supply a sufficient level of linoleic acid to meet the requirement for this nutrient during that period (Scott *et al.*, 1976). The present investigation showed no significant differences in body weight gains or feed conversion efficiencies between animals fed a corn or grain sorghum-based diet containing 30% wheat millrun and a low level of MBM (15%). Rice bran and polishings contained high levels of linoleic acid, which may have been sufficient to make up for the deficient levels in the grain sorghum.

Certain leaf meals included in broiler mashes up to a level of 10% have had no negative effect on gains or feed conversion efficiencies of birds (Bird, 1944; Gerpacio *et al.*, 1967; Elegino *et al.*, 1974).

Squibb *et al.* (1953) observed an increase in chick body weight gains when up to 20% of various leaf meals were included in the diets, claiming that the forage meals were excellent sources of protein, riboflavin and vitamin A activity. The 10% level of alfalfa meal used in the present study was detrimental to body weight gains, probably because it was combined in diets with high levels of an inferior quality MBM protein source and also because it was not a high protein leaf meal.

Rice bran and polishings and wheat millrun had lower energy levels, but higher protein and more favorable amino acid levels, than corn or grain sorghum (Table 19). Maust *et al.* (1971) fed 40% rice bran substituted for glucose in a basal diet and observed body weight gains in animals comparable to those in animals fed the basal diet, which contained no rice bran. The rice bran used in that study had a metabolizable energy value of 3.03 calories/g and it contained 30% neutral detergent fiber. Rice bran, replacing corn as an energy source at a level of 60%, depressed chick body weight gains by 30% in a corn-SBM diet (Kratzer *et al.*, 1974), whereas 40% wheat bran caused no significant depression in body weight gains. Rathore *et al.* (1970) fed 24.5% wheat bran combined with 40% rice bran and did not observe a reduction in animal performance compared to performance of animals fed a standard conventional cereal-fish meal ration. Saunders *et al.* (1968) claimed that the heavy cell walls of the aleurone layer of wheat, which composed 30 to 50% of the wheat bran, reduced the availability of nutrients. Cave *et al.* (1965a, b) have shown that certain wheat milling fractions have relatively low metabolizable energy values and result in poor protein utilization. The wheat millrun used in this study consisted of approximately 50% wheat bran.

One experimental diet containing a high level of MBM, and therefore, a high calcium level (Diet 14), resulted in body weight gains and feed conversion efficiencies that approached those of the commercial feed (Diet 10). This could be due, in part, to the increased levels of essential amino acids contributed by the higher levels of MBM.

In conclusion, this study demonstrated that [1] broiler mashes that contained a high level of MBM in combination with wheat millrun or rice bran and polishings resulted in depressed body weight gains in animals compared to those of animals fed a commercial diet; [2] a 30% level of wheat millrun combined with MBM produced greater body weight gains in the finisher period than a comparable level of rice bran and polishings combined with MBM; [3] a 10% level of alfalfa meal depressed gains; and [4] corn resulted in greater body weight gains than grain sorghum when these grains were compared at a level of 38.5% of the diet. Although producing inferior gains, diets based on rice bran and polishings resulted in improved feed conversion efficiencies and, therefore, reduced feed cost per unit of gain. Diet 15, which contained rice bran and polishings and 21% MBM in a grain sorghum-based diet with no alfalfa meal included, resulted in the production of animals with the most economical body weight gains. This diet reduced the cost per unit of gain in the finisher period by 37% compared to that of animals fed the commercial feed. All of the experimental diets produced more economical body weight gains in animals in the finisher period compared to animals fed the commercial feed, except for Diet 12, which contained 16% MBM combined with grain sorghum, wheat millrun and alfalfa meal, and Diet 16, which contained 19% MBM, grain sorghum, rice bran and polishings, and alfalfa meal.

Pen location affected the performance of birds significantly. Birds in the west pens consumed less feed ($P < 0.01$) and had improved feed conversion efficiencies ($P < 0.05$) compared to birds in the east pens.

Broiler Trial 2

In this trail, a comparison of corn versus grain sorghum-based diets in the starter period showed that body weight gains of birds fed the corn diet were greater ($P < 0.01$) to those of birds fed grain sorghum (Table 29). No significant differences were observed in the comparison of high versus low protein (MBM) levels, but the third contrast showed that high SBM levels resulted in greater body weight gains in birds ($P < 0.01$) compared to those in birds fed low SBM levels. In the finisher period, there was a difference in body weight gains of birds fed corn versus grain sorghum ($P < 0.01$), and of birds fed the high level of protein (MBM) ($P < 0.05$) compared to those fed the low protein level.

In both the starter and finisher periods, an all paired means comparison using Tukey's test showed that two diets, one containing low MBM and low SBM combined with corn (Diet 24), and one containing high MBM and low SBM combined with corn (Diet 22), resulted in body weight gains that were not significantly different from the two commercial feeds used during the starter period. In the finisher period, the body weight gains of birds fed Diet 22 were lower ($P < 0.05$) compared to birds fed the commercial feed, which gave the greatest body weight gains (Diet 29). The high versus low level of SBM resulted in a greater difference in body weight gains of animals in the starter period than in the finisher period. This indicated that the high SBM level supported greater body weight gains during the starter

TABLE 29.--Broiler Trail 2: Effect of High and Low Levels of Meat-and-Bone Meal on Performance of Broiler Birds Fed Corn or Grain Sorghum Based Diets.

Item	Diet Number 21	22	23	24
	High MBM		Low MBM	
	Corn-Based			
	High SBM	Low SBM	High SBM	Low SBM
Starter period (0-6 weeks)				
Number of birds	101	98	101	97
Avg 6-week wt, g	1116	1135	1167	1118
Avg daily gain, g	26	26	26	26
Avg daily feed intake, g	58	58	64	59
Feed/gain	2.3	2.2	2.4	2.3
Feed cost/100 kg gain, US $	48.25	44.44	49.34	45.49
Finisher period (6-8 weeks)				
Number of birds	99	96	101	97
Avg 8-week wt, g	1628*	1641*	1740	1708
Avg daily gain, g	36	36	41	42
Avg daily feed intake, g	109	109	114	114
Feed/gain	3.0	3.1	2.8	2.7
Feed cost/100 kg gain, US $	60.15	59.21	54.88	50.44
Overall (0-8 weeks)				
Number of birds	100	97	101	97
Avg daily gain, g	28	29	30	30
Avg daily feed intake, g	70	71	76	72
Feed/gain	2.5	2.5	2.5	2.4
Feed cost/100 kg gain, US $[c]	51.22	48.13	50.73	46.73
Dress percentage	74	74	72	72

TABLE 29.--(Continued)

Diet Number							
25	26	27	28	29	30		
High MBM		Low MBM					
Grain Sorghum-Based							
High SBM	Low SBM	High SBM	Low SBM	Commercial		± SDM[a]	T x L[b] (P <)
99	101	100	103	96	100		
1086	1017**	1038**	966**	1126	1128	169	0.02
25	23	24	22	26	26	4.0	
56	54	62	49	56	61	5.6	
2.2	2.3	2.6	2.2	2.2	2.4		
39.16	39.22	44.56	36.06	55.06	58.08		
98	101	97	103	94	99		
1614*	1630*	1466**	1452**	1781	1700	263	0.00
38	44	31	35	47	41	10.7	0.00
109	111	98	104	116	111	7.2	
2.9	2.5	3.2	3.0	2.5	2.7		
48.14	39.25	50.85	44.82	56.93	58.21		
99	101	99	103	95	100		
28	28	26	25	31	30	4.7	0.00
69	68	71	63	71	74	4.9	
2.4	2.4	2.8	2.5	2.3	2.5		
41.41	39.23	46.13	38.25	55.53	58.11		
73	71	73	71	74	73		

*Value is less than (P < 0.05) control diet (Diet 29).

**Value is less than (P < 0.01) both control diets (Diets 29 and 30).

[a]SDM = Standard Deviation of the Means.

[b]T x L = significance of treatment x location interaction.

[c]Overall feed cost/100 kg gain was calculated by a sum of 75% of the value for the starter period plus 25% of the value for the finisher period. For example, in Diet 21: [($48.25/100 kg gain) x 75%] + [($60.15/100 kg gain) x 25%] = $51.22/100 kg gain.

period, which may have been due to more favorable amino acid levels, needed for the early growth period, that were contributed by the SBM.

The significant differences in bird body weight gains observed from feeding corn or grain sorghum diets in Trial 2, as compared to results in Trail 1, where no difference occurred, could have been due to the fact that wheat millrun or rice bran and polishings were not used in the experimental diets in Trial 2. These feedstuffs may have provided more favorable amino acid or fatty acid levels, which would have prevented the depressed body weight gains that occurred from feeding the grain sorghum diets. Another factor contributing to the difference in results of animals fed corn or grain sorghum diets in the two trials could be that in Trial 1, a commericial feed was fed from two to six weeks of age, a period when the low linoleic acid content of grain sorghum may have critically affected growth.

There were no significant differences in feed conversion efficiencies of birds fed any of the experimental diets. However, lower feed conversion efficiencies occurred in broilers in the west pens compared to those in the east pens. The experimental diets in Broiler Trial 2 contained higher levels of metabolizable energy than the diets in Trial 1, because of a greater proportion of grains used in the Trial 2 diets, as compared to by-products used in Broiler Trial 1, which had a lower energy content. In Broiler Trial 1, birds in the west pens had improved feed conversion efficiencies compared to those in the east pens, but the differences were not significant. Birds in Broiler Trial 2 consumed less average daily feed and had decreased body weight gains compared to birds in Broiler Trial 1. In Broiler Trial 2, birds in the east pens had greater body weight gains compared to birds in the west pens ($P < 0.01$).

Fuller and Mora (1973) stated that during heat stress, the chicken may have difficulty in consuming sufficient amounts of feed to provide net energy for optimal growth when fed diets containing a high heat increment. They claimed that high environmental temperatures caused a reduction in feed intake of animals, creating an energy deficiency in the bird, which resulted in reduced body weight gains. An increase in the metabolizable energy content of the diet would tend to reduce feed consumption by animals and, therefore, could cause decreased body weight gains due to an inadequate intake of other nutrients (Scott *et al.*, 1976). This may be one explanation for the lower body weight gains of the birds in Broiler Trail 2 compared to those of birds in Broiler Trial 1.

Agudu (1971) observed an increase in body weight gains and feed conversion efficiency in layer birds as the protein level of the diet was increased from 16 to 24%. He mentioned that higher protein diets seemed desirable in situations where maximal growth was required in a shorter time period (for example, broiler production). In the present study, an increase in protein level was accompanied by an increase in mineral levels, which appeared to be detrimental to the performance of the birds, but the metabolizable energy content of the diets remained nearly constant. Body weight gains were greater in broiler birds fed diets containing lower levels of MBM and, therefore, lower protein and mineral levels.

Njike *et al.* (1975), working in Nigeria, found that by increasing the dietary protein level from 10 to 16% by using increasing levels of SBM, the body weight gains and protein efficiency ratios of White Plymouth Rocks were improved, but then decreased when birds were fed diets containing more than 16% protein. In studies using groundnut meal and SBM as a single protein supplement to a cereal-based diet, Wethli *et al.* (1975) found that a maximum growth rate could not be obtained, even when very high dietary protein levels were used. These researchers suggested that the amino acids supplied by the low-quality protein source were in such disporportion compared to the animal's needs that utilization of the first limiting amino acid(s) was impaired. They concluded that the quality of an inferior protein source cannot always be offset by increasing the level of dietary protein. They also mentioned that while a maximum growth rate was an important objective in a competitive economy, it may not be an important criterion for poultry production in other parts of the world.

The MBM product used in this trial was of improved nutritional value compared to that which was used in Broiler Trial 1. It had an increased protein level and a decreased mineral level, due to a refinement in the processing methods which removed a greater amount of the bone from the meal. Gartner and Burton (1965) found a tendency for body weight gains to decrease and food conversion efficiencies to increase as the percentage of bone in MBM increased. Diets which contained high levels of MBM and, therefore, contained high calcium levels, resulted in decreased body weight gains and decreased the feed conversion efficiencies of birds in Broiler Trial 1. In the present trial, it was shown that improved body weight gains and feed conversion efficiencies could be obtained when lower calcium levels (due to lower levels of MBM) were contained in corn-based diets, especially in the finisher period. However, the results were opposite when grain sorghum replaced corn in the diet (Table 30). As the calcium and protein level increased in the diet, there were decreased body weight gains, feed consumption, and improved feed conversion efficiencies of birds fed corn-based starter diets. There was a decrease in feed conversion efficiencies of birds fed corn-based diets in the finisher period, indicating that the

TABLE 30.--A Comparison of Performance of Broiler Birds Fed Increasing Dietary Calcium and Crude Protein Levels.

	Starter Period[a]					Finisher Period[b]				
Diet Number	% Ca[c]	% CP[c]	6-Week Wt, g	ADF[c]	F/G[c]	% Ca	% CP	8-Week Wt, g	ADF	F/G
Corn diet number[d]										
23	1.06	18.7	1867	64	2.4	0.82	16.5	1740	114	2.8
24	1.45	18.9	1118	59	2.3	1.32	16.9	1708	114	2.7
21	1.54	20.9	1116	58	2.3	1.34	18.9	1628	109	3.0
22	1.93	21.1	1135	58	2.2	1.80	19.1	1641	109	3.1
Grain sorghum diet number[c]										
27	1.06	18.9	1038	62	2.6	0.77	16.7	1466	98	3.2
28	1.45	19.2	966	49	2.2	1.12	16.6	1452	104	3.0
25	1.54	21.0	1086	56	2.2	1.29	19.0	1614	109	2.9
26	1.93	21.2	1017	54	2.3	1.68	19.0	1630	111	2.5

[a]From 0 to 6 weeks of age.

[b]From 6 to 8 weeks of age.

[c]Ca = Calcium; CP = Crude Protein, ADF = Average Daily Feed; F/G = Feed Per Unit of Gain.

[d]Diet number refers to the diet numbers in Broiler Trial 2 (Tables 23 and 24).

higher protein level was more beneficial than a lower mineral level for improved performance of birds fed corn-based diets in the starter period. The reverse appeared to be true for the finisher period. Birds fed grain sorghum-based diets showed improved performance as mineral and protein levels increased in both the starter and finisher periods.

Kondos (1968) stated that after four weeks of age, body weight gains of chickens were little affected by high calcium levels in the diet and that the amin problem of using meat meals after this age was one of amino acid imbalances and deficiencies.

Hammond (1942) concluded that yellow milo (grain sorghum) was equal in value to white corn as a source of energy in properly-balanced layer hen diets, but that corn was superior to milo in low-quality diets (for example, feeds containing no protein supplement). Yellow grain sorghum was higher in protein and lower in fat than yellow corn and contained only one-tenth of the vitamin A activity (Smith, 1930). Damron *et al.* (1968) found that bird resistant varieties of grain sorghum did not depress feed intake or body weight gains. In the present trial, grain sorghum-based diets resulted in an inferior bird performance in body weight gains and daily feed consumption was lowered. However, the lower cost of grain sorghum made the cost per unit of gain more economical in birds fed diets based on this grain. Reduced bird performance in the present study may be related to deficient levels of linoleic acid or excessive tannin levels of the grain sorghum-based diets. Skurray and Cumming (1974) noted that methionine was the first limiting amino acid in a corn-based diet and that valine, isoleucine and arginine were not limiting, but that in a grain sorghum-based diet, the imbalance of essential amino acids was greater. It can be concluded from this trial that [1] grain sorghum depressed body weight gains of broiler birds to a greater extent in the starter period than in the finisher period compared to those of birds fed corn diets; [2] the difference between high versus low levels of MBM were more pronounced in the finisher period than in the starter period, and showed an advantage of low MBM levels with corn-based diets, but a greater advantage of high MBM levels with grain sorghum-based diets; and [3] a higher level of SBM appeared to be more essential for improved performance of birds in the starter period compared to the finisher period.

From an economical viewpoint, Diet 28 (containing grain sorghum, a high level of MBM, and a low level of SBM), reduced the cost per unit of gain in the starter period by a margin of 34.5% compared to the more economical of the two commercial feeds. Costs per unit of gain in birds fed the other experimental diets approached these economical gains, and body weight gains in birds fed any of the experimental diets were more economical than body weight gains of birds fed the commercial feeds. In the finisher period, the cost per unit of gain improved in birds fed any of the experimental diets compared to the cost per unit of gain of birds fed the commercial diets (except for the corn-based diet, which contained a high level of MBM). Birds fed Diet 26, which contained grain sorghum, a high level of MBM and a low level of SBM, showed the most improved performance in the finisher period by a reduction in the cost per unit of gain. For the entire eight-week period, the most economical performance was observed in birds fed Diet 28, indicating that the grain sorghum-based diet, containing low SBM and MBM levels supported economical body weight gains of broiler birds.

Summary of Animal Evaluation of Feedstuffs

Market swine and broiler birds had economical body weight gains on various rations consisting mainly, and in some cases entirely, of local feedstuffs. The body weight gain levels were lower than those of animals fed commercial feeds, and resulted in longer periods to reach market weight. However, the cost of body weight gains were lower.

Swine fed diets containing Belizean meat-and-bone meal as the only protein supplement had less efficient feed conversion efficiencies and lower rates of body weight gains (see Table 25, Diet 16). The feed cost of production was higher for these animals than for those fed diets containing some soybean meal. Body weight gains improved when supplemental lysine sources were used in combination with the MBM. This was shown in Swine Trail 2 in the improved performance of animals fed diets containing a low level of SBM and synthetic lysine (Table 26, Diets 23 and 27), and in Swine Trial 3 in the performance of animals fed blood meal and lysine (Table 27, Diets 31 and 33). In both cases, the feed cost of production was improved.

In Broiler studies, an effect similar to that in the swine was observed when MBM was used as the only protein supplement. In Broiler Trial 1, birds were produced at a lower cost per unit of gain, compared to those fed the commercial feed, when fed diets containing MBM and SBM (Table 28, Diet 15). Birds fed this diet had the most economical gains, which were 37% lower compared to the cost per unit of gain of birds fed the commercial feed (Table 28, Diet 10).

Supplementation of the MBM with SBM in the broiler diets resulted in a proportionally greater increase in performance during the starter period than during the finisher period. This was also true in the grower period of swine compared to the finisher period. During the finisher period of both the swine or the broilers, economical body weight gains were obtained when the animals were fed diets containing MBM as the only protein source (Table 27, Diet 36 and Table 28, Diets 11 and 15).

Mill by-product feedstuffs used to replace grain portions of the diets, resulted in more economical gains and improved feed conversion efficiencies. These resulted in body weight gains at a reduced cost due to the lower prices of the rice bran and polishings and wheat millrun. High levels of the wheat millrun resulted in greater cost per unit of gain compared to the rice bran and polishings (Table 26, Diets 26 and 27 and Table 28, Diets 11 and 15). The rice bran and polishings in diets resulted in the production of animals with lower cost per unit of body weight gain compared to diets containing wheat millrun, if the two were available for the same price.

The wheat millrun, however, offered advantages in storability, which made its use worthwhile even at a price equal to the rice bran and polishings. The occurrence of rancidity at a rapid rate in the rice bran and polishings did not permit long-term storage (not greater than two weeks) without a reduction in the acceptability of the feed by the animals. Price differences and storability, therefore, were important reasons for the development of a number of different composition rations.

Low levels of molasses replaced a small portion of grain as an energy source in broiler diets (Tables 20 and 21; Tables 23 and 24). High potassium levels contributed by the molasses in combination with high calcium and phosphorus levels in the MBM may have caused much of the feather soiling that occurred. Birds fed diets containing high levels of MBM had soiled feathers compared to birds fed SBM and little or no MBM.

Some of the experimental diets, although they resulted in a reduced feed cost, also resulted in decreased feed conversion efficiencies, which caused an increase in the cost per unit of gain. This was observed in Diet 12 in Broiler Trial 1 (Table 28), which cost less than the commercial feed (Diet 10). Both diets resulted in approximately the same cost per unit of gain. Other diets, however, which also cost less than the commercial feed, resulted in the production of birds at a lower cost per unit of gain compared to the commercial feed. This was seen, for example, in the results from the use of Diet 15 in Broiler Trial 1 (Table 28). Differences in feed conversion efficiencies by birds fed these diets were caused by the level of wheat millrun and alfalfa meal (Diet 12) or rice bran and polishings (Diet 15) in the diet.

V. DISCUSSION AND CONCLUSIONS

This project has demonstrated that a number of organizations with common interests can combine their efforts in a strong linkage system to assist in the development of agricultural production. The need of the small-scale animal producer for more economical feeds has led to an increased awareness of the potential use of local resources. Until these studies were conducted by the Feeds Project, the Government of Belize could offer no specific recommendations to farmers with regards to the economical advantages of various feedstuff combinations. These studies showed that increased profits were possible with the use of feeds composed of indigenous feedstuffs.

Rations were developed with a degree of flexibility in that certain items could be replaced for one another as prices of feedstuffs fluctuated or as the availability of ingredients varied. This research has shown that it was possible to produce rations containing a minimum amount of imported ingredients and which would result in lower costs of gain than the commercial feeds.

Proximate analysis of feedstuffs and animal growth performance and feed conversion efficiencies were used to obtain an indication of the nutritional values of feedstuffs available in Belize. Results from the swine and poultry diets tested showed that [1] a low to medium-level of MBM combined with grain sorghum resulted in the most economical animal performance if the cost of grain sorghum was less than corn; [2] if grain sorghum and rice bran and polishings were priced nearly the same, then a mixture of 50% grain sorghum and 50% rice bran and polishings could be used with a low level of MBM to produce animals having economical gains; [3] if wheat millrun and rice bran and polishings were the same price, then a 50/50 mixture of these two could be used in a 50/50 mixture with grain sorghum and used combined with a low level of MBM. Wheat millrun and rice bran and polishings could be used interchangeably, depending on price, availability and proximity to the farmer. Also, wheat millrun could be stored longer than rice bran and polishings without spoiling, and pigs wasted less wheat millrun than did chickens. Corn could be used to replace grain sorghum in rations to cause a slight advantage in body weight gains, if corn and grain sorghum had a similar price. If more rapid gains were desired, the addition of L-lysine increased gains and improved feed conversion efficiency.

Environmental differences or variations in energy contents of diets altered feed intake. In these situations, the feed consumption information should be used to calculate the levels of nutrients that are needed in the diet to assure that the minimum daily requirements are consumed by the animal. It is necessary to establish more precise nutrient levels in diets for animals in the tropics and especially for combinations of unusual feedstuffs.

Different feedstuffs that were similar in chemical composition and sold at the same price varied in actual feeding value (Arnott and Lim, 1966). For this reason, it was wise to adopt a flexible approach in the development of rations. An example of price determination versus feeding value was given by Gunn (1951), where he noted that gingelly cake was a popular feed in India, but it was not outstandingly nutritious. He attributed its popularity as being the reason for its high price. In Belize, the cost of rice bran and polishings and wheat millrun were lower than the cost of corn, although these feedstuffs were of a comparable nutritive value. Results from Broiler Trial 1 indicated that rice bran and polishings improved feed conversion efficiencies compared to the grains. When corn had to be imported, the price increased until it approached the price of MBM. Flexibility in ration formulation allowed an economical ration to be maintained by the substitution of corn with rice bran and polishings or wheat millrun.

Another example of demand affecting the price of feedstuffs was the small amount of cohune nut meal produced by the cohune processing industry. Increased demand for the by-product over the three-year period caused an increase in the price from US $0.11/kg to $0.16/kg, even though the nutritional value of the feedstuff did not change. Testing of alternative least-cost rations demonstrated that lower-priced ingredients could be substituted for higher-priced ones as prices fluctuated and still provided rations that produced economical gains.

Limited amounts of protein supplement have determined the capacity for commercial feed production from local feedstuffs in Belize. Belize has enough by-products to produce sufficient animal feeds to meet the energy demands of livestock production. In addition, increases in the production of sugarcane, bananas, citrus, beer, meat and seafoods will result in larger amounts of by-product resources that can be used in livestock feeds. Wastes from some of these industries, such as the beer brewer's grains, banana waste, and blood from the meat packers create disposal problems, which will result in increased pressure to convert the wastes into commercial feedstuffs. The beer brewery, for example, cannot depend on the farmers to collect the wet spent grains daily. Also, farmers waste energy if they transport the brewery by-product waste too great a distance, because the wet grains contain about 80% moisture. Once at the farm, the grains spoil rapidly, if they are not preserved. Banana production results in piles of rejected fruits which rot and are wasted. There is not enough livestock in the area where this fruit is produced to consume all of the waste bananas during the season of harvesting. Ensiling or drying the bananas would provide an additional feed resource for animal producers.

At the meat packing plant, the disposal of blood from slaughtered animals creates a problem. Processing this waste into a blood meal would provide an additional protein supplement source. Fish trash from the fishing cooperatives is not used, due to lack of appropriate transport, storage and processing equipment. This is yet another untapped protein supplement resource that would improve the livestock feeds situation in Belize.

It should be noted that in the determination of the costs of imported versus local feeds used in this study, the values were calculated using FOB (Free on Board) prices at the Belize port of entry. If a more thorough system of shadow pricing was used to determine the feed costs (Gittenger, 1972), the result would be a decreased actual cost to the Belizean economy in the use of indigenous feed items. This is due to the drain in foreign exchange (which is a limited resource to a nation), when feeds are purchased from abroad. For this reason, the imported feeds should be assigned a higher value than the actual price paid for them. The restraint on domestic production when importing feeds must also be considered when placing an economic value on imported items. In effect, this would cause rations composed of indigenous feedstuffs to be even more economical as the proportion of local feedstuff consumed per unit of body weight gain increased.

In a lesser-developed country, submaximum animal performance may be inefficient from the biological standpoint, but medium to low levels of animal performance still often result in the highest economic efficiency (McDowell, 1977). The studies presented in this thesis have demonstrated that lower-quality by-product feedstuffs, when used in a ration balanced to meet nutritional requirements, were valuable for providing economical body weight gains of animals.

APPENDIX I

BELIZE: COUNTRY BACKGROUND

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Location

Belize is located on the eastern seaboard of Central America between latitudes 18°29'W and 15°54'N and longitudes 80°9'W and 88°10'W. The mainland area totals 22,662 km^2, while the offshore islands area totals approximately 300 km^2.

The country is bounded by the Republic of Guatemala on the south and west and by the Republic of Mexico in the north (Jenkin *et al.*, 1976). (See map of Belize, Figure 15).

Belize City, the main port and former capital, is situated on the eastern seaboard. Belmopan, the capital, is 80 km inland. Central Farm, Agricultural Experiment Station, where the feed trials for Phase 1 of the project were conducted, is located in the Cayo District, 35 km west of Belmopan.

Climate

The climate is subtropical with a temperature range of 10°C to 35.5°C on the coast, and a greater temperature range inland (Ministry of Trade and Industry, 1972). Rainfall ranges from an average of 128 cm annually in the North to 436 cm annually in the South (Ministry of Agriculture and Lands, 1975).

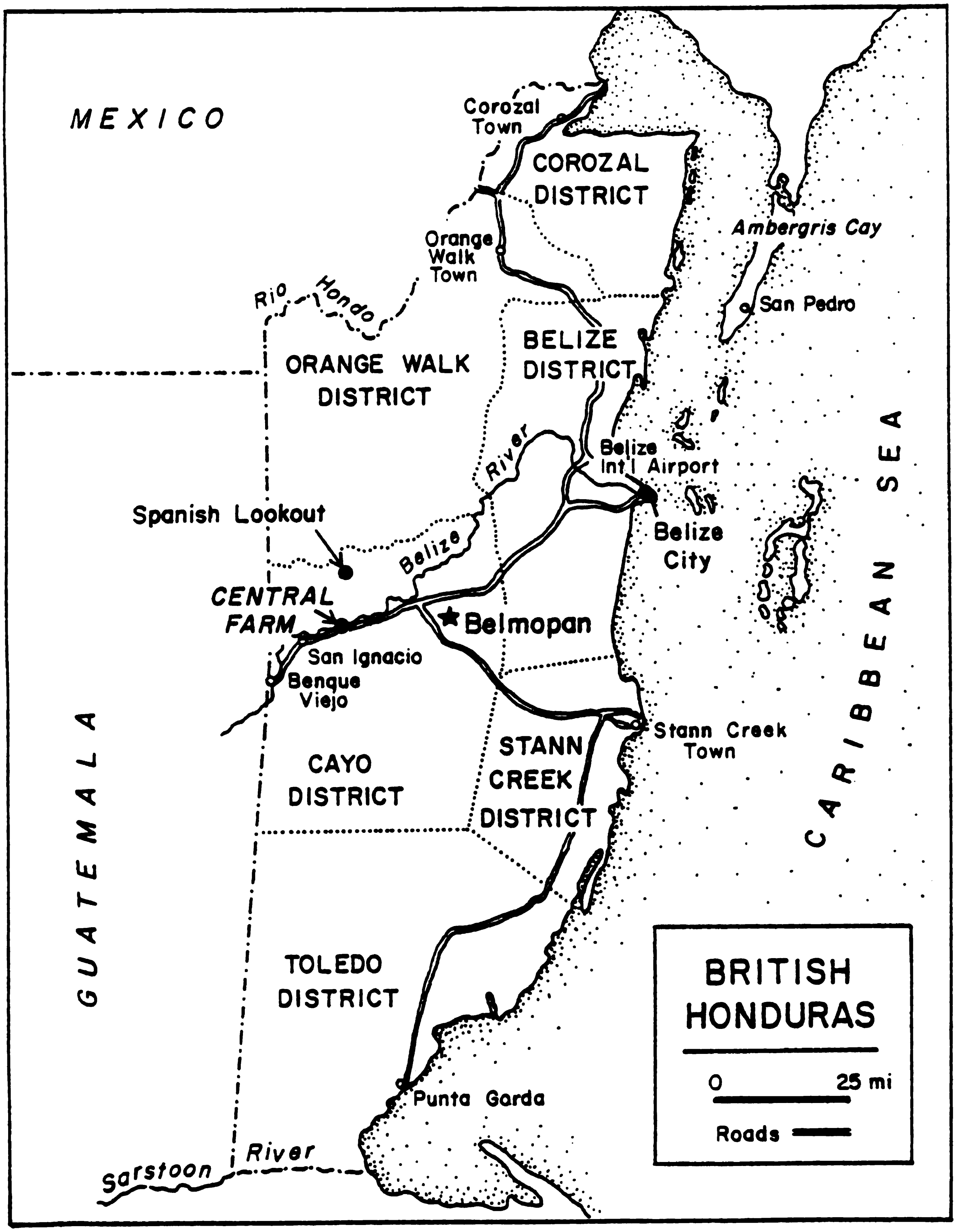

Figure 15.--Map of Belize.

Dramatic changes in climate occur during May and June, and again in October and November. The main rainy season is hot and begins in June and continues through October, with an occasional short dry spell. The rainy season usually ends in October, when the transition from summer to winter occurs (Jenkin *et al.*, 1976). At the end of October, the weather becomes cooler, leading into the cool season with occasional light rainfall from November through February. During this period, the night temperature may drop to 7.2°C in low-lying areas (Barclays, 1969; Ministry of Agriculture and Lands, 1975). By January or February, skies are clear with 6 to 8 hours of daily sunshine, high daytime temperatures and low night temperatures, low relative humidity and low rainfall, and occasionally, a completely dry month (Jenkin *et al.*, 1976).

There is a more gradual change to summer occurring from April to June. The period from May to October is characterized by increased cloud formations and less sunshine, lower day and higher night temperatures, higher relative humidity and heavy rainfall. Heaviest rainfall occurs in May and June and a second rainfall peak occurs in September and October. There is a mid-season drought between the two heavy rainfall periods (Jenkin *et al.*, 1976). The average dry season temperature in low-lying areas is 30.5°C with a maximum temperature of 38°C. Average relative humidity is 85 percent (Barclays, 1969). The highest elevation in the country is 1,128 meters above sea level. Elevation at Central Farm is approximately 46 m above sea level. Day length ranges from 11 to 13 hours (Ministry of Agriculture and Lands, 1975).

Land

Approximately 2.2 million acres are suitable for agricultural development, half of which is best suited to arable farming, and half suitable for grazing (Ministry of Agriculture and Lands, 1975). Only 15 percent of this land is currently utilized for agricultural production.

Agricultural products rose from 40 to 75% ot total domestic exports from 1960 to 1970. The agricultural sector accounts for 40% of the total Gross Domestic Product (Ministry of Agriculture and Lands, 1975), an increase from 16% in 1972 (Ministry of Trade and Industry, 1972).

People

Belize consists of a population of which 40% are of African descent, 40% are Latin-Indian descent, 15% are of Jamaican, Lebanese, Chinese and other descent, 3.4% are of European descent and 1.6% are of East Indian descent. The Belize District and the main road to Cayo (San Ignacio) are predominantly composed of Creole villages. West of Cayo are people of Mayan Indian and Spanish/Mayan descent. There are a number of Mennonite settlements, which are a Protestant sect of European origin. Expatriates consist mainly of United States Caucasians involved with farming (Jenkin *et al.*, 1976) and English who hold overseas office positions.

APPENDIX II

ANALYSIS OF FEED INGREDIENTS

TABLE 31.--Analysis of Citrus Pulp Pellets and Grain Sorghum.[a]

Item	Lab No.[b]	Date	% DM[c]	% CP[c]	% Ash[c]	% EE[c]	% CF[c]	% Ca[c]	% P[c]	% Silica
Citrus pulp pellets[d]	MSU	9/13/76	87.7	4.8	5.4	2.0	----	----	----	---
	MSU	5/28/77	87.1	6.4	3.9	---	----	----	----	---
	(Tag on Package)		89.0	5.0	---	2.0	16.0	----	----	1.0
	MSU	4/28/77	85.6	5.8	4.4	---	----	----	----	---
	F 413	2/14/78	87.3	5.1	6.3	2.0	11.1	1.73	0.10	---
		$\overline{X}$	87.3	5.4	5.0	2.0	13.5			
		± SDM[f]	1.22	0.66	1.07	0.0	3.46			
		n	5	5	4	3	2			
Grain sorghum[e]	MSU	12/21/76	92.4	8.4	1.5	2.6	----	0.01	0.23	---
	MSU	4/18/77	----	9.5	---	---	----	----	----	---
	MSU	5/28/77	90.0	13.7	---	---	----	----	----	---
	MSU	5/18/77	89.2	7.5	1.4	---	----	----	----	---
	F 55	6/14/77	88.4	8.6	2.4	---	----	----	----	---
	F 67	6/22/77	88.3	9.6	2.5	---	----	----	----	---
	F 85	7/15/77	89.7	10.1	1.5	---	----	----	----	---
	F 52	4/16/77	88.4	8.1	1.3	---	----	----	----	---
		$\overline{X}$	89.5	9.4	1.8					
		± SDM	1.46	1.92	0.53					
		n	7	8	6					

[a]Analysis given on an as fed basis for Tables 31 through 42.

[b]MSU indicates sample was analyzed at Michigan State University; F___ entry indicates sample was analyzed at Central Farm, Belize.

[c]DM = dry matter; CP = crude protein; EE = ether extract; CF = crude fiber; Ca = calcium; P = phosphorus.

[d]Waste from the production of orange and grapefuit juices (not including seeds) at Salada Company, Stann Creek, Belize.

[e]Northrup King Variety 222, grown in the Cayo District, Belize.

[f]Standard deviation of the means.

TABLE 32.--Analysis of Yellow Grain Corn, White Grain Corn, and Corn + Cob + Husk.

Item	Lab No.	Date	% DM	% CP	% Ash	% EE	% CF	% Ca	% P	% CWC/ADF/ADL[a]
Yellow grain corn[b]	F 4	4/29/77	88.8	8.6	1.3	---	---	----	----	
	F 20	5/18/77	89.5	7.6	1.4	---	---	----	----	
	F 44	6/04/77	88.0	9.3	1.4	---	---	----	----	
	F 54	4/28/77	88.3	8.6	1.6	---	---	----	----	
	F 84	7/15/77	87.8	8.6	1.2	---	---	----	----	
	F 317	12/22/77	88.7	8.8	1.6	3.2	1.3	----	0.27	
	MSU	12/22/77	89.5	8.0	1.3	3.8	---	0.01	0.19	
	F 386	1/25/78	86.0	8.3	1.8	3.4	1.6	----	0.27	
	F 246	10/31/77	92.5	8.3	1.6	3.0	1.9	----	----	
	F 579	8/02/78	87.5	8.8	2.1	3.1	2.0	----	0.38	
	F 622	9/30/78	89.6	6.1	0.8	3.1	1.4	0.04	0.25	
	F 635	10/10/78	88.1	7.8	2.1	4.1	2.4	0.03	0.30	
		$\overline{X}$	88.7	8.2	1.5	3.4	1.8	0.03	0.28	
		± SDM	1.57	0.82	0.37	0.41	0.41	0.149	0.062	
		n	12	12	12	7	6	3	6	
White grain corn	F 45	2/09/77	88.3	8.9	1.2	---	---	----	----	
	F 46	2/09/77	86.9	9.8	3.2	---	---	----	----	
Corn + cob + husk	F 394	2/06/78	89.3	8.3	2.1	3.2	9.4	----	0.22	
	MSU	8/30/76	86.8	6.5	2.2	2.9	---	----	0.25	34.9/16.1/2.6

[a]CWC = cell wall constituents; ADF = acid detergent fiber; ADL = acid detergent lignin.

[b]Mexican Synthetic Variety VS 550 A.

TABLE 33.--Analysis of Beer Brewer's Spent Grains, Bone Meal and Burnt Bone Ash.

Item	Lab No.	Date	% DM	% CP	% Ash	% EE	% CF	% Ca	% P	% NDF[d]
Beer brewer's spent grains[a]	F 423	2/20/78	87.9	21.1	4.3	6.1	19.1	-----	----	----
	F 446	3/16/78	21.2	5.1	0.9	0.7	4.9	0.07	0.12	----
(dried)	MSU	11/10/78	85.5	15.4	----	5.7	----	0.19	0.09	57.0
Bone meal[b]	MSU	12/21/76	98.0	32.1	36.9	20.6	----	13.77	6.86	----
	MSU	12/21/76	95.8	32.0	44.0	17.8	----	15.16	7.40	----
	F 515	5/29/78	92.6	26.6	57.1	7.4	----	25.7	7.66	----
		$\overline{X}$	95.5	30.2	46.0	15.3		18.21	7.31	
		± SDM	2.72	3.2	10.2	6.96		6.523	0.408	
		n	3	3	3	3		3	3	
Burnt bone ash[c]	F 182	5/09/77	----	----	----	-----	----	32.60	15.30	----

[a]Obtained from Beliken Beer Brewery, Belize City.

[b]Obtained from Belize Beef Corporation, Belize City.

[c]Produced by burning bones over an open fire on a metal sheet until charred, then ground to a powder.

[d]NDF = neutral detergent fiber.

TABLE 34.--Analysis of Meat-and-Bone Meal.

Item	Lab No.	Date	% DM	% CP	% Ash	% EE	% CF	% Ca	% P	ppm Fe/Cu/Zn
Meat-and-bone meal		12/18/76	95.6	41.4	33.7	15.3	----	-----	5.82	
		12/18/76	95.7	37.0	34.2	17.3	----	11.46	5.57	
		5/28/77	----	39.1	----	----	----	-----	----	
		5/18/77	93.0	38.6	22.8	----	----	-----	----	
	F 66	6/22/77	91.6	47.5	20.0	----	----	-----	----	
	F 120	8/15/77	90.1	48.2	21.4	----	----	-----	----	
		7/15/77	92.2	51.3	21.4	----	----	-----	----	
	F 88	7/08/77	92.6	46.5	22.6	----	----	-----	----	
	F 132	8/07/77	90.5	41.4	8.0	----	----	-----	----	
	F 152	8/16/77	----	41.8	----	----	----	-----	----	
	F 234	10/26/77	----	45.6	----	----	----	-----	----	
		8/24/77	93.0	46.8	20.0	17.3	----	6.07	3.75	514/7.1/61
	F 320[a]	12/22/77	93.7	47.5	23.0	19.2	2.0	-----	1.11	
	MSU[a]	12/22/77	94.5	45.9	21.6	17.8	----	6.74	2.76	
	F 333	1/10/78	93.3	48.1	24.0	16.6	3.1	10.83	----	
	F 578	8/02/78	94.9	45.7	22.1	20.7	1.0	-----	2.72	
	F 605	10/06/78	95.6	30.5	44.0	15.4	----	10.00	5.36	
	F 606	10/06/78	93.9	29.8	46.8	13.9	----	9.64	5.36	
	F 621	9/30/78	96.1	35.9	24.0	15.2	2.9	9.17	2.40	
	F 636	10/10/78	94.7	46.8	20.5	15.7	1.5	6.00	2.90	
	F 659	11/06/78	89.5	44.2	22.2	8.4	2.6	-----	2.45	
	F 688L[b]	11/23/78	91.1	59.8	16.1	12.8	1.0	4.27	5.45	
	F 689D[b]	11/23/78	93.6	52.0	27.8	14.4	1.0	8.00	----	
		$\overline{X}$	93.3	44.0	24.8	15.7	1.9	8.02	3.98	
		± SDM	1.96	6.83	8.92	2.97	0.89	3.282	2.236	
		n	20	23	20	14	8	10	12	

[a]One sample was divided and analyzed at both Central Farm (F) and MSU.

[b]Two batches of meat-and-bone meal from one shipment were compared; one was a light burnt orange color (L), and the other was a dark brown color (D).

TABLE 35.--Analysis of Wheat Millrun, Screenings, Bran and Shorts + Mids.

Item	Lab No.	Date	% DM	% CP	% Ash	% EE	% CF	% Ca	% P	% CWC/ADF/ADL
Wheat millrun[a]	MSU	8/20/76	86.5	14.3	4.7	3.4	----	----	0.29	32.9/8.7/2.2
	MSU	5/30/77	89.4	15.8	5.8	---	----	----	----	
	MSU	7/08/77	90.0	16.8	3.8	---	----	----	----	
	F 133	8/07/77	87.4	14.4	3.4	---	----	----	----	
	F 226	10/24/77	88.2	16.2	6.5	4.5	9.8	----	----	
	F 321	12/22/77	88.9	15.0	4.1	5.3	6.8	----	----	
	F 332	1/10/78	80.4	15.0	5.2	3.6	10.0	0.32	0.86	
	F 387	1/25/78	88.5	14.7	3.6	3.3	7.1	0.43	0.60	
	F 624	9/30/78	89.0	11.4	6.2	1.5	10.2	0.03	1.35	
	F 658	11/06/78	88.4	17.4	9.0	1.6	6.1	0.09	1.16	
	MSU	11/20/78	87.0	15.3	---	4.3	----	0.10	1.05	41.0 (% NDF)
		$\overline{X}$	87.6	15.1	5.2	3.4	8.3	0.19	0.88	
		± SDM	2.61	1.58	1.72	1.34	1.86	0.172	0.389	
		n	11	11	10	8	6	5	6	
Screenings[b]	F[c]	12/04/77	88.5	14.3	5.6	2.7	10.1	----	----	
	MSU[c]	12/04/77	89.3	14.4	5.4	3.4	----	0.174	0.49	
Bran	F[c]	12/04/77	88.2	15.8	6.4	4.0	11.6	----	----	
	MSU[c]	12/04/77	89.0	13.9	4.8	4.4	----	0.101	0.95	
Shorts + mids	F[c]	12/04/77	87.9	15.4	4.1	4.0	7.3	----	----	
	MSU[c]	12/04/77	88.5	14.3	3.6	4.5	----	0.078	0.76	

[a]A mixture of bran, shorts, and middlings in a 5:3:2 ratio, respectively, unless noted otherwise.

[b]Screenings is the portion obtained when the whole wheat grain is screened and cleaned before polishing.

[c]One sample was divided and analyzed both at Central Farm (F) and MSU.

TABLE 36. Analysis of Rice Bran and Polishings, 1st Polish, 2nd Polish and 3rd Polish.

Item	Lab No.	Date	% DM	% CP	% Ash	% EE	% CF	% Ca	% P	% CWC/ADF/ADL
Rice bran and polishings[a]	MSU	8/20/76	85.0	11.6	7.9	6.5	---	----	0.87	12.5/3.4/0.08
	F	5/18/77	90.1	15.1	7.8	----	---	----	----	
	F	7/15/77	89.6	13.9	8.7	----	---	----	----	
	F 225	10/ 24/77	89.3	12.5	6.3	9.2	4.5	----	----	
	F 577	8/02/78	88.4	12.2	6.5	11.1	2.9	0.02	1.19	
	F 623	9/30/78	88.4	9.6	8.4	7.1	6.5	0.02	1.60	
	F 663	11/06/78	88.9	13.7	10.9	4.7	5.9	0.05	1.64	
	MSU	11/20/78	86.4	12.3	----	14.0	----	0.05	1.53	34.0 (% NDF)
		$\overline{X}$	88.3	12.6	8.1	8.8	5.0	0.04	1.37	
		± SDM	1.72	1.66	1.54	3.39	1.60	0.017	0.329	
		n	8	8	7	6	4	4	5	
1st polish	F 299	12/13/77	88.1	15.5	6.5	8.6	8.2	----	----	
	MSU	12/13/77	89.7	14.8	4.2	12.8	---	0.06	0.96	
2nd polish	F 300	12/13/77	87.9	16.4	7.8	11.5	6.5	----	----	
	MSU	12/13/77	89.3	16.2	5.8	16.7	---	0.03	1.43	
3rd polish	F 301	12/13/77	88.3	12.6	6.3	8.5	2.7	----	----	
	MSU	12/13/77	89.0	11.9	6.6	10.0	---	0.02	1.42	

[a]A mixture of rice bran and polish produced from three polishings of the rice grain, Costa Rican variety CR 11-13 (produced at Big Falls Ranch, Belize District, Belize).

TABLE 37.--Analysis of Cohune Nut Meal and Cohune Nut Whole Kernels.

Item	Lab No.	Date	% DM	% CP	% Ash	% EE	% CF	% Ca	% P	% CWC/ADF/ADL
Cohune nut meal[a]	MSU	9/07/76	85.7	14.6	5.6	14.9	----	0.01	0.60	50.7/31.3/6.0
	F 429	3/11/78	93.2	18.8	4.6	20.2	12.8	0.10	0.54	
	F 442	3/14/78	90.9	15.7	4.0	25.6	19. 5	0.10	0.54	43.5/46.4/---
		$\overline{X}$	89.9	16.4	4.7	20.2	16.2	0.07	0.56	
		± SDM	3.84	2.18	0.81	5.35	4.74	0.052	0.035	
		n	3	3	3	3	2	3	3	
Cohune nut meal[b]	F 353	1/20/78	96.8	9.0	1.8	53.8	18.7	----	----	
Cohune nut (whole kernels)	F 428	3/11/78	91.9	9.2	7.3	53.2	7.2	0.08	0.27	
	MSU	11/10/78	89.1	7.0	---	63.9	----	0.05	0.05	25.0 (% NDF)

[a]Produced by steam expreller type processing on a commercial basis by Belize International, Belize City.

[b]Produced in village on small-scale basis, using hot water to extract oil (dried 48 hours at 58°C).

TABLE 38.--Analysis of Soybean Meal.

Item	Lab No.	Date	% DM	% CP	% Ash	% EE	% CF	% Ca	% P
Soybean meal[a]	F 19	5/18/77	89.7	40.7	7.3	3.1	----	----	----
	F 227	10/24/77	90.1	43.9	6.4	1.7	6.1	----	----
	F 319[b]	12/22/77	90.5	44.5	6.2	1.4	5.3	0.80	0.50
	MSU[b]	12/22/77	90.3	42.5	5.9	1.5	---	0.88	0.88
	F 354	1/21/78	88.7	45.3	7.4	2.1	6.2	0.49	0.70
	F 576	8/02/78	88.6	37.8	7.1	2.2	7.5	0.18	0.61
		$\overline{X}$	89.6	42.4	6.7	2.0	6.3	0.59	0.67
		± SDM	0.82	2.80	0.62	0.62	0.91	0.320	0.161
		n	6	6	6	6	4	4	4

[a]Imported from the United States.

[b]One sample was divided and analyzed at both Central Farm (F) and MSU.

TABLE 39.--Analysis of Pigeon Pea, Pods and Leaves; Leaf Meal and Forage.

Item	Lab No.	Date	% DM	% CP	% Ash	% EE	% CF	% Ca	% P	% CWC
Pigeon pea:										
Pods	F 81	7/15/77	90.3	11.4	9.7	----	----	----	----	----
Leaves (dried)	F 90	7/08/77	88.2	22.1	5.7	----	----	----	----	----
	F 134	8/05/77	87.4	20.1	5.0	----	----	----	----	----
	F 149	7/20/77	87.6	19.9	5.0	----	----	----	----	----
Leaf meal	F 271	11/08/77	92.1	23.6	12.8	4.6	20.7	----	----	----
Forage[a]	F 313	12/19/77	28.2	5.0	1.5	0.3	7.9	----	----	5.1
	F 80	7/15/77	90.7	16.1	8.4	----	----	----	----	----

[a]Forage consisted of leaves, stems and pods.

TABLE 40.--Analysis of Root Crops.

Item	Lab No.	Date	% DM	% CP	% Ash	% EE	% CF	% Ca	% P	% Starch
Root crops:										
Cassava tuber (peeled)	F 272	11/29/77	40.4	0.8	1.2	0.1	0.8	----	----	----
Cassava tuber (unpeeled)	F 312	12/19/77	32.2	0.8	1.0	0.7	1.2	----	----	----
Sweet potato	F 273	11/29/77	30.2	1.0	1.1	0.5	0.7	----	----	----
Cassava starch trash	F 419	2/16/78	36.1	0.4	0.4	0.3	1.0	0.16	0.09	32.59
Cassava bread trash	F 420	2/16/78	52.8	0.6	0.7	1.2	2.0	0.17	0.04	49.10

TABLE 41.--Analysis of Leaf Meals.

Item	Lab No.	Date	% DM	% CP	% Ash	% EE	% CF	% Ca	% P	% CWC/ADF
Leaf meals:										
Leucaena	F 49	2/22/77	89.1	25.7	7.2	---	----	----	----	
leaf meal[a]	F 441	3/14/78	89.3	24.1	7.3	1.6	15.0	----	----	32.1/17.5
	F 574	7/26/78	96.6	24.9	7.5	3.0	14.2	1.62	0.15	
Desmodium	F 414	2/11/78	90.0	23.8	8.3	2.8	18.5	2.01	0.33	
leonii	F 440	3/14/78	89.6	24.9	7.7	2.8	18.8	----	----	27.5/22.9
(CF-29) leaf meal	F 575	8/01/78	90.3	14.3	7.1	2.6	19.6	0.58	0.17	
Ramon leaf meal	F 47	1/24/77	86.9	14.2	12.7	---	----	----	----	
Chichiba leaf meal	F 48	1/28/77	86.3	23.2	10.4	---	----	----	----	
Plum leaf meal	F 148	7/20/77	86.5	12.5	6.0	---	----	----	----	
Trumpet leaf meal	F 560	7/26/78	94.6	14.0	9.7	9.6	16.3	1.44	0.10	
Hibiscus leaf meal	F 573	7/26/78	95.3	9.2	9.6	3.9	7.3	1.62	0.40	
Rice bean leaf meal	F 596	10/06/78	90.5	17.7	17.8	1.9	11.6	1.11	0.39	
Russian comfrey leaf meal	F 598	10/06/78	90.3	16.9	29.7	1.3	7.9	0.86	0.56	
Hog bush	F 569	4/26/78	96.1	22.0	19.7	2.7	14.7	2.67	0.41	
	F 600	10/06/78	87.8	16.2	24.7	1.2	11.7	0. 31	0.05	
Peanut leaf	F 601	10/06/78	92.8	16.5	21.3	1.5	15.9	2.11	0.32	

TABLE 41.--Continued.

Item	Lab No.	Date	% DM	% CP	% Ash	% EE	% CF	% Ca	% P	% CWC/ADF
Leaf meals:										
Pumpkin leaf	F 602	10/06/78	81.5	18.2	18.0	1.2	9.1	0.90	0.38	
Radish lead	F 603	10/06/78	92.2	19.6	22.1	3.2	11.8	1.24	0.22	
Cabbage	F 604	10/06/78	90.0	15.9	24.8	4.5	8.8	4.18	0.37	
Alfalfa[b]	F 21	5/18/77	89.6	17.0	9.5	---	----	----	----	
	F 318	12/22/77	91.6	19.3	10.1	1.3	23.0	2.63	0.53	

[a]Leucaena leucocephala.

[b]Imported from the United States.

TABLE 42.--Analysis of Grass Meals and Other Items.

Item	Lab No.	Date	% DM	% CP	% Ash	% EE	% CF	% Ca	% P
Grass meals:									
sugar cane top	F 599	10/06/78	94.03	6.5	18.8	3.3	25.1	1.03	0.38
Elephant grass	F 91	7/08/77	87.1	18.6	9.2	---	----	----	-----
	F 135	8/05/77	84.8	13.0	9.9	---	----	----	-----
	F 147	7/21/77	86.5	11.4	9.7	---	----	----	-----
	F 150	8/19/77	87.3	12.7	11.1	---	----	----	-----
	F 595	10/06/78	93.8	8.4	20.0	1.9	33.5	3.60	0.07
Para grass	F 92	7/08/77	89.1	14.6	12.5	---	----	----	-----
	F 136	8/05/77	84.7	16.1	10.9	---	----	----	-----
	F 151	8/19/77	87.4	15.2	11.0	---	----	----	-----
Other Items:									
Lime-stone[a]	V 85	6/22/77	----	----	----	---	----	39.99	-----
	MSU	8/24/77	----	----	----	---	----	38.10	0.08
Bone ash	F 182	10/25/77	----	----	----	---	----	32.60	15.30
Horse eye bean meal	F 50	2/21/77	89.0	16.8	3.0	---	----	----	-----
Red kidney beans (boiled)	F 89	7/08/77	45.8	13.9	1.4	---	----	----	-----
	F 592	10/06/78	----	18.3	20.2	0.6	3.8	0.09	0.22
Blood meal[b]	F 522	6/12/78	89.8	72.3	2.5	14.4	4.3	0.01	0.04
Rice hull ash	F 227	10/24/77	----	----	----	----	----	0.92	0.64

[a]Limestone analysis also indicated the following mineral contents: magnesium carbonate = 0.36%; iron = 660 ppm; copper = 4.0 ppm; zinc = 22 ppm.

[b]Flash dried, ring process. Imported from the United States.

APPENDIX III

CLIMATIC INDICATORS FOR CENTRAL FARM, BELIZE

TABLE 43.--Average Monthly Temperature, Relative Humidity, Radiation, Windspeed, Sunshine, Rainfall, and Evaporation.[a]

	Jan	Feb	Mar	Apr	May
Mean daily maximum temp (°C)	28.3	28.0	30.2	33.4	34.5
Extreme daily maximum temp (°C)	31.7	33.9	38.9	38.9	37.2
Mean daily minimum temp (°C)	17.5	17.0	19.0	19.8	20.8
Extreme daily minimum temp (°C)	11.1	7.8	11.7	9.4	14.4
Mean daily % RH at 0900 h	88.6	85.4	82.6	76.0	74.7
Mean daily % RH at 1500 h	66.8	64.6	62.0	61.8	68.0
Gunn Belani radiation integrator totals (cm)	353	372	479	468	524
Mean wind speed over 24 h (mi/h) (at 0900 h)	2.8	4.0	3.8	4.9	4.7
Mean wind speed over 24 h (mi/h) (at 1500 h)	2.8	3.9	3.8	4.9	4.8
Mo. total sunshine (h)	171	160	180	237	232
Total mo. rainfall (inches)	3.32	1.58	2.26	0.96	4.33
Mo. total pan evaporation (inches)	3.64	3.71	5.36	6.38	7.25

TABLE 43.--Continued.

June	Jul	Aug	Sep	Oct	Nov	Dec
32.1	31.2	31.7	31.5	31.0	28.5	28.4
36.7	33.9	35.0	36.1	33.3	32.8	31.7
22.1	21.9	21.4	22.0	21.3	18.8	18.0
18.3	17.8	18.3	19.4	17.8	9.4	12.2
79.3	83.4	83.9	82.4	83.2	85.4	86.2
69.0	76.0	75.8	76.1	70.3	72.8	69.0
427	410	450	459	406	282	----[b]
4.5	4.2	3.6	3.4	2.4	2.1	2.5
4.5	4.0	3.7	3.4	2.5	2.1	2.5
183	163	174	146	143	123	143
7.45	7.55	6.52	8.75	5.01	8.08	3.88
5.78	5.61	5.61	4.60	4.17	3.36	4.23

[a]Jenkin *et al.*, 1976. (Means are for period from 1968-1971.) (Conversion factors: C = 5/9 (F-32); F = (9/5 C) + 32.)

[b]No information available.

APPENDIX IV

METRIC CONVERSION FACTORS USED IN THIS THESIS

APPENDIX IV

METRIC CONVERSION FACTORS USED IN THIS THESIS

1 cm = 0.39 in

1 m = 39.37 in

1 km = 0.62 mi

1 sq cm = 0.155 sq in

1 sq m = 1.20 sq yd

1 g = 0.035 oz

1 kg = 2.2 lb

1 metric ton (mt) = 2200 lb

1 sq ft = 0.09 sq m

1 hectare (ha) = 2.47 acres

APPENDIX V

DESCRIPTION OF STATISTICAL METHODS OF ANALYSIS

APPENDIX V

DESCRIPTION OF STATISTICAL METHODS OF ANALYSIS

Swine Trials

A two-way Analysis of Variance (ANOVA) was made using light and heavy group blocks as one factor times the dietary treatments. Tukey's Honestly Significant Difference (HSD) test was used for all pair-wise comparisons between the treatments. The test statistic was

$$q_{\alpha,t,n-t} = \frac{\bar{y}_1 - \bar{y}_2}{\sqrt{MS_E/r_s}}$$

where:

t = the number of diets

n = total number of animals used

y_1-y_2 = difference between the two dietary treatment means being compared

MS_E = mean square error

r_s = the number of animals per treatment (of two pens combined) or per pen (if comparing each individual pen as a treatment). r_s = the smaller amount if there were variable numbers of animals in the treatments being compared.

Broiler Trials

Broiler Trials were analyzed by the least squares method, and included the variables of location and sex. All pair-wise comparison of means was made using Tukey's HSD test as mentioned previously for the swine trials. Also, Bonferroni's t-test was used to obtain a greater degree of sensitivity for comparison of results using designed non-orthogonal contrasts. An example of this test, using the four contrasts in Broiler Trial 1 (see page) would be as follows:

Contrast 1.--SBM versus no SBM (Diets 11 + 12 + 13 + 15 + 16 + 17) versus (14 + 18).

Contrast 2.--leaf meal versus no leaf meal (12 + 13 + 14 + 16 + 17 + 18) versus (11 + 15).

Contrast 3.--wheat millrun versus rice bran and polishings (Diets 11 + 12 + 13 + 14) versus (15 + 16 + 17 + 18).

Contrast 4.--corn versus grain sorghum (Diet 19) versus (Diet 11).

The test statistic for the fourth contrast, for example, was

$$t_{B_{\alpha,m,\nu}} = \frac{\bar{y}_{19} - \bar{y}_{11}}{\sqrt{MS_E\left(\frac{1}{r_{19}} + \frac{1}{r_{11}}\right)}}$$

where

m = the number of contrasts (4)

ν = total degress of freedom (number of animals = 983).

For the second contrast, then

$$t_B = \frac{(\bar{y}_{12} + \bar{y}_{13} + \bar{y}_{14} + \bar{y}_{16} + \bar{y}_{17} + \bar{y}_{18}) - (3\bar{y}_{11} + 3\bar{y}_{15})}{\sqrt{MS_E\left(\frac{1}{r_{12}} + \frac{1}{r_{13}} + \frac{1}{r_{14}} + \frac{1}{r_{16}} + \frac{1}{r_{17}} + \frac{1}{r_{18}}\right) - \left(\frac{9}{r_{11}} + \frac{9}{r_{15}}\right)}}$$

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