AGENCY FOR INTERNATIONAL DEVELOPMENT
WASHINGTON, D. C. 20523

BIBLIOGRAPHIC INPUT SHEET

FOR AID USE ONLY
Batch 40

1. SUBJECT CLASSIFICATION

A. PRIMARY
Serials

Y-AL10-5200-GG50

B. SECONDARY
Agriculture--Pests of animals

2. TITLE AND SUBTITLE
Ruminant livestock development programs in the tropics,emphasizing livestock production systems through improved breeding and disease control; annual report,1974/1975

3. AUTHOR(S)
(101) Tex.A&M Univ. Dept.of Animal Science

4. DOCUMENT DATE	5. NUMBER OF PAGES	6. ARC NUMBER
1976	255p	ARC

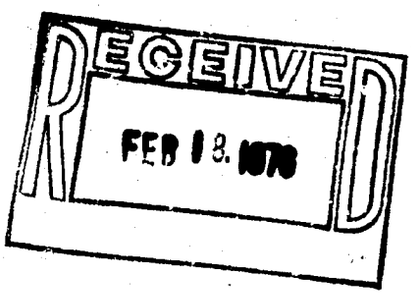
7. REFERENCE ORGANIZATION NAME AND ADDRESS
Tex.A&M

8. SUPPLEMENTARY NOTES *(Sponsoring Organization, Publishers, Availability)*
(Research summary)

9. ABSTRACT

10. CONTROL NUMBER	11. PRICE OF DOCUMENT
PN-AAC-143	
12. DESCRIPTORS	**13. PROJECT NUMBER**
Animal husbandry Livestock Tropics	**14. CONTRACT NUMBER** CSD-3675 211(d)
	15. TYPE OF DOCUMENT

AID 590-1 (4-74)



AID - 211(d) ANNUAL REPORT

1 July 1974 to 30 June 1975

to

U. S. AGENCY FOR INTERNATIONAL DEVELOPMENT
Washington, D. C.

Grantee

TEXAS A&M UNIVERSITY

Institute of Tropical Veterinary Medicine
College of Veterinary Medicine

&

Department of Animal Science
College of Agriculture

AID - 211(d) ANNUAL REPORT

1 July 1974 to 30 June 1975

to

U. S. AGENCY FOR INTERNATIONAL DEVELOPMENT
Washington, D. C.

Grantee

TEXAS A&M UNIVERSITY

Institute of Tropical Veterinary Medicine
College of Veterinary Medicine

&

Department of Animal Science
College of Agriculture

ITVM FACULTY & GRADUATE STUDENTS

TEXAS

FACULTY:

Fred D. Maurer, Director; D.V.M., Ph.D.*
Kenneth L. Kuttler, Associate Director; D.V.M., Ph.D.
L. Gary Adams, D.V.M., Ph.D.

GRADUATE STUDENTS:

Thomas M. Craig, D.V.M., 211(d)*
John H. Wyss, D.V.M., 211(d)*

C. Tom Kyzar, D.V.M., Army.
Sonny D. Reynolds, D.V.M., Army.

COLOMBIA

FACULTY:

Radmilo A. Todorovic, D.V.M., Ph.D.
Donald E. Corrier, D.V.M.
Kenneth C. Thompson, D.V.M., Ph.D.
David C. Hopps, D.V.M., Research Assistant*

* Drs. Craig and Wyss and, partially, Drs. Hopps and Maurer are the only members of staff or students currently funded by 211(d).

211(d) Annual Report
June 1975

Title: "Expanding Competence in the Design & Execution of Livestock Development Programs in the Tropics, Emphasizing Ruminant Livestock Production Systems Through Improved Breeding & Disease Control" AID/csd-3675

Grantee: Texas A&M University
College Station, Texas

1/2 to Institute of Tropical Veterinary Medicine,
College of Veterinary Medicine and

1/2 to Animal Science Department

This one-half of the report is for the
Institute of Tropical Veterinary Medicine.

Director: Dr. Fred D. Maurer

A. Statistical Summary:

Period of Grant: 1 July 1972 to 30 June 1977
Amount of Grant: $250,000.00 to the ITVM, College of Veterinary Medicine

Expenditures: For current year, 1974-1975, $46,766.52
Accumulated, $85,871.21
Anticipated for next year, $81,768.00

B. Narrative Summary:

In keeping with USAID and Consortium plans, each Consortium member sent representatives to survey their respective areas of interest in Guyana. Dr. Tom Craig represented the Institute of Tropical Veterinary Medicine (ITVM) and the College of Veterinary Medicine there from 23 May to 1 September 1974. While in Guyana, he worked in close cooperation with Guyanese veterinary authorities and was usually accompanied by one of them as he conducted his survey of animal disease and parasites in the major livestock regions of the country. In the course of the survey he routinely collected serum samples and parasites which he brought back to the ITVM laboratory for testing. The testing took much of Dr. Craig's time for the next five months following his return to Texas. The complete report of his work is provided in

Appendix I. Copies of it have been provided to the Guyanese authorities who have expressed appreciation and have requested that his work be continued. This we would be interested in doing if funds were available. The report has also been made available to other Consortium members so that the observations and results may be incorporated into the general livestock industry model being developed by the full Consortium.

The ITVM library of references, reprints, texts, and papers on tropical veterinary medicine is being continually expanded and cataloged.

Our library is also being strengthened by papers and publications by our own faculty and by visiting lecturers who have contributed to our workshops. These are listed in Appendix III and under Accomplishments 4. (b).

The collection of training aids consisting of colored slides with commentaries and histologic sections is growing with new and improved additions. A list of these is provided in Appendix II.

We have had three graduate students who have received some support from 211(d) funds this year; Drs. Craig, Hopps and Wyss, all three of whom are scheduled to receive Ph.D. degrees in 1975, with specialties in Tropical Veterinary Medicine. The subjects of their research are presented elsewhere in this report.

C. Detailed Report:

I. General Background and Purpose of the Grant

Living here in the United States where food has always been relatively abundant, and those with low incomes can obtain welfare, it's hard to appreciate that world food supplies are grossly inadequate in both quantity and quality.

Several things have intensified world food shortages in recent years: The excessive growth of the human population; the shift of rural populations to the cities; the great increase in the consumption of cereal grains in the developed countries; lack of adequate food storage; adverse weather conditions, and uncontrolled animal disease.

Proteins are most deficient with some 400 million people estimated to be suffering from protein deficiencies. A purely vegetarian diet is deficient in vitamin B_{12} and lacks phospholipids essential for the development

of the central nervous system. The inclusion of a small amount of animal protein per day provides the essentials for growth and nutrition so that the rest of the diet can be composed of available plant foods. Further, animal proteins are most readily consumed in adequate quantity, even by children, following the processing available even in a primitive environment. There is no question of the necessity for the use of animals as a vital world food resource. Some 65% of the world's land area can only contribute to man's food supply through ruminants which can utilize the forages available there. Some 40% of crop nutrient would be wasted if it were not fed to livestock. The greater the food deficite the more vital that animal production be efficient. It is the objective of the Consortium to increase animal production through the improvement of all aspects of animal breeding, nutrition, health and management.

Maximum livestock production requires healthy animals. It is our prime objective under 211(d) to increase the efficiency of livestock production in the tropics through improved animal health. We consider the development of information and the training of people in the diagnosis, prevention, and control of disease to be our mission and to integrate this information into that of the Consortium so that comprehensive plans and methods for livestock production in the tropics can be developed and applied.

II. Objectives of the Grant:

1. Objectives Restated

To improve staff capability at Texas A&M University to design and conduct efficient disease prevention and control programs for ruminant livestock production in the tropics. This objective to be attained through the provision of training and experience for staff personnel. The training to be accomplished through staff involvement in academic education, research, and field application. Since efficient livestock production involves management, breeding, nutrition and economic considerations as well as disease control, this is a cooperative Consortium effort to develop all essential aspects of livestock production.

2. Review of Objectives

The area of responsibility within the 211(d) Consortium delegated to the ITVM is to develop a high level of competence in the diagnosis, prevention, and control of those livestock diseases of the tropics which most seriously handicap livestock production. Many of these diseases are most severe in the least developed countries which have also done the least research work to develop effective means of control. It follows that for many of those diseases there is a great need for research, and a scarcity of information which is widely scattered through the world's literature. To assemble such information as is available requires the collection of reprints from obscure foreign journals, the proceedings of international animal disease conferences and correspodence with other workers. It is also the purpose of the workshops in which we participate to update our information on specific diseases.

In view of the situation on the literature for exotic animal diseases it follows that an adequate training and research program aimed to push forward the application of pertinent knowledge must entail the development of an accessible library through the following steps:

(1. Develop and keep current a library of relevant information on each major exotic animal disease;

(2. Develop training aids which will include colored slide transparencies for projection of clinical cases, of gross and histopathology, pathogenic organisms, and parasites;

(3. Collect pathologic specimens, consisting of gross tissues, histologic slides, blood smears and pathogenic organisms;

(4. Conduct an active research program to develop a better knowledge of each disease;

(5. Conduct a research program to develop and apply improved methods for diagnosis, treatment, and prevention of each disease;

(6. Develop and conduct a training program to convey available information to undergraduate professional students, graduate students, veterinarians and livestock producers.

III. Accomplishments by our 211(d) Program in 1974-75 include the following:

1. Additions of reprints, theses, dissertations, reference books and periodicals have been made to the ITVM library of information on exotic diseases which handicap livestock production.

2. The ITVM library of training aids has been improved through the addition of study sets of Kodachrome slides accompanied by a brochure of commentaries for each set. Study sets have been loaned and material for them exchanged with other investigators to increase our coverage. Please see Appendix II.

3. Graduate Student Training:

The ITVM and its professional staff are involved in the training of post-D.V.M. foreign and U. S. graduate students in several different ways.

All of our graduate students who receive their training in Texas obtain their formal academic training in one or more of the departments of Veterinary Microbiology, Pathology, or Parasitology in the College of Veterinary Medicine here at Texas A&M University. Those who are supported by our AID programs then do their research on a problem which helps fulfill our AID mission and responsibilities either here in Texas, in Colombia, or elsewhere abroad where we have an obligation, as in Guyana.

This past year Drs. Craig, Wyss and Hopps have been full or part-time 211(d) fellows.

Dr. Tom Craig has been working toward a Ph.D. degree. He did his academic work in Veterinary Parasitology and his research involved a survey of livestock diseases in Guyana, South America, which he conducted during the period of 23 May to 1 September 1974, followed by five months of laboratory work in our Texas ITVM laboratories on the specimens collected in Guyana. His detailed research report is enclosed as Appendix I. Dr. Craig's report will contribute to the livestock production model being prepared for Guyana by other members of the 211(d) Consortium.

Dr. Craig completed all requirements except for the writing of his dissertation in January 1975, so was dropped from 85% of his 211(d)

funding on 31 January 1975. He will continue to work 15% of his time for 211(d) until 1 September 1975, at which time he will become a full-time faculty member here in Veterinary Parasitology. He will complete the writing of his dissertation and receive his Ph.D. later in 1975. His dissertation is on "The Prevention of Bovine Parasitic Disease in Various Environments within the Lowlands of Guyana".

Dr. John Wyss was a 211(d) fellow working toward his Ph.D. degree in Veterinary Microbiology from 1 September 1973 until he completed his research in December 1974, at which time he became a full-time staff member of our AID/csd-1947 program stationed in the Texas laboratory of ITVM. Dr. Wyss's dissertation is entitled, "The Invitro Culture of Babesia bigemina Utilizing Bovine Cells". He expects to receive his degree in August, 1975.

Dr. Wyss has been providing some consultation for the Texas Animal Health Commission on the problems of Texas Fever and vector Boophilus ticks which continually threaten the Texas cattle industry from Mexico.

Dr. David Hopps did the academic work toward the Ph.D. degree in Veterinary Parasitology on a fellowship provided by that department. He has now been employed three-quarter time as a Research Assistant on our AID/csd-1947 contract in Colombia, since July, 1973. There he has worked three-quarters for the program and one-fourth on his own research. His research project, however, "A Comparison of Serologic Tests for the Diagnosis of Bovine Babesiosis" is also in furtherance of our responsibilities to AID. He has now completed his research and needs to devote himself full-time to writing of his dissertation, so was shifted effective 1 June 1975 to a much lower 211(d) stipend. His research and dissertation are fully in line with 211(d) objectives in increasing his and our collective capacity to increase livestock production through improved disease control; disease control in turn being dependent upon efficient methods of diagnosis.

We have had two U. S. Army Veterinary Corps officers as graduate students whose salaries, allowances and major travel expenses are paid by the Army.

Major Sonny D. Reynolds, VC, has been working toward a Master's degree in Veterinary Microbiology. His research was conducted here in the ITVM laboratories and he has completed his thesis entitled, "Evaluation of Methods of Premunition to Anaplasma marginale". His degree will be awarded in August, 1975.

Captain Tom Kyzar, VC, is working toward a Master's degree in Veterinary Microbiology with his research being conducted in cooperation with our team in Colombia, on the subject of "The Development and Use of the Card Test in the Epidemiology of Babesiosis". Cpt. Kyzar has been in Colombia since August, 1974, is scheduled to return in July 1975, and will complete his degree this autumn.

Robert M. Miller, a graduate student in entomology, carried out his research in our ITVM laboratories with the guidance of Dr. Kenneth Kuttler. His Master's thesis entitled, "Investigations on Transstadial Transmission of Bovine Anaplasmosis and Benign Bovine Theileriosis in Cattle by two Species of Amblyomma (Acarina: Ixodidae)" reveals a subject which is of importance to the epidemiology of anaplasmosis which, in turn, is a major handicap to livestock production in the tropics. Hence, a study which contributed materially to 211(d) objectives.

Dr. Gary Adams has been assisted in his ITVM research by graduate student Fernando Lozono of Colombia, who is studying "Cell Mediated Immunity in the Bovine". Dr. Lozono's academic degree will be in Veterinary Pathology. Dr. Lozono has financial support from the Rockefeller Foundation.

In addition to these students whose research has been conducted within our program, there are others - both U. S. and foreign - upon whose graduate committees the ITVM professional staff has served because the subjects of their study would contribute to our field of interest.

Drs. Adams, Galvin and Maurer served on the Ph.D. committee of Dr. Antonio Betancourt who has done his academic work in Veterinary Parasitology and who will return to CIAT in Colombia where he will do his research on parasitic diseases of the bovine in cooperation with our staff.

Our staff in Colombia, Drs. Todorovic, Corrier and Gonzalez

and research assistant Ray Long have trained several veterinarians from Colombia, Brazil, and other Latin countries in the preparation, standardization and use of the stabilates needed in the immunization of cattle against anaplasmosis and babesiosis.

4. Informal training and continuing education has been accomplished by the ITVM faculty as follows:

(a. A four-day international hemoprotozoal disease workshop was conducted at CIAT in Palmira, Colombia, March 1975, at which ITVM staff members served as section chairmen and presented the following papers:

Dr. Kuttler presented a paper prepared by Dr. Maurer describing the ITVM, its mission and accomplishments.

Dr. Kuttler - "The Diagnosis of Anaplasmosis in the U.S.A." and "The Immunization Control of Anaplasmosis".

Dr. Todorovic - "The Diagnosis of Bovine Babesiosis".

Drs. Adams and Galvin - "The Immunization Control of Bovine Babesiosis".

Drs. Adams, Galvin and Mateus - "Review of the Monteria ICA/Texas Experiments, I, II, III, IV."

Drs. Adams and Kuttler - "Review of Experience with Imidocarb in Texas".

Drs. Gonzalez and Todorovic - "Introduction to Premunition Work in Valle del Cauca".

Dr. Corrier - "The Epidemiology of Bovine Anaplasmosis and Babesiosis in the Lowland Tropics of Colombia".

Dr. Thompson - "A Review of Knowledge of the Vectors of Bovine Anaplasmosis".

This workshop was attended by research workers on hemoprotozoal diseases from Europe, Africa, Australia, Latin America, and the U. S. A., so that the papers and their discussion provided a unique pooling of up-to-date information. A workshop report containing the above papers is

to be prepared and a copy will be retained in the ITVM library.

(b. A 211(d) workshop on Foreign Animal Diseases was presented by the ITVM here during 21-23 May 1975. Working participants from Tuskegee College of Veterinary Medicine, the U. S. D. A. Emergency Disease Program, the Armed Forces Institute of Pathology and ITVM presented papers on the following subjects:

Dr. George Shelton, Dean, Welcome.

Dr. F. D. Maurer - "Livestock - A World Food Resource Threatened by Disease".

Colonel R. M. McCully - "African Horsesickness"

Dr. K. L. Kuttler - "Anaplasmosis Research".

Colonel Gil Trevino - "Swine Vesicular Disease".

Dr. Y. Cho - "Exotic Newcastle".

Dr. William Moulton - "Foot & Mouth Disease".

Dr. L. G. Adams - "Trypanosomiasis".

Dr. E. C. Sharman - "Newcastle Disease Outbreak, California".

Dr. F. D. Maurer - "Rinderpest".

Dr. Cousins - "Leptospirosis".

Dr. John Wyss - "Babesiosis".

Colonel R. M. McCully - "Besnoitea".

Dr. Sonny Reynolds - "Bovine Pleuropneumonia".

Colonel McCully - "Bovine Petechial Fever (Ondiri Disease)".

Dr. Tom Craig - "Dictyocaulus viviparus" and "Boophilus".

Dr. K. L. Kuttler - "East Coast Fever".

Dr. F. D. Maurer - "African Swine Fever".

The papers presented at this workshop were made available to each participant and to Dr. Nels Konnerup of USAID. In addition, a set has been placed in the ITVM library to help update the coverage of these diseases.

(c. Weekly seminars have usually been held in the ITVM laboratories to keep the faculty and graduate students informed of ITVM activities, research plans, and to report progress.

(d. Dr. Kuttler presented a lecture to a university class on tropical agriculture and is scheduled again this fall. Dr. Kuttler also attended the Third International Congress of Parasitology in Munich, Germany, August 25 - 31, 1974, where he presented a paper on "Chemotherapy and Eradication of Anaplasmosis".

(e. Dr. Maurer has presented the following papers in addition to those in the workshops:

At a Texas A&M conference on Population Growth and World Food Supply presented a paper on "The Effects of Animal Disease on World Food Supplies".

To Army Veterinarians at Fort Sam Houston, a continuing education lecture on Exotic Animal Diseases.

Before the American Society of Clinical Pathologists served on a panel on Animal Diseases Affecting Man, in Washington, D. C.

Served as Chairman on Eqine Diseases at the 75th Conference of Veterinarians in Pullman, Washington.

Presented a Seminar before the Department of Physiology & Pharmacology, College of Veterinary Medicine, Texas A&M University, on "The ITVM and the Relationships of Livestock Production to World Food Supplies".

Served as a visiting lecturer on the 211(d) program at Tuskegee College of Veterinary Medicine, presented a seminar on "The Need for Improving Livestock Health to Meet World Food Requirements".

Presented a lecture on the ITVM and effects of animal disease on food resources at a Texas A&M class on Tropical Agriculture.

5. Training provided through consultation and assistance on Tropical Animal Health Problems by the Professional Staff of ITVM.

Dr. K. L. Kuttler conducted a field trial for the protection of 145 head of registered Santa Gratuadis cattle on the LaRamona Ranch in The Dominican Republic, against anaplasmosis and babesiosis. This was done by combining a system of Anaplasma premunition and Imidocarb therapy for Babesia. Past experience at this ranch had shown that when such imported

cattle were moved from the Dominican Republic quarantine station on the ranch they suffered serious losses from these tick-borne diseases. Imidocarb therapy two weeks after release from quarantine was effective against the Babesia, and no losses have occurred from either disease during the five months' period they have now been exposed to infected ticks on the farm.

Drs. Kuttler and Maurer participated in a planning conference at McAllen, Texas, with State, U.S.D.A., and Mexican officials on the new research facilities and program at Falcon Dam, 26-29 January, 1975.

Drs. Kuttler and Maurer met in Austin with the Texas Animal Health Commission and officials of the Texas Department of Agriculture Export Division in planning for the new research facility for partial ITVM use at Falcon Dam. The State Export Division has agreed to provide a cattle-holding facility for our use there in the fall of 1975. This is being done to facilitate research which will help us in the development of immunization methods for the protection of U. S. cattle being shipped to tropical countries where the cattle will be exposed to frequently fatal hemoprotozoal diseases.

August 18-23, 1974, Drs. Maurer and S. McConnell attended a meeting in Bogota, to help develop plans for research on and control of Foot and Mouth Disease in Colombia. This disease will become an increasingly serious threat to Central and North America with the opening of the new Pan American highway through Panama and into Colombia, where Foot and Mouth is prevalent. ITVM, in cooperation with Dr. McConnell of Veterinary Microbiology, proposed a research project involving the vaccination of cattle against Foot and Mouth Disease through use of a jet injector which Dr. McConnell has adapted for use in domestic animals. Good cooperative plans were developed but they have been delayed, in part, from lack of funds.

April 13-14, 1975, Dr. Maurer participated in a 211(d) planning meeting in Atlanta, where plans were developed to involve the Consortium in another country besides Guyana. Exploratory steps were taken for the participation of an African country.

Dr. Tom Craig spent the period of 23 May to 1 September, 1974, conducting research on animal health on behalf of the 211(d) Consortium. His field work was followed by five months of laboratory work here to complete

the examination and prepare the report on specimens collected in Guyana. His detailed report is in Appendix I. We have had excellent reports from Guyana expressing appreciation for the work Dr. Craig did there and voicing their wish that the work he initiated could be expanded to a more comprehensive study with assistance for research on major animal disease problems.

While in Guyana, Dr. Craig attended a veterinary conference in Trinidad, where he presented a paper on "Epidemiological Aspects of Bovine Hemoparasite Control".

While in Guyana, Dr. Craig and Dr. T. J. Galvin participated in a planning conference for the prevention and control of Foot and Mouth Disease in Guyana.

Dr. Galvin presented a paper at a veterinary meeting in Guyana on our haemoparasite research in Colombia.

Dr. Maurer completed work on the National Academy of Sciences Committee on "African Agricultural Research Capabilities" and the 221 page report was published under that title by the Academy. The Committee was supported by USAID funds under Contract No. AID/csd-2584, Task Order No. 7.

Dr. Adams has been conducting research on the cell mediated immunity response of cattle to Anaplasma and Babesiosia infections. He has found that there is both a cell mediated immune response as well as a humoral immunity following exposure to these organisms. His work continues with the objective of developing methods for the production of a maximal protective immunity against these diseases by both cellular and humoral means.

6. Faculty Exchanges to Facilitate Training:

The two workshops described under Item 4 provided for exchanges of faculty.

In addition, Dr. E. Wells from CIAT in Colombia, presented a paper here on trypanosomiasis when he and Dr. Todorovic came in May, 1975, to plan for our next year's program.

7. Publications:

The faculty and graduate students of ITVM have been active

in writing up their work. Over 94 papers, publications, theses and dissertations have been prepared. The references and abstracts of them are presented in Appendix III.

Expenditures Allocated to Accomplishments
for Period: 1 July 1974 to 30 June 1975

Guyana research program	
Salaries	9,000.00
Travel & per diem	3,617.00
Teaching - related salaries	3,000.00
Training Aids	
Related salaries	12,000.00
Supplies & operations	1,600.00
Equipment	403.00
Information Exchange	
Related salaries	5,800.00
Related travel	948.00
Graduate Assistantships	0,395.00

(Related salaries are estimated)

IV. Impact of Grant Support Activities in Developing Institutional Capabilities:

Thanks to this 211(d) program, we have been enabled to convert potentially valuable training material collected during the course of our AID/csd-1947 research program into useful study sets. Study sets of colored slides accompanied by a commentary which permits a student to utilize them independently at his own pace without supervision. This combination of a 211(d) program with a closely related research contract has considerable advantage. Without the related research, the costs of accumulating information and materials for the 211(d) program would far exceed current funding.

The increased availability of training aids and reference material has made it possible for us to offer a graduate course on foreign animal diseases and conduct workshops which materially contribute to the training effort. The participation of the staff in the preparation of training materials is in itself a valuable training exercise for those of us involved.

These training aids are not only for internal use but for use of the several departments of the Veterinary College or other Consortium members.

The competence developed by our staff from the training and experience received through this 211(d) grant and our AID/Colombia contract has enabled us to render considerable assistance on both domestic and foreign animal disease problems which are handicapping production.

The continuing threat of bovine babesiosis (Texas Fever) to Texas cattle through the reinvasion of Texas by Boophilus tick vectors from Mexico has caused much concern among Texas cattlemen who have asked us for help. In large measure, through this stimulus, we have been invited to work on this disease in the new laboratory facilities at Falcon Dam in the Rio Grande River.

Texas and U. S. cattlemen are also handicapped in the exportation of U. S. cattle to Latin America because of losses which occur to susceptible imported cattle from babesiosis and anaplasmosis. The great need to immunize U. S. cattle prior to shipment to infected areas has created much interest among exporters in our premunition research. As a result, the

Texas Department of Agriculture Export Division has offered to build a cattle research barn for us at the Falcon site. This new facility will provide us with the opportunity to work with the tick vectors as well as with the causal organism. This will be a major advantage and permit us to do work here which previously could only be done abroad.

V. Utilization of Institutional Resources in Development:

During the last two years every ITVM staff member has been called upon by some agency of the federal or state government to assist in some foreign program or animal disease problem apart from the 211(d) and AID/Colombia contracts. In addition to those reported last year, Dr. K. L. Kuttler participated this year in the prevention of babesiosis in cattle in the Dominican Republic. He has also assisted through correspondence in the solution of problems in Haiti and Costa Rico.

All of the members of our faculty have continually served on graduate student committees and devoted considerable time to the training of graduate students. For example, Dr. Adams has been the chairman on two graduate student committees and a member on four others.

Our staff and graduate student contributions to the literature have been substantial. A total of over 94 publications are listed and abstracted under Appendix III.

VI. Other Resources for Grant Related Activities:

Texas A&M University has provided all physical facilities, offices, laboratories, libraries, animal quarters, utilities, and many items of equipment for both the 211(d) and AID/Colombia programs. Less tangible has been the free cooperation, consultation, and training offered our staff and graduate students by the University, and especially the Veterinary faculty. It would not have been possible for us to offer degree training through our 211(d) grant if we had not had close cooperation and excellent support from Dr. L. Grumbles, head of Veterinary Microbiology; Dr. C. Bridges, head of Veterinary Pathology, and Dr. R. Bell, head of Veterinary Parasitology, and their faculties. Dr. Bell, for example, with considerable sacrifice, gave

up Dr. Tom Galvin for a two year period while Dr. Galvin has worked in our AID/Colombia project in Colombia. Dr. Grumbles and Dr. Bridges have been willing to pay one-half salaries of Drs. Kuttler, Todorovic, and Adams while they have worked in Tropical Veterinary Medicine. Further, Dr. Grumbles has supported Drs. R. Hidalgo and Dr. Stewart McConnell to work on anaplasmosis and other cattle diseases in close cooperation with our staff in Tropical Veterinary Medicine.

ITVM was enabled to utilize $7,000.00 of Texas A&M Research reserve funds to support Dr. Adams's research this past year.

The Veterinary College photography laboratory has been very helpful in the duplication of photographs for study sets at no cost for labor or equipment.

Dr. Hopps, our graduate student currently completing his research in Colombia, was supported for the two years of his academic work by the Department of Veterinary Parasitology.

VII. Next Year's Plan of Work and Anticipated Expenditures:

Several 211(d) Consortium planning meetings have been held during which there has been agreement that the Consortium should become involved in the study of a country other than Guyana, preferably in Africa.

The ITVM reason for preferring an African country is the need for us to have access to African animal diseases many of which do not occur in the Western Hemisphere. Obviously, if we are to develop a competence for improving livestock health and productivity in the tropics, we need to be knowledgeable of all major tropical diseases wherever they occur. Contagious diseases anywhere are a threat to world food resources.

An approach by correspondence to Kenya may be followed by a preliminary visit to develop the opportunity and establish areas of responsibility for the Consortium members and the Kenyan Government. This to be followed in our case by a two or three month survey of the Kenyan livestock disease situation with emphasis on the diseases and parasites of sheep and goats.

The draft proposal ITVM has provided for possible work inKenya is provided in Appendix IV. This is being included because whether or not arrangements can be made with the Kenyan Government we would like to make a similar proposal to alternate African countries.

The development of our library of information on foreign animal diseases and of our library of training aids will continue. In addition, to utilizing accumulated illustrations and developing them into finished study sets with commentaries, Dr. Maurer plans to revisit the Armed Forces Institute of Pathology and the USDA Emergency Disease Program Center, both of which are in the Washington, D. C. area and from them to obtain copies of pictures which can be added to our collection for the preparation of study sets. In addition, we will grasp any opportunities such as arise during any foreign travel to obtain information or illustrations on foreign diseases of significance. There are some important diseases for which adequate illustrations are not available in the U. S. and for which foreign travel will be required to obtain them unless they can be obtained through exchange with foreign workers. Unfortunately, illustrations obtained through exchange are not always of as good a quality as we can take ourselves. It is estimated that the travel expense incident to this work will be roughly $6,000. The film and related processing and equipment will likely cost about $2,000.00.

During 1 July 1975 to 30 June 1976, the following personnel expenses are anticipated:

Dr. Tom Craig will receive 15% of his salary from 211(d) funds 1 July 1975 to 1 September 1975, $ 574.00

Mrs. H. Cluck, secretary, will receive her salary for the fiscal year starting 1 July 1975 to 30 June 1976, 7,882.00

Three-fourths of Dr. Maurer's salary and allowances will be paid from 211(d) funds, 25,255.00

Dr. David Hopps and one additional graduate student, for period 1 June 1975 to 30 June 1976, 11,250.00

Planned Workshops & Seminars:

A continuing education seminar for Latin livestock producers

as a one-day portion of the annual Texas Animal Agriculture Conference will be presented primarily by 211(d) Consortium members of Texas A&M here in April of 1976.

In the fall of 1975, a tick vector workshop is scheduled in the CIAT laboratories in Colombia, which will involve our professional staff.

On-the-job training of Brazilian veterinarians by our personnel in Colombia will continue. The purpose being to train them in methods of protecting Brazilian cattle against Babesia and Anaplasma by premunition and therapy. Requests have been made for our subsequent involvement in the establishment of a premunition center in Brazil.

Weekly staff seminars for the ITVM staff and graduate students will continue for the planning and review of our work and to provide opportunities for guest lecturers from outside.

The success of our 1975 workshop on exotic animal diseases has encouraged us to conduct one annually.

211(d) BUDGET

1 July 1975 through 30 June 1976

	Salaries			Fringe Benefits*			Work	TOTAL
	%	month	salary	Soc. Sec.	Unemp.	Ins.	Comp.	
Fred Maurer	75	12	$24,066.00	824.85	52.50	180.00	$132.36	$25,255.71
Tom Craig	15	2	545.00	80.62	1.31	4.50	3.00	574.43
Helen Cluck	100	12	7,190.00	420.61	52.50	180.00	39.55	7,882.66
Wayne Morgan	10	12	1,536.00	82.48	5.25	18.00	8.45	1,650.18
Margie Sharpe	05	12	434.00	25.37	2.62	9.00	2.39	473.38
J. Watson	05	12	393.00	23.00	2.62	9.00	2.16	429.78
Secretary	20	12	663.00	38.82	10.50	36.00	3.65	751.97
							TOTAL	$37,018.11

Graduate Assistantships	
David Hopps @$750.00/month for 3 months	2,250.00
Two New Fellowships	18,000.00
Travel	12,000.00
Equipment	4,000.00
Library	1,500.00
Supplies	7,000.00
TOTAL	$81,768.00

*Fringe Benefit Rates

Social Security, 5.85% of first $14,100.00
Unemployment Insurance, 1.25% of first $4,200.00
Workman's Compensation, .55% of local salaries

EXPENDITURES:

1972-1974	1 July 1974 - 30 June 1975	Estimated 1975-76
$39,104.69	$46,766.52	$81,768.00

Table I

Distribution of 211(d) Grant Funds and Contributions From Other Sources of Funding*

Review Period 1 July 1974 to 30 June 1975

	(List all grant-related activities)	211(d) Expenditures			Non-211(d) Funding Amount for 197
		Period under Review 74-75	Cumulative Total	Projected Next Year	Projected to end of Grant	
*	e.g. Research	$11,600.00	$16,484.00	$21,500.00	$32,000.00	AID/csd-1947 = $228,791.00 1 April 1975 - 31 December 75
*	Teaching	3,000.00	3,237.00	3,500.00	3,500.00	
	Libraries					
*	Information	5,800.00	7,800.00	7,500.00	6,500.00	Free consultation Coll Vet Med faculty & ITVM. Academic training for ITVM grad students in Coll Vet Med.
*	Training Aids	12,000.00	13,880.00	12,000.00	12,000.00	Secretarial help
	Supplies	1,600.00	5,228.00	5,000.00	5,000.00	$ 6,000. Photo equipment
	Equip.	403.00	1,853.00	2,000.00	569.00	150,000. University provided labs. & animal facilities.
	Travel & Info. Exch.	1,950.00	4,450.00	10,000.00	11,000.00	40,000. Promised from State Export Division for cattle Research facility at Falcon Dam.
	Graduate Assistant	10,395.00	32,937.00	20,250.00	11,800.00	20,000. Estimated support from College of Vet Medicine.

* Includes estimated prorata salaries & travel to Research, Teaching, Information & Training Aids.

Table II

(Actual & Projected)

Under Institutional Grant #AID/csd-211(d) 3675

Review Period 1 July 1974 to 30 June 1975

(Lines Items to Conform to Budget in Grant Document	Expenditures to Date		Projected Expenditures				TOTAL BUDGET
	1974-75	Cumulative to Date	1974-75	1975-76	1976-77		
	Period Under Review	1972-75	2	3	4		
e.g. Salaries	$29,589.58	$32,993.29		$37,018.00	$52,000.00		$122,011.00
Travel	4,564.62	12,316.23		12,000.00	10,000.00		34,316.00
Equip.	402.84	1,852.90		4,000.00	1,000.00		6,853.00
Other: Teaching							
Libraries	214.98	543.33		1,000.00	1,500.00		3,543.00
Publications				500.00	500.00		1,000.00
Supplies	1,599.35	5,228.06		6,500.00	5,500.00		17,228.00
Graduate Assistant-ships	10,395.15	32,937.40		20,250.00	11,861.00		65,049.00
	$46,766.52	$85,871.21		$81,768.00	$82,361.00		$250,000.00

REPORT OF THE USAID 211d BEEF CATTLE PRODUCTION CONSORTIUM, CONCERNING LIVESTOCK DISEASES IN GUYANA

This report consists of information gained through review of literature; personal communication; observation from 23 May to 1 September, 1974, in those areas of Guyana where cattle are raised; and subsequent laboratory findings.

Not all disease conditions of cattle are discussed. Only those caused by infectious agents or factors affecting large numbers of livestock are considered here. Fortunately, most of those infectious diseases which have decimated the livestock populations of other lands are not present in Guyana or other Western hemisphere countries. If this status is to be maintained, stringent laws affecting imports must be maintained.

CATTLE DISEASES

Tuberculosis:

Inspection records of the Georgetown municipal abattoir were examined for the two and one-half years preceding this study in which 33,889 cattle were slaughtered at this premise and 1,105 (3.26%) were found with lesions suggestive of tuberculosis. As a result of this finding 1,639 cattle were tested by the caudal fold test and 46 reactors identified a prevalence of 2.9%. The cattle tested were selected mostly from animals producing milk for human consumption. These cattle were selected due to public health considerations and relative ease of handling as compared to beef cattle. Each animal had to be handled twice in order to be sensitized and to detect delayed hypersensitivity. Several clinical cases of tuberculosis were identified and appropriate action suggested. The results of tuberculosis testing in various areas of the country are indicated in Table I.

Due to the public health significance of such findings together with the general lack of pasteurization facilities, it is recommended that the Ministries of Health and Agriculture institute a plan of action and introduce suitable legislation towards the eventual eradication of bovine tuberculosis in Guyana. The first efforts should be directed to the public milk supply especially that supplied to various Governmental agencies, i.e., hospitals, schools, etc. The onus should be placed on the producer to provide adequate facilities for the testing of his animals. An accurate method of identifying individual animals must be provided.

The caudal fold test should be quite adequate for conditions encountered in Guyana, but if problems arise in certain areas due to nonvisible lesions reactors, other tests may be considered.

TABLE I TUBERCULIN REACTORS

	No. tested	Reactors	% Reactors
Matthews' Ridge	83	0	0
Essequibo	179	0	0
Mazaruni, Bartica	83	5	6.0
West Demerara	273	0	0
East Bank Demerara	164	8	4.9
Georgetown	263	1	0.4
East Coast Demerara	95	8	7.7
West Berbice	48	8	16.2
East Berbice	314	16	5.1
Ebini	97	0	0
Rupununi	32	0	0
TOTAL	1,639	46	2.9

* In this table and all others in the report the areas of the country are as follows and are indicated in Figure I.

Matthews' Ridge: Matthews' Ridge and Kaituma.

Essequibo: Essequibo coast from Suddie to Charity and the islands of Leguan and Wakenaam.

Mazaruni, Bartica: Mazaruni Prison and Bartica.

West Demerara: West Demerara and East Essequibo coast from Vreed-en-Hoop to Parika and the west bank of the Demerara River from Vreed-en-Hoop to Wales.

East Bank, Demerara: The east bank of the Demerara River from Timehri to Georgetown.

Georgetown: Georgetown and environs including Bel Air Dairy.

East Coast Demerara: From Georgetown to the Abrary River.

West Berbice: From the Abary River to the Berbice River including Kabawa.

East Berbice: From New Amsterdam to Sisters on the east bank of the Berbice River and New Amsterdam to Crabwood Creek along the coast and Black Bush Polder.

Ebini: The Government experiment station at Ebini.

Rupununi: The villages and ranches of Orinduik, Karasabai, Anni, Lethem, Pirara, Marakanata, Napi, Yupukarri, Manari, St. Ignatius, Manari outstation, Dadanawa and Aishalton.

FIGURE I


GUYANA
matthews' ridge
essequibo
georgetown
east coast demerara
west demerara
east bank demerara
west berbice
east berbice
mazaruni bartica
ebini
rupununi

Brucellosis:

A total of 368 sera were tested using the brucellosis card test. No positive sera were identified. This agrees with data collected in 1972 and 1973. Earlier reports indicating a high prevalence of brucellosis probably indicate laboratory error as the present serological study and clinical evidence does not indicate disease. It would appear that this disease is not now a problem in Guyana, and vigorous surveillance of imported livestock should prevent its introduction.

Leptospirosis:

A serological survey done in 1973 indicates a prevalence of 38% of the cattle tested in Guyana had leptospira antibodies. Those sero types associated with cattle disease found in Guyana are listed (not all positive sera were of bovine origin): L. hardjo, L. sejroe, L. canicola, L. icterohaemorrhagiae, L. hebdomadis, L. pomona and L. grippotyphosa. At first glance it would seem that Leptospira are important pathogens in Guyana, especially in view of the high rainfall and warm climate.

No evidence of leptospirosis was encountered either as an acute infection of young calves or a chronic abortion problem. The organism is very susceptible to pH levels lower than 6, and transmission via the acidic ground waters of Guyana is probably negligible.

If, however, in a local area, clinical signs of disease, associated with a rising titre to Leptospira occurs, vaccination with appropriate bacterin may be used. It is unlikely that the use of bacterins against Leptospira as a prophylactic measure at this time would be economically justified.

Anaplasmosis:

A total of 788 sera from native cattle were tested using the Anaplasma marginale card test. There were 668 (84.7%) serologically positive cattle. A considerable percentage of the non-positive cattle were less than 6 months of age (Table II) Eighty four imported cattle at Mon Repos were similarly tested and 55 (65.5%) were serologically positive. A large percentage of those not found to be positive were from one group imported about two and one-half months prior to testing (Table III). Sera from 168 native and imported cattle were tested, at the Texas A&M University Institute of Tropical Veterinary Medicine (ITVM) laboratory with the Anaplasma complement fixation(CF) test. The results compared with those obtained by card test are indicated in Table IV. An agreement of 85.1% was noted between tests.

The serological prevalence of anaplasmosis in various breeds of cattle in Guyana are indicated in Table V. Zebu and Zebu-cross cattle are defined as those with recognizable Bos indicus breeding; European and European-cross which are those exhibiting breed characteristics of any readily recognizable breed (Hereford, Holstein-Friesian, Charolais); and Creole which are cattle of unknown ancestory without sufficient breed

TABLE II

HEMOPARASITE SEROLOGY UTILIZING THE ANAPLASMA RAPID CARD TEST AND BABESIA COMPLEMENT FIXATION TESTS

	A. marginale		B. bigemina		B. argentina	
	>6 mos.	≤6 mos.	>6 mos.	≤6 mos.	>6 mos.	≤6 mos.
Matthews Ridge	*78-84 92.9%	15-16 93.8%	9-84 10.7%	2-16 12.5%	2-84 2.4%	1-16 6.3%
Mazaruni, Bartica	12-12 100%	4-6 66.7%	1-11 9.0%	5-5 100%	0-12 0%	1-5 20.0%
Essequibo	31-38 81.6%	6-10 60.0%	17-37 45.9%	6-10 60.0%	10-37 27.0%	3-10 30.0%
West Demerara	35-53 66.0%	15-22 68.2%	9-53 17.0%	2-22 9.1%	2-53 3.8%	1-22 4.5%
East Bank Demerara	23-25 92.0%	5-13 38.5%	7-24 29.2%	3-14 21.4%	9-25 36.0%	1-13 7.7%
Georgetown	37-45 82.2%	11-12 91.7%	10-44 22.7%	2-12 16.7%	1-44 2.3%	2-12 16.7%
East coast Demerara	59-66 89.4%	22-30 73.3%	17-65 26.2%	15-29 51.7%	5-66 7.6%	1-30 3.3%
West Berbice	23-30 76.7%	4-5 80.0%	14-20 70.0%	4-5 80.0%	7-20 35.0%	3-5 60.0%
East Berbice	41-46 89.1%	6-12 50.0%	22-45 48.9%	6-12 50.0%	4-45 8.9%	0-12 0%
Ebini	90-91 98.9%	6-9 66.7%	27-91 29.7%	6-9 66.7%	9-91 9.9%	6-9 66.7%
Rupununi	118-124 95.2%	27-39 69.2%	35-121 28.9%	18-39 46.2%	14-121 11.6%	5-38 13.2%
	547-614 89.1%	121-174 69.5%	168-595 28.2%	69-173 39.9%	63-598 10.5%	24-172 14.0%

* Number positive - number tested

' Percent positive

TABLE III

Serology for Hemoparasitic Organisms at Mon Repos, Guyana

	Imported heifers*					
Groups	A. marginale		B. bigemina		B. argentina	
1	8-8**	100.0***	5-8**	62.5***	3-7**	42.9***
2	10-11	90.9	10-11	90.9	5-11	45.5
3	6-6	100.0	6-6	100.0	3-6	50.0
4	5-6	83.3	5-6	83.3	2-6	33.3
5	11-13	84.6	8-13	61.5	7-13	53.8
6	11-13	84.6	11-13	84.6	5-13	38.5
7	0-21	0	14-22	63.6	13-22	59.1
8	3-17	16.7	16-17	94.4	15-17	83.3
9	16-27	59.3	24-27	88.9	25-25	100.0
Total	70-122	57.4	99-123	80.5	75-120	62.5
Native heifers****	7-8	87.5	1-8	12.5	1-8	12.5

* Heifers imported into Guyana from Boophilus-free zones at 4-6 months of age, present in country from 6 weeks to 1 year at time of collection. Group 1 in Guyana the longest period of time; group 9 shortest. Heifers imported at 4 to 8 week intervals.

** Number serologically positive - number tested

*** Percentage serologically positive

**** Selected native heifers raised with imported heifers at Mon Repos associated with different groups of approximately equal size and condition.

TABLE IV

Comparison of the Anaplasma Complement Fixation (CF) Test and Card Test Test (CT) Results Using Sera Collected in Guyana

	CT+	CT-	% Agreement
CF+	102	8	92.7%
CF-	17	41	70.7%
% Agreement	85.7%	83.7%	

characteristics to be placed elsewhere.

TABLE V

A Comparison of Cattle Breeds in the Prevalence of Hemoparasite Positive Sera in Guyana

	A. marginale	B. bigemina	B. argentina
Zebu and Zebu X	162-186 87.1%	45-181 24.9%	19-163 11.7%
European and European X	250-305 82.0%	107-299 35.8%	40-257 15.6%
Creole	254-295 86.1%	85-290 29.3%	28-263 10.6%

This high prevalence of infection within the country practically ensures that imported cattle will come into contact with the organisms during their first year in the country (Table VI). The possible use of a killed A. marginale vaccine prior to export, or supervised premunition on arrival, may help relieve the serious stress placed on the animals during the acute phase of the disease.

Babesiosis:

Both Babesia argentina and Babesia bigemina were identified in blood films collected in Guyana. Complement fixation tests were run on sera collected from various regions in Guyana. The criteria for a positive serum was one that demonstrated 3 or 4+ (less than 50% hemolysis) intact sheep erythrocytes in a test system using a 1:5 serum dilution screen test. Of 768 native cattle tested, 237 (30.9%) were serologically positive for B. bigemina and 87 of 770 (11.3%) were positive for B. argentina (Table II). Cattle recently imported into Guyana were similarly tested with 99 of 123 (80.5%) positive for B. bigemina and 75 of 120 (62.5%) positive for B. argentina (Table III).

Boophilus ticks are the only known vector of bovine Babesia in the Western hemisphere. Several studies done elsewhere indicate a resistance by Zebu cattle to Boophilus ticks and a lower prevalence of Babesia due to lower challenge and a natural resistance to B. argentina by Bos indicus cattle. Table V indicates the prevalence of serologically positive cattle in various breed types with the Zebu cattle having a lower prevalence of antibodies than European cattle. Serological testing indicates only the presence or absence of antibody and give no indication of severity of disease an animal might have had or may experience. Perhaps the criteria of 3 or 4+ as being positive was too high to get a true picture of the prevalence of babesiosis as sera of many of the cattle considered negative had the ability to fix some complement. This ability to fix complement may have been due to small amounts of specific antibody or

TABLE VI

Serological Changes Incurred by a Group of Heifers Imported Into Guyana

Calf No.	A. marginale * 1	25	35	51	B. bigemina 1	25	35	51	B. argentina 1	25	35	51	PCV[1] 1	25	35	51
6143	-	-	-	+	-	-	+	+	-	-	A	+	35	31	22	25
6281	-	-	-	-	-	-	+	+	-	+	A	+	34	33	21	34
6514	-	-	-	-	A	-	-	+	A	-	-	+	30	28	29	22
6520[2]	-	-			-	-			-	-			35	19		
6581	-	-	-	-	-	-	+	-	-	+	+	+	31	21	22	16
6598[3]	-	-	-	-	-	-	+	+	-	-	+	+	38	25	27	28
6694	-	-			-	+			A	-			33	22		
6878	-	-	-	+	-	+	-	+	-	+	-	+	30	28	15	26
6886	-	-	-	-	-	-	-	+	-	-	-	+	34	31	21	36
6896	-	-	-	+	-	+	A	+	A	+	A	+	28	19	26	33
6906	-	-	-	+	-	+	+	+	-	+	-	+	40	43	30	26
6912	-	-	-	+	-	-	+	+	-	-	-	+	47	46	34	35
6931	-	-	N	+	-	+	N	+	-	+	N	+	35	19	N	29
6971	-	-	-	+	-	-	A	+	-	-	A	A	35	25	26	23
6985	-	-	N	+	-	+	N	+	-	+	N	+	31	25	N	25
7040	-	-	-	+	-	-	-	+	-	-	-	+	32	25	23	27
7050	-	-	-	+	-	+	+	+	-	+	-	+	32	10	25	29
7062	-	-	-	+	-	-	+	+	-	-	+	+	31	15	21	24
7096	-	-	-	-	-	-	+	+	-	+	+	+	42	19	25	23
7144	-	-	-	+	-	-	+	+	-	-	+	+	39	35	26	24
7153	-	-	-	+	-	-	+	+	-	-	+	+	39	13	22	29
7168	-	-	-	+	-	+	+	+	-	-	-	+	34	37	29	29
7187	-	-	-	+	-	-	-	+	-	-	-	+	38	31	26	28
7188	-	-	-	+	-	+	+	+	-	A	-	A	35	30	37	29
7192	-	-	-	-	-	-	+	+	-	-	A	+	35	31	24	27
7209	-	-	-	-	-	-	+	+	-	-	-	+	39	28	25	24
7211	-	-	-	-	-	+	+	+	-	A	+	+	44	33	27	29
7231	-	-	-	-	-	-	+	+	-	-	-	+	34	28	25	30
**	0	0	0	16	0	10	17	25	0	9	7	24	35.4	27.7	25.3	27.3
	28	28	26	26	27	28	24	26	25	26	19	24				
	0	0	0	61.5	0	35.7	70.8	96.2	0	34.6	36.8	100				

* days after arrival in Guyana

** number positive/number tested over percentage positive

[1] PCV packed erythrocyte volume

[2] calf died with B. argentina parasitemia

[3] calf died with B. bigemina parasitemia

A anticomplementary serum

N not available

to non-specific erythrocytic antibody against the crude antigen utilized in the complement fixation test.

The susceptibility of imported cattle to Babesia infections are demonstrated in Table VI. As can be seen from Table VI, the calves first demonstrated B. argentina and B. bigemina antibody by day 25 and A. marginale by day 51. Despite timely treatment, two calves of the original test group died with signs of babesiosis which indicated the need for extreme caution when importing cattle, especially from Babesia-free areas. The use of prophylactic drug treatment or induced premunition coupled with appropriate drug therapy is indicated especially when large numbers of cattle are imported.

Trypanosomiasis:

The examination of 1060 blood films from both native and imported cattle revealed four animals with a parasitemia of Trypanosoma vivax. In addition, 657 wet mounts were examined in an effort to detect trypanosomes; no trypanosomes were seen in wet mounts. The serological prevalence is unknown as is the economic importance of this organism.

Eperythrozooniasis:

One of 1060 blood films examined contained Eperythrozoon wenyoni and two contained E. teganoides. These calves were anemic and concurrently infected with Babesia bigemina. It is likely the Eperythrozoon parasitemia was stimulated by the stress incurred by the Babesia infection.

Helminth Parasites:

In an effort to determine which helminths are present in the country and give support to the field veterinarian as far as treatment and control programs are concerned, gastro-intestinal tracts from 21 cattle slaughtered at the Georgetown abattoir and 9 from the Lethem abattoir were examined grossly, washed, and an aliquote of gastro-intestinal contents examined with a dissecting microscope. The liver, larynx, heart, diaphragm, skeletal muscle, nuchal ligament and body cavities were examined grossly. One hundred fifty fecal flotations were examined. Feces were collected from young calves and from cattle with clinical signs of gastro-intestinal helminthosis.

The following helminths parasitizing cattle in Guyana were identified: Cotylophoron sp., Ostertagia sp., Trichostrongylus axei, Haemonchus contortus, Cooperia punctata, Bunostomum phlebotomum, Strongyloides papillosus, Toxocara (Neoascaris) vitulorum, Capillaria bovis, Oesophagostomum radiatum, Moniezia sp., Trichuris discolor, Dictyocaulus viviparus, Mammaomonogamus (Syngamus) laryngeus, Onchocerca linealis, Artionema (Setaria) labiatopapillosa and lesions of Stephanofilaria stilesi.

Comparisons of the helminthic fauna of the gastro-intestinal tracts of cattle from coastal areas and the Rupununi are given in Table VII. The cattle slaughtered at Lethem were older cattle killed at the end

of the rainy season, whereas in Georgetown, cattle from one year to aged were slaughtered during the rainy season. No history was available as to anthelmintic treatment of these cattle. Comparisons of numbers of worms obtained would not be significant. It is likely that examination of younger cattle (< 6 months of age) or at different seasons would result in relatively different faunas. Parasite profiles for the rainy season at Georgetown and Lethem are indicated in Figure II.

TABLE VII

Gastro-intestinal Helminths from Two Environmentally Dissimilar Areas of Guyana

	Georgetown (Coastal)		Lethem (Rupununi-Savannah)	
	%[1]	mean[2]	%[1]	mean[2]
Haemonchus	85.7	276	100.0	798
Trichostrongylus	76.2	114	100.0	259
Ostertagia	76.2	151	11.4**	20
Bunostomum	19.0	48	-----	---
Cooperia	81.0	1932	44.4	255
Capillaria	4.8	10	11.1	10
Oesophagostomum*	57.1	48	11.1	20
Trichuris	9.5	15	22.2	40

[1] Percent of cattle from which helminths were recovered

[2] Mean number of helminths recovered from parasitized cattle

* Gross intestinal lesions of larval Oesophagastomum radiatum were identified in 19 of 21 Georgetown cattle and 9 of 9 from Lethem. Only adults are recorded in this table.

** Only L_4 Ostertagia recovered at Lethem

Table VIII indicates the prevalence of Mammomonogamus laryngeus and Onchocerca linealis in different geographic regions of Guyana.

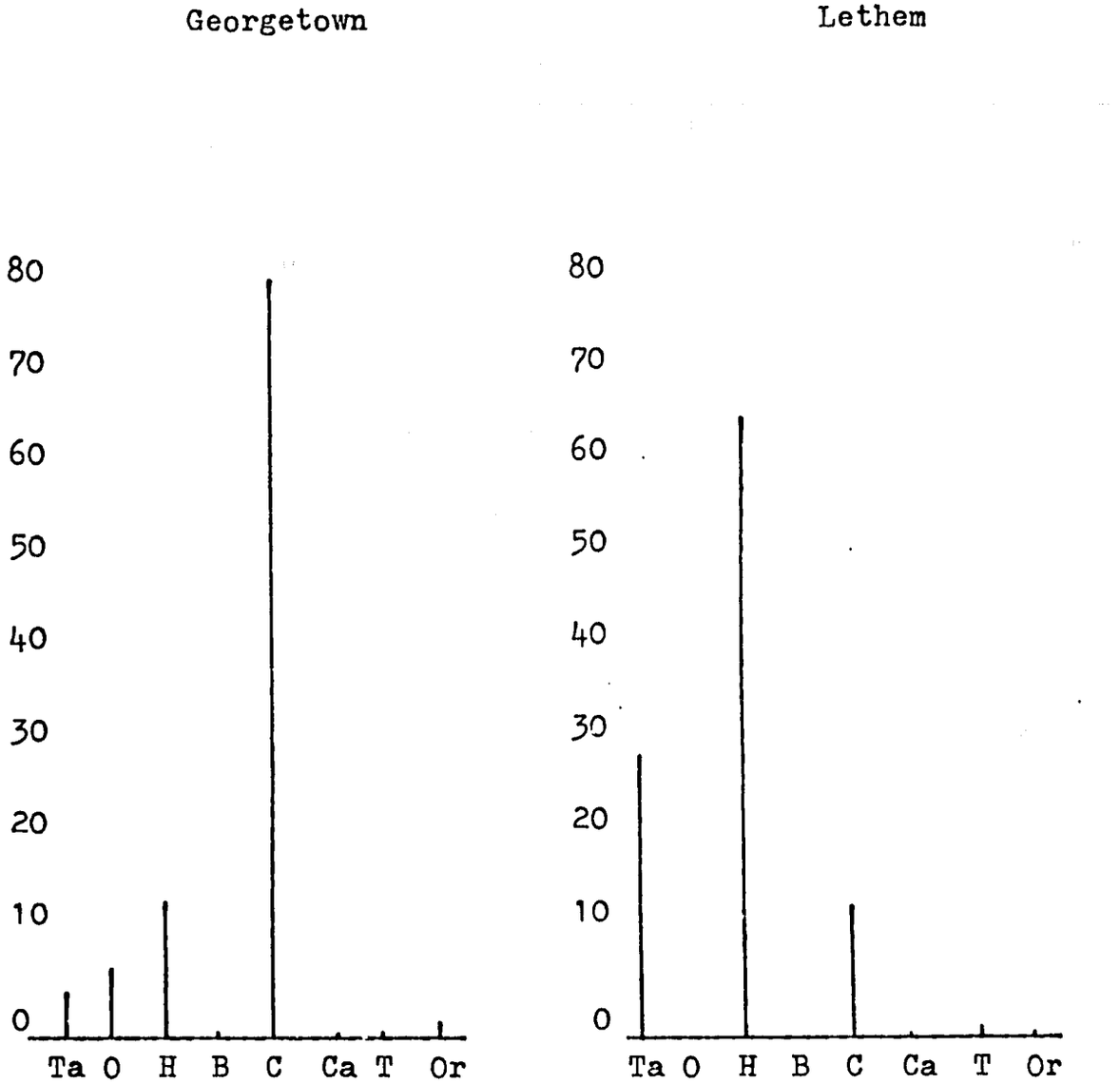
TABLE VIII

	Mammomonogamus		Onchocerca	
Georgetown	17/53*	32.1%	28/52	54.9%
Ebini	0/1	0	0/1	0
Lethem	0/13	0	22/33	66.7%

* Number positive/number examined, % positive

FIGURE II

Parasite Profiles of Cattle in Different Environmental Areas of Guyana. Percentages of parasite genera based on total number of adult trichostrongyloid nematodes recovered.



Ta= Trichostrongylus; O= Ostertagia; H= Haemonchus; B= Bunostomum; C= Cooperia; Ca= Capillaria; T= Trichuris Or= Oesophagostomum

Lesions of Stephanofilaria stilesi were observed only at Ebini. At the time of observation the intermediate host Haematobia irritans was present at Ebini in tremendous numbers, not noted in other parts of the country.

The most interesting observation was the failure to find evidence of infection with, or confirmed reference to, Fasciola sp., or Cysticercus bovis. The methods of meat inspection as generally practiced in Guyana might very well allow individual infections with these parasites to go unnoticed, but, if present, they would eventually be identified.

One of the possible reasons for the lack of Cysticercus bovis infections in Guyana may be sociological as many of the cattle owners and herdsmen do not eat beef. However, this does not apply to the Rupununi. When cysticercosis is first identified, efforts should be made by the Ministries of Agriculture and Health to trace the human source of Taenia saginata and cattle possibly exposed should be slaughtered under rigid inspection.

Because fascioliasis and schistosomiasis are unknown in Guyana, the Ministries of Health and Agriculture, possibly in conjunction with the University of Guyana, should undertake a survey of the snail population in the country with particular attention to pH, salinity and water temperatures where the snails are gathered. If snails suitable to be vectors of these conditions are found then vigorous examination of imported livestock and examination of persons from endemic areas should be instituted.

External Parasites:

Boophilus microplus ticks were found in nearly all parts of the country. No attempts were made to compare populations in the various regions, due to difficulties in assessing tick numbers under field conditions. However, it was noted that the numbers of ticks parasitizing cattle was the greatest on the Essequibo coast, especially at the Essequibo Boys' School. The number of ticks found on some of the cows was so great as to give a pebbled appearance to the skin. These cattle were suffering from severe allopecia and any resistance they may have established was completely overwhelmed. It is suggested that the ticks from this area be examined for ixocide resistance.

Boophilus microplus was also found on horses and water buffalo, but cannot be considered an important parasite of these species.

The cattle from Aishalton, Rupununi, were apparently free from Boophilus ticks. No ticks were found on careful examination of sixteen head of cattle, and the vaqueros stated that cattle did not have ticks at Aishalton. However, 4 head were serologically positive to at least one species of Babesia, which is as far as is known transmitted only by Boophilus ticks or by blood passage. Perhaps further investigation would reveal small numbers of ticks, possibly present only during certain seasons. If indeed only small numbers of ticks or no ticks are found in the area, the reason for this should be ascertained.

Amblyomma triste was collected from a cow at Ebini; this is the first report of this tick species in Guyana. It is unlikely that this tick is an important cattle parasite. Several A. cajennense were found in the vicinity of corrals in the Rupununi, and it is likely that they occasionally parasitize cattle but it is not considered to be an important cattle parasite at this time.

The tail louse Haematopinus quadripertusus was seen on cattle in coastal regions; most were seen on poorly managed farms.

Flying insects, or their larvae, parasitizing cattle in Guyana include: Haematobia (Siphona) irritans, Cochliomyia hominivorax, Dermatobia hominis Simulium haematopotum and several genera of mosquitoes. The first three species were found in greatest numbers at Ebini, and S. haematopotum only in the Rupununi. Other flying insects are undoubtedly parasitizing Guyanese cattle, but specimens were not collected.

Foot-and-Mouth Disease:

Periodic outbreaks of Foot-and-Mouth Disease have occurred in the Rupununi Savannah. The economic disruptions that such a disease causes are far greater than the actual losses of production. Because of the ease with which it is possible to move livestock from Brazil, strict surveillance and a good education program to inform the local population about the dangers of moving livestock are necessary. Attempts to keep Guyana free of Foot-and-Mouth Disease will require the utmost cooperation on the part of the Brazilian authorities. A buffer zone vaccination program along the Brazilian border using killed vaccine will aid in prevention of the spread of the disease to susceptible cattle in other parts of the country.

Foot-and-Mouth Disease-free zones could be set up in the country in areas where the disease has never been reported and beef from the Rupununi is not consumed.

Rabies:

Rabies in cattle has been reported from the Rupununi, upper Berbice and Essequibo islands. Vaccination programs and vampire bat Desmodis rotundis control will help to control the disease in cattle.

Care must be taken not to diagnose all central nervous system disease as being rabies. Accurate diagnosis should be determined in all outbreaks.

Mineral Deficiencies:

Previous studies indicate the following minerals to be deficient in certain areas of Guyana: Phosphorus, cobalt, copper and zinc.

Sera from 429 cattle were examined by standard tests* to determine

* Hycel Test Kits, Hycel Inc. Houston, Texas

calcium and phosphorus levels. Results are indicated in Table IX. The results indicate that the serum calcium and phosphorus levels in general fall within the accepted normal range, however, phosphorus levels at Matthew's Ridge are less than the generally accepted 4 mg/dl. The generally high phosphorus levels in the Rupununi are surprising in view of past findings.

The technical problems were encountered with sera from certain areas. Hemolysis may have caused an abnormally high spectrophotometer reading. This was not considered to be a problem with many samples, and samples obviously hemolyzed were not used for serum chemistry.

Mineral supplements are recommended for all areas of Guyana with local needs considered as to the contents of the supplements.

Others:

Reports mention outbreaks of anthrax and blackleg but they do not seem to be widely present now, possibly due in part to the low pH of the soils within the country.

I have encountered what appears to be a clostridial infection in calves whose post mortem findings include subcutaneous edema, gasseous inflation of liver and kidney, and pulmonary emphysema, edema and rapid autolysis. Diagnostic capabilities for anaerobic organisms are essential for accurate diagnosis and recommendations.

Liver cirrhosis is seen occasionally in the abattoirs as are cattle showing lesions of photo sensitivity. The plant, or plants, suspected of causing this toxicity should be fed to experimental animals and results noted.

Specimens for histopathology were examined at Texas A&M University and helped to confirm diagnoses of hepatic damage and possible clostridial infections. Indications of chronic infectious disease were encountered, indicating possible hemoparasitic infection.

A condition known as "water itch" in calves is often seen on the coast during the rainy season. Unsuccessful attempts were made to isolate pathogenic fungi. The etiology of this condition should be investigated.

Clinical diagnoses of dermatophilosis were made. The lesions were most commonly found on the trunk and neck and could be associated with tick infestation. It is possible that Dermatophilus congolensis is the etiologic agent of "water itch"

The foremost 'disease' of cattle in Guyana is one of malnutrition. The practice of penning animals without access to forage at night and of milking beef cows during the first few months of a calf's life are not ones

TABLE IX

SERUM CHEMISTRY

AREA	>8 mo. No.	>8 mo. Ca Meq/L	>8 mo. PO4 mg/dl	≤8 mo. No.	≤8 mo. Ca Meq/L	≤8 mo. PO4 mg/dl
Matthew' s Ridge	28	5.02± 0.39	3.74 ± 0.64	5	4.62± 0.39	4.96 ± 1.27
Mazaruni, Bartica	8	4.53 ± 0.56	6.63 ± 1.7	5	4.46 ± 0.07	6.72 ± 0.59
Essequibo	19	4.44 ± 0.48	6. . ± 1.2	5	4.74 ± 0.84	7.53 ± 0.62
West Demerara	25	5.13 ± 0.52	4.08 ± 0.54	13	5.31 ± 0.54	4.86 ± 0.54
East bank Demerara	9	4.66 ± 0.5	5.55 ± 2.05	9	5.12 ± 0.75	7.07 ± 1.45
Georgetown	20	4.88 ± 0.46	4.34 ± 1.56	11	4.79 ± 0.55	6.59 ± 2.36
East coast Demerara	29	4.97 ± 0.57	4.78 ± 1.62	18	5.24 ± 0.64	6.81 ± 2.61
West Berbice	14	4.33 ± 0.67	5.72 ± 1.72	3	5.27 ± 0.49	7.78 ± 1.6
East Berbice	22	4.16 ± 0.48	6.98 ± 1.83	5	4.74 ± 0.58	7.63 ± 1.78
Ebini	22	4.28 ± 0.56	6.21 ± 1.36	10	4.51 ± 0.49	6.85 ± 0.99
Rupununi	60	5.04 ± 0.55	6.21 ± 1.68	18	5.38 ± 0.55	8.41 ± 1.24
	256	4.77 ± 0.6	5.45 ± 1.79	102	5.08 ± 0.28	6.86 ± 1.92
Imports	24	5.04 ± 0.39	4.76 ± 0.51	47	4.82 ± 0.38	7.66 ± 1.6

which allow the young animals to reach their full potential prior to weaning.

These malnourished cattle are more susceptible to the inroads of parasitisms or infectious disease as well as being inefficient converters of roughage into meat.

SHEEP AND GOAT DISEASES

Not much work has been done with the diseases of sheep and goats which is rather surprising, considering the esteem in which mutton is held in Guyana. The purpose of these investigations was to look at cattle diseases; however, in the course of work, sheep and goats were examined.

Internal Parasites:

The younger sheep were in generally poor condition throughout the country, with the exception of the areas of East Berbice and Karasabai in the Rupununi. The older animals were in better condition. An important consideration in sheep and goats is that of internal parasitism. The following helminths were found: Paramphistomum sp., Haemonchus contortus, Ostertagia sp., Trichostrongylus axei, Bunostomum trigonocephalum, Cooperia curticei, Trichostrongylus colubriformis, Moniezia sp., and Oesophagostomum columbianum. Management practices, such as a definite breeding season, pasture rotation and strategic drenching of ewes at the time of parturition coupled with vigorous, effective anthelmintic treatment of lambs and kids are necessary to keep the parasite numbers in control.

Mineral Deficiencies:

Mineral deficiencies encountered in cattle are likely to be present also in sheep and they may in fact be more sensitive to trace mineral deficiencies. Trace mineral deficiencies, especially Cobalt and Selenium, should be investigated. Serum calcium and phosphorus determinations were run on 9 sheep. Serum calcium levels were $5.86 \pm .53$ Meq/L and phosphorus 6.26 ± 1.05 mg/dl within the normal range.

Clostridial Infections:

Diseases caused by Clostridium spp., are a problem wherever sheep are raised. Gross lesions and histopathology indicate that Guyana is not an exception. Adequate diagnostic facilities are needed to determine which specific clostridial diseases are present in the country.

HORSE DISEASES

The horse has a definite role in the cattle industry of Guyana and death or incapacity of horses can cause serious disruptions to the industry. No post mortem examinations on horses or donkeys were performed during this investigation, but available information indicates that the internal parasite problem in Guyana is similar to that of other countries with a similar climate. A regular worming program should be carried out.

External Parasites:

Anocenter nitens was found on horses living between the Demerara and Berbice Rivers, on the coast and in the Rupununi. Regular treatment of the ears of horses infested with this tick is recommended as tick worry, secondary bacterial, fungal infections or myiasis can occur as a result of heavy infections. Anocenter may be the vector of Babesia equi in Guyana. Boophilus microplus ticks were found on horses at Ebini, but it is not thought this tick is an important parasite of horses in Guyana.

Trypanosomiosis:

Wet blood mounts and stained blood films were examined from 47 horses. No trypanosomes were observed. However, well documented evidence indicates that Trypanosoma evansi infections have caused considerable death losses in the Rupununi district and it is likely that outbreaks may occur in the future. Prompt diagnosis and treatment will be necessary to control the disease.

Babesiosis:

Examination of 47 stained blood films failed to disclose evidence of Babesia organisms. However, serological testing, at the USDA Agricultural Research Center, revealed 30 of 45 sera had CF titers of 1:5 or higher to B. equi but all sera were negative for B. caballi. Data on serologic status and packed erythrocyte volumes (PCV) are given in Table X.

Rabies:

Bat transmitted rabies has been a recurring problem especially in the Rupununi. This problem should be handled in the same manner as with cattle.

Encephalomyelitis:

Both Eastern and Venezuelan types of viral encephalomyelitis have been reported in Guyana. Accurate differential diagnosis of CNS disturbances in horses is essential as the viral encephalomyelitis, rabies, trypanosomiasis and cerebral babesiosis may have similar clinical signs.

Hemagglutination inhibition titers were run on 46 sera for Eastern

TABLE X

Serological Testing of Horses in Guyana

District	No.	Sex	Age	[1]PCV	[2]VEE	[3]EEE	[4]EIA	[5]B. equi
Coastal								
Golddiggings	1	F	1½	23	80	40	+	5
"	2	F	6 mo	29	20	40	+	40
"	3	M	1	36	-	-	-	
"	4	F	7	40	-	-	+	40
"	5	F	1	32	20	-	+	160
"	6	F	10	26	-	-	+	640
Kabawer	7	M	Aged	37	20	20	+	5
"	8	M	10	30	20	-	+	20
"	9	M	10	31	-	-	+	-
"	10	M	10	33	-	-	+	-
Rupununi								
Karasabi	11	M	5	36	-	-	-	20
"	12	M	5	30	-	10	-	-
"	13	M	3½	33	-	-	-	-
"	14	M	8	33	-	-	-	-
"	15	M	10	28	20	10	+	-
"	16	M	7	30	20	20	-	5
Aishalton	17	M	10	30	10	-	+	10
"	18	M	17	26	-	-	+	5
"	19	M	3	30	40	40	+	-
"	20	F	5 mo	39	20	-	-	40
"	21	M	7	34	40	-	+	10
Dadanawa	22	*M	3	37	40	-	-	-
"	23	M	11	33	20	40	+	40
"	24	M	7	36	-	-	+	20
"	25	M	1	31	-	-	+	5
"	26	M	7	30	-	10	+	5
"	27	M	2½	33	-	10	-	5
Manari Outstn.	28	M	3	32	40	40	+	-
"	29	F	7	31	-	-	+	10
"	30	M	3	40	-	40	-	10
"	31	M	6	36	-	40	+	80
"	32	M	7	35	-	-	+	-
"	33	M	5	36	20	-	+	-
"	34	M	6	36	10	-	+	5
Meetizur	35	M	1 wk	43	80	10	+	40
"	36	F	2½	46	20	-	-	5
"	37	F	3 mo	47	40	-	-	-
"	38	F	6	33	40	-	+	10
"	39	F	9	39	20	-	+	-
St. Ignatius	40	M	8	21	10	-	+	40
"	41	F	8	37	20	-	+	20
"	42	M	3	31	-	-	+	-
"	43	M	5	33	-	-	+	5
"	44	F	4	27	-	-	+	-
"	45	M	Aged	25	10	-	+	80
"	46	M	12	26	20	20	+	320

* Imported horse

TABLE X (Cont'd)

[1] PCV = packed erythrocyte volume determined by microhematocrit

[2] VEE = Venezuelan Equine Encephalomyelitis reciprocal of hemagglutination inhibition test titer

[3] EEE = Eastern Equine Encephalomyelitis reciprocal of hemagglutination test titer

[4] EIA = Equine Infectious Anemia immuno-diffusion test

[5] B. equi = Babesia equi reciprocal of complement fixation test titer

(EEE), Western (WEE) and Venezuelan (VEE) encephalomyelitis at the TAMU Department of Veterinary Microbiology Laboratories. Three horses had a titer of 1:10 for WEE; all three also exhibited a titer of at least 1:40 to one of the other two viruses and it is thought that this indicates a cross reaction, and not evidence of WEE being present in Guyana. However, 15 of 46 exhibited titers of 1:10 or higher to EEE and 25 of 46 for VEE. It is likely that some cross reactivity was also present but evidence presented in Table X indicates the recent presence of both organisms within Guyana.

It is recommended that valuable horses be vaccinated annually or bi-annually against Eastern and Venezuelan encephalomyelitis, and upon diagnosis of the disease a vigorous vaccination program be instituted in the district where diagnosed. To further prevent the spread of disease, if Venezuelan encephalomyelitis is diagnosed, strict quarantine of horse movement from that district is advocated.

Equine Infectious Anemia:

Clinical evidence did not indicate a high prevalence of equine infectious anemia (EIA) in Guyana. At the Texas State Veterinary Diagnostic Laboratory, College Station, Texas, the agar gel immuno-diffusion test (Coggins test) was run on 46 sera; 34 were positive for EIA. Sera collected for this test was taken from horses in West Berbice and the Rupununi. The prevalence of disease seemed to be equally high in all areas of the country except for Karasabi, Rupununi where only 1 of 6 (16.7%) horses were serologically positive as compared to 33 of 40 (82.5%) in other areas tested as indicated in Table XI.

Due to the small number of horses tested, it is not known whether vector-borne diseases are less of a problem in Karasabi than in other areas of the country, or, due to sampling methods, negative horses were selected at Karasabi and a high percentage of positive horses elsewhere. The serological prevalence of vector-borne diseases is indicated in Table XI.

It would seem that EIA may be an important factor in the general poor condition exhibited in horses in the country. This lack of stamina and chronic poor doing would make the horses more susceptible to effects of poor nutrition and infectious disease.

TABLE XI

Comparison of Vector-Borne Diseases of Horses in Guyana as Indicated by Serological Means

	VEE	EEE	EIA	B. equi
Karasabi	2/6 33.3*	3/6 50.0	1/6 16.7	2/6 33.3
Rest of Country	23/40 57.5	12/40 30.0	33/40 82.5	28/39 71.8

* number positive/number tested percent positive

Brucellosis:

Three horses with fistulous withers and/or pollevil were tested serologically for brucellosis by the card test. All were negative.

Tetanus:

Tetanus is present in Guyana and care should be taken to routinely use tetanus antitoxin with all surgical producers or puncture-type wounds in horses. Valuable horses should be immunized with toxoid. The practice of packing wounds with fresh cow or horse dung should be discouraged.

Nutrition:

As with other species, poor nutrition of horses could be considered the number one medical problem throughout the country. Serum calcium and phosphorus levels were determined at the Department of Pathology laboratories at TAMU. Sera from 15 horses were found to contain 11.44 ± 2.13 mg/dl calcium with a range of 9.8 to 18.1. Sera from 18 horses were found to contain 4.96 ± 2.06 mg/dl phosphorus with a range of 2.85 to >10. It therefore seems unlikely frank calcium or phosphorus deficiencies are likely to occur at least in those horses having access to phosphorus supplements. The status of trace minerals in the diet of horses in Guyana is unknown but there was no clinical evidence of disease caused by trace mineral dificiency.

In most areas of the country where horses are utilizing unimproved pastures without concentrate supplementation, the protein and caloric intake is generally insufficient to allow for normal growth rates and to allow energy to be used for much work. The pony-type horse such as is often seen, especially in the Rupununi, is probably the only class of horse which will survive the environment without supplementation. It is unlikely the "breeding up" of horses with outside stock having greater stamina will be successful without the addition of concentrates to the diet.

VETERINARY SERVICES IN GUYANA

Two important deficiencies exist in veterinary services in Guyana. There is a lack of continuity of veterinary service and a well equipped diagnostic center.

Due in part to the inability of government to attract and keep competent veterinarians, a lack of continuity exists. This lack of continuity requires that each veterinarian entering an area must acquaint himself with local disease conditions without benefit of knowledge acquired over the years.

A staff of less than adequate size and the rapid shifting of veterinarians from one area of the country to another also contributes to this

lack of continuity. In order to attract and keep the quality of veterinarians desired, it will be necessary to provide remuneration and working conditions in line with that provided for similar qualified personnel in government and to take into account the wages provided in countries of similar development. The necessity for young veterinarians to have to hold outside jobs, as well as their duties for the ministry, in order to provide for their families is ridiculous.

No competent veterinary service can exist without the aid of a diagnostic laboratory. This laboratory must consist of a facility which will allow for diagnostic procedures and which contains equipment to carry out the work as well as personnel well trained in diagnostic techniques. The proposal for establishing such a center in Mon Repos near the proposed center for the training of field veterinary assistants is good, as personnel associated with the diagnostic center may be able to take part in the training program.

Three more field veterinary officers are needed; one in the Rupununi; one in Berbice and a third in the West Coast Demerara, Essequibo. Regular veterinary service must be provided for Matthews' Ridge and Ebini.

The idea of Veterinary field assistants is a good one. However, the present livestock assistants are not as effective as they should be. This lack of effectiveness is in some degree due to the failure of continuing and direct supervision by the respective veterinary officers. Having more veterinary officers and a program setting down duties and responsibilities of the livestock assistants will be necessary to get the full value from these men. A more careful selection of men to be trained in this area is necessary.

The livestock assistant has a great opportunity for extension work in his area, but I have found that many do not even know the names of the farmers living in their districts even after a residence of 1 or 2 years.

Little or no efforts are placed on extension work with the young. Reestablishment of 4-H clubs, young farmers' groups, etc. would be desirable. The livestock assistant, with guidance, could be instrumental in establishing such groups. Without such programs to interest the young in agricultural pursuits, the highest quality young men and women go into other fields of endeavour. It is from work with rural youth that future veterinarians, livestock assistants and other agriculturists should come.

ACKNOWLEDGMENTS

In the course of this study a great number of persons were involved in the collection and evaluation of data. It will not be possible to acknowledge all of the people who contributed to this study; however, I will attempt to recognize some of those whose work was most important to the study.

Whilst in Guyana, the cooperation of the Ministry of Agriculture and National Development, Dr. P. A. Reid, Minister, was invaluable. Dr. Peter Fernandes, principal veterinary and livestock officer, and Dr. Frank Mongul, principal veterinarian, Ministry of Health, provided contacts and cooperation with members of their respective Ministries and the general populace without which this work could not have been accomplished. I am especially grateful for the help rendered by various livestock assistants and AI technicians throughout Guyana, and to individual farmers who allowed us to sample their livestock.

The following veterinary and livestock officers gave of their time and advice in the collection and evaluation of data; S. Ramudit, E. Sanford, L. Applewhaite, A. Fox, N. Raja, N. Holder, V. McPherson, C. Edwards and L. Amsterdam. Laboratory assistance was provided by Mr. N. Sawh, Ms. J. Mohammed and Mr. Quintain. Assistance in the abattoirs was provided by Mr. Fung-on, M. Don and G. Lomax.

Special thanks go to Dr. T. J. Galvin for assistance in collection of samples and identification of helminths and valuable advice and encouragement.

Laboratory assistance was provided by members of the TAMU, ITVM staff in Colombia and Texas, L. E. Rameriz, R. F. Long and Ms. J. Slaughter, TAMU; Department of Veterinary Pathology, Dr. L. G Adams and Ms. J. Coker; Department of Veterinary Microbiology, Dr. J. E. Grimes; Department of Veterinary Parasitology, Ms. L. Logan; Department of Entomology, M. Price; Texas State Veterinary Diagnostic Laboratory Coordinator, Dr. H. Whitford; United States Department of Agriculture, Haemoprotozoan Diseases Laboratory, Dr. W. M. Frerichs.

Helpful suggestions and aid were rendered by other members of the ITVM staff, Drs. F. D. Maurer, R. A. Todorovic and K. L. Kuttler; USAID Food and Agriculture Officer, Guyana, Mr. G. S. Eason, gave valuable advice and Ms. Z. Zaman secretarial assistance.

Thanks also go to Ms. E. Craig for assisting in field collections and record keeping and H. Cluck for preparation of this report.

Thomas M. Craig
D.V.M., M.S.

APPENDIX II

Training Aids Prepared

The following study sets consisting of 35 mm Kodachrome colored slides which illustrate clinical, gross, and histologic pathology of tropical diseases have been prepared. For each set of colored slides there is a folder with a spiral binder containing commentaries for each slide. Also, for some diseases for which text book descriptions are not readily available we have also included a summary description of the disease.

East Coast Fever (ECF), 4 sets of 55 slides with commentaries
Babesiosis of Deer, 4 sets of 23 slides with commentaries
Theileria of Deer, 4 sets of 15 slides with commentaries
Bluetongue of Deer, 4 sets of 39 slides with commentaries
Bluetongue of Sheep, 4 sets of 39 slides with commentaries
Foot & Mouth Disease in England, 4 sets of 26 slides with commentaries
Disease Distribution Maps, 3 sets of 26 slides with commentaries
Hemorrhagic Septicemia in Buffalo, 4 sets of 11 slides with commentaries
Chagas' Disease, 3 sets of 84 slides with commentaries
Chagas' Disease, 3 sets of 25 tissue sections with commentaries
San Miguel Sealion Virus, 4 sets of 13 slides with commentaries
Rinderpest (R), 4 sets of 40 slides with commentaries
Rinderpest (R), 2 sets of 78 slides with commentaries
African Swine Fever (ASF), 4 sets of 62 slides with commentaries
Hog Cholera (HC), 4 sets of 54 slides with commentaries
African Horsesickness (AHS), 4 sets of 40 slides with commentaries
Epizootic Lymphangitis, 4 sets of 20 slides with commentaries
Equine Piroplasmosis, 4 sets of 51 slides with commentaries
Canine Piroplasmosis, 4 sets of 29 slides with commentaries

In addition, we have accumulated colored slides on the following diseases which will be used for study sets when additional slides of adequate coverage and quality are taken or otherwise obtained.

Bovine Streptothricosis
Vesicular Stomatitis
Teschens Disease
Contagious Ecthyma
New Castle Disease
Bovine Petechial Fever
Rift Valley Fever
Bovine Mammilitis
Tuberculosis
Heartwater
Vesicular Exanthema
Maedi
Louping Illness
Sheep Pox
Fowl Plague
Malignant Catarrhal Fever
Trypanosomiasis
Glanders
Bovine Papillary Stomatitis

During this past year, Dr. Maurer gave to the Institute of Tropical Veterinary Medicine a personal collection of 3,000 histopathological tissue sections mounted and stained on glass slides. A large percentage of these are on exotic animal diseases of the tropics. This constitutes a rare collection of specimens unavailable in other U. S. veterinary colleges. The current cost of preparing tissue sections is $2.00 per slide quite apart from the expense of collecting the tissues in several foreign countries. The slides are indexed and catalogued for convenient use.

It will be noted in the list of publications and in the title of papers delivered by our staff and visitors at the Workshops that we have comprehensive descriptions of many of the diseases for which we also have study sets so that we are well equipped with the essentials for the training of veterinarians on these diseases.

APPENDIX III

KUTTLER, K. L., ZARAZA, H. and ROBERTS, E. D.: Hematologic and Clinical Response to Anaplasmosis Vaccines and the Comparative Efficacy of These Vaccines, As Measured by Field and Experimental Challenge. Proceedings of the 5th National Anaplasmosis Conference, February 28-29, 1963, Stillwater, Oklahoma.

Twenty, 3-month-old calves were divided in 4 equal groups. Group 1 was inoculated with an attenuated Anaplasma marginale, group 2 received an A. marginale adjuvant vaccine, group 3 was infected with virulent A. marginale followed by treatment, and group 4 remained as unvaccinated controls. All animals were moved into an Anaplasma endemic zone 3 months later and allowed to undergo natural field challenge. Evidence of acute anaplasmosis was observed in all calves, except those premunized by virulent A. marginale. No significant evidence of protection was produced by either the attenuated A. marginale or the adjuvant vaccine when compared to the unvaccinated controls. The group premunized with virulent A. marginale failed to respond to natural exposure.

Hematologic response to virulent, attenuated, and killed A. marginale vaccines was measured in 18 mature cattle divided into 3 groups. The group receiving virulent A. marginale was treated 25 days after infection (Burroughs Wellcome Compound 356C61). No death losses occurred in this group, but moderate infections were observed to result in a significant reduction of PCV. The attenuated A. marginale vaccine produced a low level parasitemia, a marked serological response as measured by the complement-fixation test (CF), and a very slight drop in PCV, which was not significantly different from values observed in an unvaccinated, non-infected, control group. The group receiving adjuvant vaccine showed only a low level, transient, CF serological response.

An experimental challenge was administered 8 weeks after vaccination to cattle receiving the attenuated and adjuvant vaccines along with a group of 5 unvaccinated controls. All controls reacted to challenge with severe acute signs of anaplasmosis. One animal was allowed to die, a second would probably have died had it not been treated. Cattle receiving the attenuated vaccine showed no signs of active infection resulting from challenge. Cattle receiving the adjuvant vaccine reacted to challenge, but less severely than did the controls.

ZARAZA, H. and KUTTLER, K. L.: Respuesta Hematologica y Clinica a Diferentes Vacunas de Anaplasmosis y la Eficacia Comparative de estas, Evaluadas por la Inoculacion Experimental. Revista ICA, (Diciembre de 1968), 3, (4): 323-331. (Spanish translation of above.)

BISHOP, J. P. and KUTTLER, K. L.: Infectivity and Immunogenicity of Irradiated Babesia rodhaini. Journal of Protozoology (1974), 21, (5): 758-760.

Babesia rodhaini parasitized mouse blood exposed to varied doses of gamma radiation up to 30,000 r was inoculated into mice. Mice inoculated with non-irradiated B. rodhaini developed progressive infections and died 7 to 11 days after inoculation. Mice infected with B. rodhaini parasitized blood exposed to doses up to and including 22,000 r developed progressive parasitemias which were delayed in comparison to mice inoculated with nonirradiated B. rodhaini. Some mice receiving parasitized blood irradiated at 26,000 r did not develop progressive parasitemias. Progressive infections were prevented by exposure to irradiation at 30,000 r.

The results of two separate experiments revealed that one inoculation of parasitized blood exposed to 30,000 r or higher apparently stimulated a resistance to a challenge infection with nonirradiated parasitized blood. While 20 out of 20 control mice died as a result of challenging infections, 9 out of 28 mice previously exposed to irradiated parasitized blood survived.

The injection of irradiated nonparasitized blood did not produce a discernable acquired resistance to B. rodhaini. Presumably the irradiated parasitized blood was responsible for the development of acquired resistance to B. rodhaini.

CARSON, C. A.: An Antigenic and Serologic Comparison of Two Virulent Strains and an Attenuated Strain of Anaplasma marginale. A Thesis submitted to the Graduate College of Texas A&M University in partial fulfillment of the requirement for the degree of Master of Science, August 1969.

An antigenic and serologic study was conducted using virulent strains of Anaplasma marginale from Texas and Colombia and an attenuated strain of Anaplasma marginale. Soluble antigens of the three A. marginale strains were compared by agar gel diffusion and immunoelectrophoresis. Serum proteins from calves infected with each of the three A. marginale strains were separated electrophoretically and reacted with rabbit anti-bovine serum in immunoelectrophoresis systems.

No differences between the soluble antigens of the three A. marginale isolates were detectable by agar gel diffusion. All three antigens moved to the same mobility zone in agar gel electrophoresis systems and each antigen formed an arc of precipitation when reacted with serum from calves infected with homologous or heterologous strains of A. marginale.

A beta and a gamma serum protein component, not exhibited in normal bovine serum, were present in the serums of animals infected with either of the virulent A. marginale strains or the attenuated strain.

CORRY, G. L. and KUTTLER, K. L.: Serological Activity of a Soluble Antigen of Theileria cervi. Experimental Parasitology (Prepared - not published)

Two basic cellular erythrocytic antigens were prepared from erythrocytes obtained from a white-tailed deer (Odocoileus virginianus) infected with Theileria cervi. The first antigen was prepared from erythrocytes lysed by freezing, the second from erythrocytes lysed with distilled water. The serologic activity as determined by the complement-fixation (CF) test was greater in the antigen lysed by freezing. Both antigens when solubilized at pH 7.2 using ultrasonic disintegration increased markedly in titer.

The two antigens were pooled and disrupted by ultrasonic disintegration in buffered mediums, ranging from pH 5 to pH 11. Optimal solubilization and serologic activity as measured with the CF test was obtained at pH 11.

The antigen solubilized at pH 11 was used to determine antibody in sera from infected deer by (CF) and by passive hemagglutination (PHA) tests. Both tests resulted in similar but not identical antibody titers.

A gel diffusion test and a ring (interfacial) test gave no valid results.

INDEX DESCRIPTORS: Theileria cervi effect of soluble antigen on complement-fixation and passive hemagglutination.

Theileria cervi is a hemoparasite of the white-tailed deer (Odocoileus virginianus), first described by Schaeffler (1961). It was thought by Marburger and Thomas (1965) and Robinson et al. (1967) to be a contributing factor of death losses among deer in Texas.

Other organisms of the same genus occur in different parts of the world where they cause diseases of varying severity in domestic and wild animals.

Laboratory diagnosis of these diseases depends primarily on microscopic detection of the parasites in stained smears. Serologic tests have been described by Schaeffler (1963), Kuttler and Robinson (1967), Kuttler et al. (1967), and Gadir et al. (1970). The antigens used in these tests were, for the most part, particulate. In this state, the cell membrane is most responsible for antigenic and serologic activity with the internal structure of the parasite cell not so greatly involved. It is not unreasonable to assume that the cytoplasm of the parasite cells contains a mosaic of antigens which when dispersed in molecular phase, i.e., when in solution, are capable of more specific or sensitive reactions. Such antigens could find wide use in serologic tests, and possibly prove of greater value in elucidating the antigenic relationship of similar intraerythrocytic parasites.

The purpose of this work, therefore, was to investigate the possibility of establishing a method of obtaining a soluble antigen from the erythrocytic stage of T. cervi that would react with the homologous antibody in an in vitro system.

KUTTLER, K. L.: Serial Passage of an Attenuated Anaplasma marginale in Splenectomized Calves. Proceedings of the 73rd Annual Meeting of the USAHA, October 12-17, 1969, Milwaukee, Wisconsin, 131-135.

Twelve serial passages of an attenuated Anaplasma marginale were made in splenectomized calves by blood inoculation. The severity of infection produced at the twelfth passage level in 4 splenectomized calves was compared to the infection occurring in 4 similar calves at a second passage level. Significantly higher parasitemias and lower packed cell volumes occurred in the twelfth passage group, suggesting an increased virulence. No deaths occurred among animals of the second passage group; whereas, 1 of 4 died in the twelfth passage group.

KUTTLER, K. L., ADAMS, L. G. and ZARAZA, H.: An Epidemiologic and Geographic Survey of Anaplasma marginale and Trypanosoma theileri in Colombia. 106th Annual AVMA Convention, July 1969, Minneapolis, Minnesota. Journal of the American Veterinary Medical Association, (June 1, 1969), 154: 1398, (abstract).

Anaplasmosis complement-fixation tests, packed cell volumes, and stained blood smears were made on 603 cattle located at 5 experiment station farms in Colombia. These farms were situated in differing climatic zones varying from 2,600 meters to 13 meters in altitude and from 13°C to 28°C in mean temperature. Specific reference was made to breed susceptibility, the influence of age, and climatic condition on the incidence and severity of infection.

A direct correlation was noted between mean temperature and incidence of anaplasmosis. At 13°C the incidence was nil; whereas, at 28°C over 90% infection was noted. The mean temperature is directly associated with altitude.

Incidence of infection in enzootic areas was generally greater in older animals, but the effect of infection as characterized by anemia was more noticeable in young animals. The incidence of anaplasmosis in European breeds did not appear greatly different when compared to native and Zebu cattle, but in some instances PCVs were significantly lower in European breeds. This was most marked at the lower elevations.

Blood cultures for T. theileri from 71 cattle at 2 experiment stations resulted in a pattern of infection similar to anaplasmosis. A high incidence of infection was noted at the lower elevation with a high mean temperature and no evidence of infection at 2,600 meters with a low mean temperature.

KUTTLER, K. L. and ZARAZA, H.: Premunization With An Attenuated Anaplasma marginale. Proceedings of the 73rd Annual Meeting of the USAHA, October 12-17, 1969, Milwaukee, Wisconsin, 104-112.

An attenuated Anaplasma marginale infection has been established in 21 calves and 12 mature cattle. The resulting infections were found to be significantly less severe than virulent A. marginale in 12 calves and 5 mature cattle. A slightly milder response to the attenuated A. marginale occurred in calves at Bogota with a mean temperature of 14°C when compared to calves similarly infected at Palmira with a mean temperature of 24°C.

Calves and mature cattle previously premunized with the attenuated organism appeared to be immune to virulent challenge using a Texas isolate of A. marginale. Experimental and natural challenge with a Colombian isolate resulted in evidence of acute anaplasmosis in both vaccinated and non-vaccinated animals.

TODOROVIC, R. A., ADAMS, L. G. and ROBERTS, D. E.: A Study of Bovine Babesiosis in Colombia, South America. Proceedings of the 106th Annual AVMA Convention, July 1969, Minneapolis, Minnesota. Journal of the American Veterinary Medical Association, (June 1, 1969), 154: 1399, (abstract).

Our research program on bovine babesiosis is a part of the Institute of Tropical Veterinary Medicine, College of Veterinary Medicine, Texas A&M University, with the research program being sponsored by the Rockefeller Foundation and conducted at the Laboratorio de Investigaciones Medicas Veterinarias laboratories, Bogota, Colombia, in cooperation with the Instituto Colombiano Agropecuario. This research effort is directed mainly toward the study and control of bovine babesiosis and the training of Colombian veterinarians and graduate students involved in these research projects.

Although bovine babesiosis is eradicated in the United States, the disease still occurs in most of the world and is of great importance as a threat to livestock industry, especially in the tropical areas of Latin American countries. In Colombia, babesiosis was first described by Lleras (1908) and later recognized as a widely distributed disease, causing great losses in purebred dairy cattle imported into enzootic areas. At the present time the incidence of babesiosis in Colombia is difficult to estimate. The disease exists as a mixed infection of Babesia bigemina, Babesia argentina, and Babesia major, and the incidence of infection appears to be related to the occurrence and activity of the tick vectors at the various altitudes.

The experiments were carried out to identify the existing Babesia species occurring in Colombia by morphologic, immunoserologic, pathologic, and chemotherapeutic methods. The immunoserologic relationship of Babesia spp. and strains were studied by gel-double diffusion precipitation, immunoelectrophoresis, and fluorescent antibody techniques. Attempts were made to develop a sensitive and practical serologic test for the diagnosis of the latent Babesia infection. Several groups of intact and splenectomized calves were inoculated with various antigens isolated from the blood of cattle with acute babesiosis and the blood from patent carriers, respectively. Response to vaccination, premunition, and challenge by tick-borne Babesia was recorded. The results of these experiments were discussed.

ZARAZA, H., KUTTLER, K. L. and ROBERTS, E. D.: Efectos de la Descarga Natural de Anaplasma marginale en Terneros Vacunados y no Vacunados. Revista ICA, (September 1969), 4, (3). (Spanish translation of: Kuttler, K. L., Zaraza, H. and Roberts, E. D.: Hematologic and Clinical Response to Anaplasmosis Vaccines and the Comparative Efficacy of These Vaccines, As Measured by Field and Experimental Challenge.)

ADAMS, L. G., HIPOLITO, O., MORALES, H., GONGORA, S. and JONES, L. P.: Dermatofilosis Bovina (Estreptotricosis cutanea) en Colombia. Revista ICA, (March 1970), 5, (1): 3-16.

Four cases of bovine dermatophilosis were diagnosed in Cordoba, Colombia and confirmed by bacteriological culture methods. Macroscopic and microscopic descriptions were made of the lesions caused by Dermatophilus congolensis.

ADAMS, L. G. and KUTTLER, K. L.: Toxicity of Alpha-Ethoxyethylglyoxal Dithiosemicarbazone in Cattle. American Journal of Veterinary Research, (August 1970), 31: 1493-1495.

Alpha-ethoxyethylglyoxal dithiosemicarbazone, administered 10 consecutive days at the dose rate of 5 mg/kg/day, caused axonal and myelin degeneration of the vagus nerve in 2 of 7 calves. Of the 7 experimental calves, 6 died of tympanites.

ADAMS, L. G. and TODOROVIC, R. A.: A Study of the Pathogenesis of Anaplasmosis in Intact Calves: Including Clinical, Clinical Pathological, Serological, and Immunofluorescent Techniques. Proceedings of the VI Congreso Panamericano de Medicina Veterinaria y Zootecnia, September 28 - October 3, 1970, Santiago de Chile, 37.

Twelve, 4-month-old, male, hemotropic disease-free, Holstein calves were inoculated subcutaneously with blood containing a Colombian isolate of Anaplasma marginale. Previous to inoculation 3 control samples were taken for bone marrow and blood determination.

Thereafter, samples were collected every 2 days and one calf was euthanatized every 2 days to collect a complete set of tissues for gross and microscopic pathological lesions as well as for the immunofluorescent study using the indirect technique. Results obtained are discussed, except those related to immunofluorescent study.

CARSON, C. A., ADAMS, L. G. and TODOROVIC, R. A.: An Antigenic and Serologic Comparison of Two Virulent Strains and an Attenuated Strain of Anaplasma marginale. American Journal of Veterinary Research, (June 1970), 31, (6): 1071-1078.

Soluble antigens of 3 Anaplasma marginale strains were compared by agar gel diffusion and immunoelectrophoretic techniques. Serum proteins from calves infected with each of the 3 A. marginale strains were separated electrophoretically and tested with rabbit anti-bovine serum in immunoelectrophoretic systems. There was no detectable difference between the soluble antigens or the 3 A. marginale strains. A beta globulin arc, which was not detectable in normal bovine serum, was present in serum of acutely affected calves, and a gamma globulin arc was lengthened in the latter serum as compared with that in serum of normal calves.

KUTTLER, K. L. and ADAMS, L. G.: Comparative Efficacy of Oxytetracycline and a Dithiosemicarbazone in Eliminating Anaplasma marginale Infection in Splenectomized Calves. Research in Veterinary Science, (July 4, 1970), 2: 339-342.

Comparisons between oxytetracycline and a dithiosemicarbazone (356C61) were made in 11 splenectomized, Anaplasma marginale infected calves. Oxytetracycline was administered at the rate of 11 mg/kg intravenously (i.v.) for 5 and 10 consecutive days. Compound 356C61 was administered at the rate of 5 mg/kg i.v. for 5 and 10 consecutive days.

Compound 356C61 appeared to be relatively more effective in the treatment of anaplasmosis, as indicated by the relative increase in packed cell volume (PCV) following treatment, and by the apparent elimination of the carrier status in animals receiving the 10 daily treatments. Compound 356C61 administered daily for 10 consecutive days resulted in rumen atony, tympanites, and death.

KUTTLER, K. L., ADAMS, L. G. and ZARAZA, H.: Estudio Epizootiologico del Anaplasma marginale y et Trypanosoma theileri en Colombia. Revista ICA, (June 1970), 5, (2). (Spanish translation of: Kuttler, K. L., Adams, L. G. and Zaraza, H.: An Epidemiologic and Geographic Survey of Anaplasma marginale and Trypanosoma theileri in Colombia.)

KUTTLER, K. L. and ZARAZA, H.: A Preliminary Evaluation of a Dithiosemicarbazone for the Treatment of Anaplasmosis. Research in Veterinary Science, (July 4, 1970), 2: 334-338.

Trials were conducted on 3 splenectomized calves treated with a single intravenous (i.v.) inoculation of a dithiosemicarbazone (356C61) using 5 mg/kg, at different stages of induced anaplasmosis infection. When compared to an untreated control this compound was effective in reducing the severity of the infection. Hematological response was least severe in the animal receiving treatment before signs of parasitemia or a decrease in packed cell volume had occurred.

Treatment with compound 356C61 (5 mg/kg i.v.) of 5 splenectomized calves and 6 intact adult cattle early in the course of an artificially induced Anaplasma marginale infection prevented death loss and reduced the severity of the subsequent reaction when compared with non-treated controls.

TODOROVIC, R. A.: Babesiellosis Bovina en Australia. Revista de la Facultad de Medicina Veterinaria y de Zootecnia, (1970), 32, (1 & 2): 45-59.

Bovine babesiosis is still of great importance as a threat to the livestock industry in Australia. Due to the complexity of the epidemiology of this disease and other factors, the eradication of this hemoprotozoan malady is not possible at the present time.

The Commonwealth Scientific and Industrial Research Organization (CSIRO) is actively engaged in control and research on Babesia. Other research and teaching institutions involved in the same problem include: the University of Queensland; New South Wales, Department of Agriculture, Cattle Tick Research Station; Queensland State Department and Animal Health Station. All of these research projects on Babesia are sponsored mainly from the Government of Australia.

The Australian research workers have contributed more than a hundred scientific publications on the various areas of Babesia research; they are foremost in this field and the best trained in the world. The research laboratories are equipped with modern scientific tools, and staffed with well-trained technicians who successfully operate these instruments. The facilities are excellent and designed particularly for Babesia research. (Slides of these facilities are available for those who are interested.)

The experience from this visit and knowledge obtained through discussion with Australian scientists working on different research projects will be invaluable for organizing a similar research program on Babesia in Colombia, South America. Furthermore, the Australian scientists with whom I visited all realized the importance of our mission in South America and expressed their willingness to cooperate with us in any manner in the future. They will be able to come to Colombia and spend time on short or long-term assignments if funds are available.

TODOROVIC, R. A., ADAMS, L. G., VIZCAINO, O. and GONZALEZ, E.: Research and Control of Bovine Babesiosis in Colombia Proceedings of the VI Congreso Panamericano de Medicina Veterinaria y Zootecnia, September 18 - October 3, 1970, Santiago de Chile, 36

Research was carried out to develop an effective program for the control of bovine babesiosis in Colombia.

Experiments were carried out at the Palmira Instituto Colombiano Agropecuario (ICA) experimental station in Valle del Cauca (altitude 1,000 meters) to produce co-infectious and sterile immunity against bovine babesiosis. Calves randomly selected were divided into four groups according to the experimental design used to evaluate the immunoserological responses to vaccination against babesiosis and tick-borne challenge The degree of this immunity was determined by tick- and blood-borne challenge. The percentage of parasitemia (P), body temperature (T), and percentage of mortality (M) were used as the basis for comparing the reaction produced after vaccination and challenge. Experiments were conducted to evaluate the prophylaxis, therapy, effects, dosage, route of infection, toxicity, and response of the animals injected with a new Burroughs Wellcome babesiacidal drug No 4A65

On the basis of the observations made from these experiments, conclusions can be drawn that some degree of sterile immunity exists, besides the well known co-infectious (premunition) immunity in Babesia infections. To understand the exact mechanism of this type of immunity, more work needs to be done. The degree of resistance and the duration of immunity in relationship to different environmental conditions, strain differences, and the pathogenicity of the Babesia spp., and the quality of tick-borne challenge need to be determined.

TODOROVIC, R. A., GONZALEZ, E. F. and ADAMS, L. G.: Immune Response of Cattle Vaccinated Against Babesiosis in Colombia, South America. Proceedings of the American Veterinary Medical Association and the American Association of Veterinary Parasitologists, June 22, 1970, Las Vegas, Nevada.

Attempts to produce co-infectious and sterile immunity in cattle against Babesia infections have been carried out by vaccinating animals with live or killed Babesia vaccines at Palmira, Valle del Cauca, Colombia (altitude 1,000 meters). Immune responses of the vaccinated animals were evaluated by several immunoserologic methods. The degree of resistance to tick-borne challenge (Boophilus microplus naturally infected with Babesia spp.) was determined by the percentage of recovery to normal parameters used in this study.

According to the experimental design used, a total of 110 animals were divided in 5 experimental groups to ascertain the immunologic responses. The first group consisted of 20 male, 85 kg, Holstein, 3-month-old calves which were premunized with Babesia bigemina, Babesia argentina, and 4 weeks later were exposed to tick-borne (Boophilus microplus) challenge. The second group consisted of 20 male, 95 kg, Holstein, 4-month-old calves subdivided into 4 groups and vaccinated with a killed Babesia vaccine derived from the erythrocytes and plasma, respectively, of animals acutely infected with Babesia bigemina and Babesia argentina. The animals were inoculated with vaccine with or without Bacto-Adjuvant Complete H 37 Ra. The third group of 40 male, 80 kg, Holstein, 3-month-old calves was divided into sub-groups. The first sub-group consisted of 20 animals which were premunized with Babesia bigemina and Babesia argentina and 8 days later were treated with a new experimental babesiacidal drug The second sub-group which consisted of 20 animals was simultaneously premunized with Babesia spp. and Anaplasma marginale and later treated with their respective specific drugs. The fourth group consisted of 20 female, 75 kg, Holstein, 3-month-old calves prophylactically treated with drug No. 4A65 and 3 weeks later exposed to Boophilus microplus naturally infected with Babesia bigemina and Babesia argentina. The fifth group consisted of 10 animals used as controls. Responses to vaccination and tick-borne challenge were evaluated by packed cell volumes, percentage of parasitemia, body temperatures, body weight, complement fixing antibody titers, general physical conditions, and percent recoveries after tick-borne challenge. Results in general indicate that resistance to babesiosis can be produced by co-infectious or sterile immunity. Experiments in prophylaxis, based on residual action of the babesiacidal drug, have given consistent and satisfactory results. In the future, it may be possible to develop control programs against bovine babesiosis based on these observations. The present status of these studies was described.

ADAMS, L. G. and FERREIRA, W. L.: Necrobacilosis Neo-Natal en Ovinos. Revista ICA, (September 1971), 6, (3).

Five cases of ovine neo-natal necrobacilosis, in the Sabana of Bogota, were diagnosed in lambs less than 2 weeks of age. Macroscopic and microscopic lesions were described and the diagnosis was confirmed by bacteriological culture techniques. This report constitutes the first known notice of the disease in neo-natal lambs in Colombia.

BISHOP, J. P.: Immune Response of Cattle Inoculated With Irradiated Babesia bigemina. A Dissertation submitted to the Graduate College of Texas A&M University in partial fulfillment of the requirement for the degree of Doctor of Philosophy, December 1971.

Babesia bigemina parasitized blood exposed to varied doses of gamma radiated up to 60 kRad was inoculated into calves. Calves infected with 1×10^{10} B. bigemina parasitized erythrocytes exposed to doses up to an including 30 kRad developed progressive parasitemias. Some calves receiving 1×10^{10} parasitized erythrocytes irradiated at levels of 36 and 42 kRad did not develop progressive infections. Progressive infections were prevented by exposure to irradiation at 48 kRad or higher. Subinoculations into susceptible splenectomized calves from parasites thus treated failed to produce active infections.

A degree of acquired resistance to infection with B. bigemina developed in calves after 1 inoculation with B. bigemina parasitized blood irradiated at 48 and 60 kRad. The resistance was sufficient to suppress multiplication of the Babesia and to permit calves to survive otherwise severe clinical infections with nonirradiated parasites. There was also less erythrocytic destruction and a smaller increase in rectal temperatures following challenge. Presumably, the irradiated parasites were responsible for the development of resistance since irradiated nonparasitized blood did not produce a discernable acquired resistance.

The acquired resistance to infection with B. bigemina developed in calves inoculated with 1×10^{10} B. bigemina irridated at 48 and 60 kRad was similar to the acquired resistance developed in calves inoculated with 1×10^{10} nonirradiated B. bigemina. It seems likely that the protective immunity produced with irradiated B. bigemina may be similar to that produced with living pathogenic B. bigemina developed in calves inoculated with 1×10^{10} B. bigemina irradiated at 48 and 60 kRad was much greater than the acquired resistance to infection developed in calves inoculated with 1×10^{10} heat killed B. bigemina. Thus, it seems likely that immunization with irradiated Babesia may provide the special immunological properties of living parasites important for producing a strong immunity while suppressing the pathogenic effects of the parasite. The Babesia parasites could be irradiated and frozen without apparent loss of immunizing properties.

DALEY, C. A.: A Sequential Study of the Pathogenesis of Disease Caused by Trypanosoma vivax in Experimentally Infected Calves, Utilizing Clinical, Pathological, Histopathological and Immunofluorescent Techniques. A Thesis submitted to the Graduate College of Texas A&M University in partial fulfillment of the requirement for the degree of Master of Science, May 1971.

Trypanosoma vivax obtained from a clinically sick cow near Neiva, Colombia, was passed in a sheep and a calf and inoculated into the jugular vein of 14 Holstein-Friesian calves. Fever occurred by 24 hours, and recurring parasitemia commenced after 72 hours. Associated with the first and subsequent parasitemias were decreases in hemoglobin, PCV, M:E ratio, serum albumin, A:G ratio and neutropenia

All calves exhibited gradual weight loss by 2 weeks and later submandibular edema usually became evident. Consistent post mortem lesions seen after 4 weeks were conspicuously hypertrophied, edematous lymph nodes, hypertrophied hemal lymph nodes, emaciation, rounded right heart, palpably firm liver, atrophied thymus and hypertrophied femoral bone marrow.

Associated with T. vivax of the infecting inoculum and succeeding parasitemias were generalized endothelial hypertrophy and mononuclear cell infiltration along blood and lymph vessels with proteinuria and bone marrow hyperplasia. At 3 weeks there were aggregations of macrophages containing engulfed material distributed along capillaries in pulmonary interalveolar tissue, and this lesion in combination with the anemia and apparent cardiac insufficiency were thought important in the development of anoxia, and probably contributed to the single fatality observed.

GONZALEZ, E F., TODOROVIC, R. A and ADAMS, L G.: Ultraestructura de la Babesia bigemina. Revista ICA, (March 1971), 6, (1): 89-112.

The morphology and some aspects related to the reproductive and feeding mechanism of Babesia bigemina have been studied by means of electron microscopy.

Although there are reports in the literature of the fine structure of Babesia canis which affects dogs, Babesia caballi which affects horses, and Babesia rodhaini which affects rodents, there is no report on the ultrastructure of B. bigemina which infects cattle.

B. bigemina was isolated from naturally infected cattle in the Valle del Cauca, Colombia, and maintained in splenectomized calves in the Laboratorio de Investigaciones Medicas Veterinarias in Bogota. Blood samples were collected from the splenectomized animals at a time when the percentage of parasitized erythrocytes was 25%, and these samples were used for electron microscopic studies.

By means of the electron microscope, different stages of B. bigemina were revealed such as oval, conoid and most commonly, pear shaped. The sizes of these forms were 2.5 to 6.5 microns in length by 2.3 microns in width. The young forms of the parasite were 1.5 by 2.5 microns. All these forms of parasites are surrounded by a dense cytoplasmic membrane which contained endoplasmic reticulum in the form of vesicles; these vesicles are composed of granules of different density. The endoplasmic reticulum appears as a homogenous mass with transparent vacuolar structures which are oval and spherical in shape. In addition to the endoplasmic reticulum, well defined dense polar bodies were found which appeared as oval shaped organelles, which communicated with the conoid part of the parasite by canals. The nucleus is the largest internal structure of the parasite and occupies one-fourth to one-third of its body. The nucleus is surrounded by a single membrane. Nucleoli were not revealed by electron microscopy.

Reproduction of B. bigemina appears to be carried out in two ways - by budding and binary fission. On the basis of these observations it is not clear which means of reproduction is more predominant. It is possible that both forms take place at the same time.

The feeding mechanism is not apparent. It appears that polar bodies play some role in this mechanism. These polar bodies could assume the function of food reservoirs of the parasite. It was also revealed that food vacuoles are similar to those in malarial parasites. The formation of food vacuoles probably results from an end process of pinocytosis as was described for Plasmodium species. We believe that both processes are involved in the feeding mechanism of Babesia parasites. Results of this study confirm the previously reported observation that there is no formation of pigment granules in Babesia; this implies that digestion of the host hemoglobin is complete; in contrast, malarial parasites form hemozoin, a blood pigment, as an end product of metabolism.

KUTTLER, K. L.: Efficacy of Oxytetracycline and a Dithiosemicarbazone in the Treatment of Anaplasmosis. American Journal of Veterinary Research, (September 1971), 32: 1349-1352.

The combination of a dithiosemicarbazone (356C61) and oxytetracycline proved more efficacious in the treatment of anaplasmosis than did either drug administered alone. The Anaplasma marginale carrier state in splenectomized calves was suppressed for as long as 120 days and was possibly eliminated by 3 injections of 356C61 (5 mg/kg) and oxytetracycline (11 mg/kg) given simultaneously at 48-hour intervals.

KUTTLER, K. L.: Promising Therapeutic Agents for the Elimination of Anaplasma marginale in the Carrier Animal. Proceedings of the 75th Annual Meeting of the USAHA, October 27, 1971, Oklahoma City, Oklahoma, 92-98 (published 1972).

Two new drugs, a dithiosemicarbazone (356C61) and 3,3'-bis(2-imidazolin-2-yl)-carbanilide dihydrochloride (4A65) have been successfully used to treat splenectomized calves with anaplasmosis. Carrier infections were eliminated with 5 or 10 mg/kg 356C61 and 11 mg/kg oxytetracycline when given 3 times at either a 24- or 48-hour interval. In addition, 5 mg/kg 356C61 plus 2 mg/kg 4A65 given 3 times at 24-hour intervals was effective in eliminating A. marginale infections. Levels of 4 and 6 mg/kg of 4A65 given 3 times at 24-hour intervals has proven successful in eliminating A. marginale infection.

KUTTLER, K. L., GRAHAM, O. H. and JOHNSON, S. R.: Apparent Failure of Boophilus annulatus to Transmit Anaplasmosis to White-Tailed Deer (Odocoileus virginianus). Journal of Parasitology, (June 1971), 57: 657-659.

Transovarial transmission of anaplasmosis occurred when two splenectomized calves were infested with unfed larvae of Boophilus annulatus, but no evidence of infection was detected in 2 intact white-tailed deer after they were infested with other larvae of common origin. All attempts to isolate Anaplasma marginale from the 2 deer by transfer of blood into splenectomized calves were unsuccessful.

MULLENAUX, C. H. and ADAMS, L. G.: La Oncocercosis Equina Asociada con el Mal de la Cruz en Colombia: Descripcion de dos casos. Revista ICA, (September 1971), 6, (3).

Two cases of equine fistulous withers were diagnosed in which Onchocerca spp. was found to be present in the affected tissues. One of the horses had a brucellosis antibody titer of 1:50 using the rapid plate agglutination method and, in the same animal, Brucella spp. was cultured from the suppurative materials of the nuchal bursitis of the withers. Macroscopic and microscopic pathological lesions caused by the nematode Onchocerca spp. were described.

TODOROVIC, R A. and ADAMS, L G.: Serologic Diagnosis of Babesiosis. Proceedings of the XIX World Veterinary Congress, August 15-22, 1971, Mexico City, 1114-1116

The detection of the carrier state of bovine babesiosis has presented a particularly difficult problem because the blood from a high percentage of carrier animals does not contain sufficient Babesia parasites on which to base the diagnosis. Therefore, a great deal of past interest was concerned with the development of serologic techniques which would aid in diagnosing babesiosis.

In this review an attempt has been made to summarize and discuss the recent advances on sero-diagnosis of babesiosis in infected cattle with special attention to the serologic procedures used in the Laboratorio de Investigaciones Medicas Veterinarias located in Bogota, Colombia. In the last two decades fundamental knowledge concerning the immuno-serology of several Babesia spp has led to the development of sero-diagnostic procedures for detection of Babesia antibodies The antigens used in these techniques originated from parasitized erythrocytes and serum or plasma of animals with acute babesiosis, and they were applied in several serologic tests The complement-fixation reaction constituted one of the earliest tests for the diagnosis of babesiosis In recent years considerable progress was made to improve the complement-fixation test for the diagnosis of babesiosis In addition, gel precipitation, fluorescent antibody, and agglutination techniques were applied for the detection of specific Babesia antibodies utilizing antigens from the parasitized erythrocytes as well as acute serum.

The investigations described in this report were conducted to develop the new techniques and to evaluate existing techniques for diagnosing bovine babesiosis Research was executed in collaboration with the Instituto Colombiano Agropecuario in the Laboratorio de Investigaciones Medicas Veterinarias in Bogota, Colombia Antigens of Babesia spp were isolated by means of two techniques and used in the complement-fixation test for the detection of Babesia antibodies in cattle experimentally and naturally infected. By means of the complement-fixation test it was possible to detect specific antibodies in the serum of cattle 8 days after blood-borne infection. A total of 5,420 serum samples of cattle infected with babesiosis were tested. The cattle were from several Colombian experimental herds with known histories of babesiosis located in Valle del Cauca, Rio Magdalena, Llanos and Monteria and from cattle artificially infected in the Laboratorio de Investigaciones Medicas Veterinarias in Bogota Approximately 95% of these samples were positive; whereas, about 5% gave discordant reactions. In addition to the complement-fixation test used in our laboratory, attempts were made to apply the double-gel diffusion for characterization of Babesia spp antigen-antibody reactions. A cross reaction was noted between Babesia bigemina and Babesia argentina in this system The application of latex-agglutination and hemo-agglutination tests for the detection of the Babesia antibodies are still under investigation in our laboratory As a result of these investigations and observations, it is apparent that more investigation is needed for the development of a practical serologic technique for the diagnosis of babesiosis and to help solve this complex biological disease problem in tropical and sub-tropical areas of the world.

TODOROVIC, R. A., GONZALEZ, E., MATEUS, G. and ADAMS, L. G.: Simultaneous Control of Helminths, Anaplasmosis and Babesiosis in Cattle. Revista de la Facultad de Medicina Veterinaria y Zootecnia, Univ. Nac. de Colombia, Bogota, (1971), 33: 47-58.

A group of 50 male, Holstein-Friesian calves, 3 to 4 months old, were used to evaluate a control program for gastrointestinal and hemotropic parasites. The experiment was conducted at the ICA experimental station in Palmira, Valle del Cauca, at an elevation of 1,000 meters. The animals were divided into 3 groups.

Twenty animals were premunized against anaplasmosis and babesiosis simultaneously; 8 days later they were treated against babesiosis using the compound 4A65 at a dosage of 1 mg/kg of body weight, and 21 and 56 days after premunition they were treated intravenously with the compound 356C61 (5 mg/kg IV) against anaplasmosis.

Twenty animals were premunized against anaplasmosis as it was done with the animals in Group I. Animals in this group were vaccinated with AGS plus adjuvant vaccine against babesiosis. The vaccine was repeated 14 days later. Animals in Groups I and II were treated twice during the experiment with Ripercol (Tetramisol) against gastrointestinal parasites.

Ten animals were not treated and were used as controls.

All three groups of calves were kept under the same environmental conditions and the same management. The experiment was carried out during a period of 8 months. Blood samples were collected to evaluate anemia and parasitemia. The antibody titer was determined by the complement-fixation test. The body weights were measured and the fecal samples were examined for the presence of gastrointestinal parasites. Animals in Groups I and II had a high degree of resistance to babesiosis and anaplasmosis infections as a result of effective premunition and vaccination techniques. However, the animals in the control group had clinical babesiosis and anaplasmosis and high infestation with gastrointestinal parasites.

The importance of simultaneous control of gastrointestinal and hemotropic parasites is pointed out and methods to control these parasites are given.

TODOROVIC, R. A., LUQUE, G. F. and ADAMS, L. G.: Contribution to the Study of the Tick Distribution in Colombia, South America. Revista de la Facultad de Medicina Veterinaria y Zootecnia (accepted for publication).

The purpose of this work was to collect and identify tick species involved in the epizootiology of bovine babesiosis in Colombia. Bovine babesiosis was reported in Colombia in 1888 but there is not any published evidence about tick species involved in the transmission of the disease. Although Boophilus microplus is the predominant tick in medium and hot climates, the exact distribution of the tick in the different regions of Colombia is not known. To develop an effective control program, the distribution of tick species needs to be determined. This is the first attempt to obtain this information about tick distribution in Colombia.

Animals naturally infected with Babesia bigemina and Babesia argentina were used as a tick collection source. The infectivity of these animals was determined by blood smears and complement-fixation techniques. The animals were located on farms in Palmira (Valle del Cauca) and Turipana (north coast), Magdalena River and Sumapaz River. Ticks were collected from different breeds: Holstein-Freisian, Zebu, Blanco Orejinegro, and Costeno con Cuernos, in animals of different ages. The ticks were collected from different parts of the animal bodies and preserved in Ethanol 95%. Adults, nymphs, and larvae were collected from both sexes for identification purposes during a 12-month period (January - December).

Dermacentor nitens was found in the animals infected with babesiosis in the Valle del Cauca, north coast, Sumapaz River; Amblyomma cayennense was found in animals infected with babesiosis and anaplasmosis in the Magdalena River and the north coast; Boophilus microplus was found in the same animals infected with babesiosis and anaplasmosis used in this experiment. Until the present time the significance of the findings of Amblyomma and Dermacentor ticks in epidemiology of babesiosis is not clear.

Experiments are in progress to determine the population and distribution of the tick species in other parts of Colombia for the purpose of investigating the exact role of Dermacentor nitens and Amblyomma cayennense in the transmission of bovine babesiosis

ZARAZA, H. and KUTTLER, K. L.: Comparative Efficacy of Different Immunization Systems Against Anaplasmosis. Tropical Animal Health & Production, (1971), 3: 77-82.

Animal response to anaplasmosis vaccination was measured using an attenuated organism, a killed adjuvant vaccine, and a virulent Anaplasma marginale. A total of 7 calves (2-4 months of age) and 5 heifers (18 months of age) received the attenuated organism; 8 calves were given the adjuvant vaccine; 7 calves were premunized with virulent A. marginale; and 7 calves remained as non-vaccinated controls. The animals were vaccinated at Tibaitata on the Bogota Savannah and later moved to the north coast of Colombia, an anaplasmosis enzootic area.

All vaccination methods produced positive CF results. The live agents resulted in low parasitemias in most instances, although the attenuated organism was particularly mild in the younger animals.

Protection from field challenge was observed in all calves premunized with virulent organism, and in 2 of 5 heifers premunized with the attenuated organism. All other vaccinated animals developed anaplasmosis which was equally as severe as seen in the non-vaccinated controls.

ADAMS, L. G.: Epizootia Espontanea de Hepatitis Toxica en Porcinos Atribuida a Aflatoxicosis. Revista ICA, (March, 1974), 9: 31-48.

Nine of the 56, 4- to 6-month-old Duroc male and female pigs died 2 months after consuming a ration consisting of 8.75% moldy peanut meal. The pigs exhibited weight loss, roughened hair coats, anorexia, lethargy, icterus, melena, increased followed by decreased rectal temperature and death. The livers of the remaining 45 pigs were condemned due to cirrhosis. Serum sorbitol dehydrogenase activities, glutamic-oxaloacetic transmission activities, bilirubin concentrations, serum beta globulin levels, serum gamma globulin levels, and total serum protein concentrations were increased as serum albumin/globulin rations, albumin levels, packed cell volume and hemoglobin contents were decreased. No changes were observed in total leukocyte counts or serum alpha globulin levels.

The principal macroscopic lesions consisted of generalized icterus, petechial and ecchymotic hemorrhages with yellow transudates occurring in the body activities. Subendocardial as well as subserosal ecchymotic hemorrhage were commonly observed. Ulceration of the gastric fundus occurred which filled the stomach, duodenum, jejunum, ileum, and colon with free digested and undigested blood. The liver was pale yellowish-brown, firm (increased cutting resistance), and cirrhotic with very accentuated hepatic lobules outlined by translucent bands. Hundreds of irregular round yellow to brown foci of hepatic nodular regeneration were interspersed throughout the hepatic parenchyma. The gall bladder was moderately edematous and contained a small amount of light green bile. The principal microscopic lesions of the liver were disorganization of the hepatic architecture, acinus formation, severe sinuscidal fibrosis, mild biliary hyperplasia, advanced hepatic nodular regeneration, extensive hepatocellular megalocytosis, hepatocellular anisocytosis, mild hepatocellular necrosis, fatty metamorphosis, and moderate cholangiolar bile plug formation. The diagnosis and etiology of these 4 cases of porcine chronic toxic hepatitis was attributed to aflatoxicosis apparently produced by Aspergillus flavus growing on peanut meal. The present article is the first report of aflatoxicosis in Colombia.

ADAMS, L. G., CRAIG, T. M., PLATT, K. B. and WYSS, J. H.: Bovine Eperythrozoonosis in Colombia. Revista ICA (accepted for publication).

Eperythrozoon wenyoni, E. teganodes and E. tuomii were diagnosed in 14 of 37 splenectomized, Holstein-Friesian, 4- to 11-month-old calves that originated from the Sabana de Bogota. Eleven calves had pure infections of E. wenyoni, 2 calves had dual infections of E. wenyoni and E. teganodes, and 1 calf had a pure infection of E. tuomii. The diagnosis was determined on Giemsa-stained blood smears, and morphological descriptions of the Eperythrozoon spp. were given. Six splenectomized calves exhibited depression and anorexia, but all 14 calves had elevated rectal temperatures. Two calves had serous conjunctivitis with excessive lacrimation. The increase in rectal temperature coincided with the onset of parasitemia while the packed cell volume decreased after the onset of parasitemia. The average incubation period and standard deviation was 14.9 ±3.5 days post-splenectomy. Treatment with 2-di-(Beta, gamma-dioxipropil)-(aminofenol)-(4 arseno 5)-Beta-(benzaxozalil)-(2)-mercaptol-proprionato de sodio at 29 mg/kg intramuscularly caused the parasitemia to become undemonstrable within 24 hours with further recrudescence occurring within 6 weeks. This is the first report of bovine eperythrozoonosis due to Eperythrozoon wenyoni, E. teganodes and E. tuomii in Colombia.

CORRIER, D. E.: A Clinical, Serologic and Pathological Study of Concurrent Anaplasmosis and Babesiosis in Experimentally Infected Calves. A Thesis submitted to the Graduate College of Texas A&M University in partial fulfillment of the requirement for the degree of Master of Science, December 1972.

Concurrent and single infections of Anaplasma marginale and Babesia bigemina were studied in 22, 7 month old, male, non-splenectomized Holstein-Friesian calves. Clinical manifestations of disease were mild, consisting primarily of slight fever, poor body condition, and reduced weight gains. Anaplasma marginale appeared to be the more pathogenic of the 2 organisms.

Associated with the appearance of parasitized erythrocytes were decreases in packed cell volume, hemoglobin, albumin:globulin ratio, and serum albumin, and slight increases in the levels of serum bilirubin, serum glutamic oxalacetic transaminase, and alpha and beta serum globulins. Decreases in PCV and hemoglobin concentration were more prolonged and severe in the concurrently infected calves. Complement fixing antibodies for Anaplasma occurred on days 17 to 26 in association with increases in alpha and beta globulins. Complement fixing antibodies for Babesia were first observed on day 12 post inoculation.

Gross lesions observed in the concurrently infected calves included a moderately excessive quantity of yellow fluid in the peritoneal and pleural cavities, moderate lymph node enlargement, splenomegaly and hepatomegaly, moderate renal congestion, and occasional serous atrophy of depot fat.

Hepatocellular degeneration and necrosis were observed in the centrolobular areas of the liver. Lymphoid hyperplasia was observed in the malpighian corpuscles of the spleen and in the lymphoid follicles of the lymph nodes. Hemosiderosis of the spleen, liver, kidney and lymph nodes was attributed to the increased removal of damaged erythrocytes from the circulation with the subsequent release of breakdown products of hemoglobin.

The biological relationship of A. marginale and B. bigemina during the concurrent infection appeared to be one of independency. Neither an inhibitory nor a synergistic relationship was apparent during the investigation. The clinical and pathological manifestations of concurrent infection were more severe than those observed during infection with either of the hemotropic parasites alone, and were attributed to the concurrent infection being additive in nature.

HERNANDEZ, J. D., ROBERTS, E. D., ADAMS, L. G. and VERA, T.: Pathogenesis of Hepatic Granulomas in Turkeys Infected with Streptococcus faecalis var. liquefaciens. Avian Diseases, (Jan. - March 1972) 16 (1): 201-216.

The pathogenesis of hepatic granulomas in turkeys has been studied by reproducing the lesions experimentally with Streptococcus faecalis var. liquefaciens isolated during a field outbreak of turkey hepatic granulomas in Colombia. The 170 turkey poults (Bronze) used were 4 weeks old. Groups of poults were inoculated intravenously or orally with 0.1 ml of a 24-hour culture of Streptococcus faecalis var. liquefaciens at a dilution of 3 x 10 on the MacFarland Nephelometer Standard 10. The oral route of inoculation reproduced a disease most similar to the naturally occurring disease.

Clinically, the acute phase of infection was characterized by a high mortality rate in the first to seventh days but only sporadically thereafter. The septicemic phase produced the formation of septic thrombi which localized in various organs, producing infarction with heterophilic infiltration. Once the septicemic phase of the problem passed, the disease was manifested primarily by a focal hepatitis initiated primarily as a focal necrotic cholangial lesion. The biliary epithelium had hyperplastic to degenerative processes which participated in the formation of biliary thrombi. Granulomas were characterized by focal areas of necrosis surrounded by Langhans-type giant cells and macrophages.

JONES, F. M.: Control of Anaplasmosis and Babesiosis in Young Cattle. A Thesis submitted to the Graduate College of Texas A&M University in partial fulfillment of the requirement for the degree of Master of Science, December 1972.

A study was conducted on the control of anaplasmosis and babesiosis in young cattle in Colombia. Three groups of 10 calves were used at each of 3 different climatic and geographic areas. One group was vaccinated with an attenuated Anaplasma marginale vaccine and a killed Babesia bigemina, Babesia argentina vaccine. A second group was injected with infected A. marginale, B. bigemina and B. argentina blood that originated from donor cattle from the eastern plains. Five days post inoculation the induced infection was treated by injection of compounds 356C61 (alpha-ethoxyethyl-glyoxal dithiosemicarbazone) and 4A65 (3,3-Bis-(2-imidazolin-2-yl) carbanilide dihydrochloride). The third group of calves was used as a control. Calves selected for use at Monteria were not native to that area. All calves were subjected to natural exposure. Ticks were collected and identified at each site.

There was no apparent significant difference in weight gains and resistence to anaplasmosis and babesiosis between groups at any site. At Bugalagrande and Girardot the absence of death losses from anaplasmosis and babesiosis in the control groups indicates that the calves had a pre-existing natural immunity, an acquired non-sterile immunity at the beginning of the study, or no challenge during the study At Monteria, it is apparent that the vaccinated and premunized calves did not develop resistance to anaplasmosis and babesiosis due to the use of antigenically different organisms; the simultaneous injection of the premunization drugs at 5 days post inoculation; the lack of sufficient sterile immunity to suppress tick-borne infection; or the inability of the very young calves to develop sufficient resistance.

The identification of Boophilus microplus ticks at all 3 sites confirms reports of this vector in anaplasmosis and babesiosis enzootic areas of Colombia. The significance of Anocentor nitens ticks on Anaplasma and Babesia spp. infected cattle is not apparent at this time.

As a result of this study, it is concluded that the control of bovine anaplasmosis and babesiosis in tropical areas is more complex than previously recognized. More investigation is needed to obtain information on strain antigenicity of Anaplasma marginale, Babesia bigemina and Babesia argentina; mechanisms of coinfectious immunity; sterile immunity; and the action of chemical compounds tested in this study.

KUTTLER, K. L.: Combined Treatment With a Dithiosemicarbazone and Oxytetracycline to Eliminate Anaplasma marginale Infections in Splenectomized Calves. Research in Veterinary Science, (November 1972), 13, (6): 536-539.

A total of 12 treatment schedules combining oxytetracycline and an alpha-dithiosemicarbazone (356C61) were tested on 36 splenectomized calves carrying Anaplasma marginale infections. Anaplasma infection was eliminated following the administration of 5 or 10 mg/kg 356C61 combined with 11 mg/kg oxytetracycline, and given 3 times at 24 or 48 hour intervals Treatments employing lower levels, fewer injections, or at greater time intervals failed to eliminate infection.

Treated, splenectomized calves failing to show evidence of an A. marginale relapsing infection within 62 days were found to be free or infection on the basis of infectivity trials conducted an average of 87 days after treatment, and by re-inoculation with A. marginale an average of 164 days after treatment.

KUTTLER, K. L.: Comparative Response to Premunization Using Attenuated Anaplasma marginale, Virulent A. marginale and A. centrale in Different Age Groups. Tropical Animal Health & Production, (1972), 4: 197-203.

Premunizing infections using virulent Anaplasma marginale (VAM), attenuated A. marginale (AAM) and A centrale (AC) have been induced in 46 mature cattle, 33 intact calves, and 38 splenectomized calves, for the purpose of comparing the relative response to these infections.

The VAM produced significantly more severe reactions in adult cattle and splenectomized calves, and a slightly more severe response in intact calves; however, these animals were relatively more resistant to all three infections. There was no detectable difference between the reactions caused by AAM and AC when measured in adult cattle and intact calves Among splenectomized calves, however, the AAM infections resulted in a milder response as measured by the relative drop in packed cell volume and percent parasitemia. The CF response was significantly lower in the AC infection.

KUTTLER, K. L., GRAHAM, O. H., JOHNSON, S. R. and TREVINO, J. L.: Unsuccessful Attempts to Establish Cattle Babesia Infections in White-Tailed Deer (Odocoileus virginianus). Journal of Wildlife Diseases, (January 1972), 8: 63-66.

Attempts to induce a demonstrable cattle Babesia infection by feeding known infected ticks on two white-tailed (Odocoileus virginianus) deer were unsuccessful. The injection of known Babesia carrier blood into an intact and a splenectomized deer failed to result in evidence of infection.

All deer were checked for possible sub-patent infections by inoculating their blood into splenectomized calves at weekly intervals for 5 weeks following exposure, but no infections were produced in the calves

Babesia infected ticks having undergone one generation on deer were unable to transmit infection to splenectomized calves on the succeeding generation.

ARMSTRONG, J. M. and TODOROVIC, R. A.: Anaplasmosis of Cattle. Texas Agricultural Extension Service, A Fact Sheet, No. 10 M-6-73, (1973), 1-4, (abstract).

A brief description of anaplasmosis, with special emphasis on recent achievements in the field of diagnosis and control was discussed and summarized for Texas A&M University Extension Service publication. This fact sheet was written principally for livestockmen to make them aware of recent developments in the field of anaplasmosis control and action that can be taken for prevention and treatment of this hemotropic disease.

BISHOP, J. P. and ADAMS, L. G.: Combination Thin and Thick Blood Films for the Detection of Babesia Parasitemia. American Journal of Veterinary Research, (September 1973), 34, (9): 1213-1214.

A method for preparing and examining combination thin and thick blood films for the detection of Babesia spp. parasitemias was developed. A technique for staining the combination thin and thick films, using a phosphate-buffered Giemsa stain solution containing alkyl phenoxy polyethoxy ethanol (APPE), was also described.

BISHOP, J. P., ADAMS, L. G., THOMPSON, K. C. and CORRIER, D. E.: The Isolation, Separation and Preservation of Babesia bigemina. Tropical Animal Health & Production, (May 1973), 5: 141-145.

Experiments were performed in Colombia to separate Babesia bigemina from contaminating organisms. Babesia bigemina was passaged serially through five splenectomized calves. The first calf was inoculated with blood carrying several different organisms, and subsequent subinoculations were done soon after blood smears from each calf were found to be positive for B. bigemina. Five blood passages were carried out in 6.5 days. Babesia argentina, B. major and A. marginale were eliminated as contaminants of the B. bigemina isolated after four passages. A frozen stabilate of the isolated B. bigemina was established.

CORRIER, D. E. and ADAMS, L. G.: Observations During Concurrent Anaplasmosis and Babesiosis in Experimentally Infected Calves. Proceedings of the 6th National Anaplasmosis Conference, March 1973, Las Vegas, Nevada, 60-65.

The clinical, serological and pathological manifestations of disease in intact calves concurrently infected with Anaplasma marginale and Babesia bigemina were investigated. Clinical signs were more severe in the concurrently infected calves than in singularly infected controls. Decreases in packed cell volume, albumin:globulin ratio, myeloid:erythroid ratio and increases in the number of reticulocytes, total serum proteins and serum gamma globulins were more pronounced in the concurrently infected calves. The concurrent infections had no apparent effect on the production of complement fixing antibodies. Gross lesions observed in the concurrently infected calves included: pleural and peritoneal transudates; splenomegaly; hepatomegaly; and moderate lymph node enlargement. Histological lesions included: moderate hepatocellular degeneration; lymphoid hyperplasia in the spleen and lymph nodes; and hemosiderosis of the spleen, lymph nodes, liver and kidneys. The relationship of A. marginale and B. bigemina during the concurrent infections appeared to be one of independency. The increased severity of the clinical and pathological signs of disease in the concurrently infected calves was attributed to the concurrent infections being additive.

CRAIG, T. M.: Infectivity and Cross Immunity Studies of Colombian Bovine Babesia Species. A Thesis submitted to the Graduate College of Texas A&M University in partial fulfillment of the requirement for the degree of Master of Science, December 1973.

Colonies of bovine hemotropic disease free Boophilus microplus ticks were established. Adult B. microplus females and eggs were incubated at 28 to 30° C. at a relative humidity of from 70 to 80%. Larvae were maintained at 24 to 28° C. and a relative humidity of 60 to 80% for maximal survival.

A colony of B. microplus infected with Babesia argentina was established by allowing non-infected ticks to feed on normal cattle for 10 to 11 days, at which time a stabilate of B argentina was inoculated into the cattle subcutaneously. This resulted in a parasitemia at the time of final tick engorgement. The organism was maintained in ticks by allowing non-infected ticks to feed on a calf which was later infected by the release of infected larvae 11 to 13 days after the non-infected larvae commenced feeding. Diagnosis of Babesia spp. in ticks was done by examination of hemolymph.

Diagnosis and estimation of the effects of Babesia spp. infections in cattle were made on the basis of thick and thin blood films, packed cell volumes, rectal temperatures, body weights, cerebral biopsies, complement fixation titers and clinical signs.

Boophilus microplus eggs, larvae and nymphs infected with B. argentina were disrupted by several methods and the resulting material inoculated subcutaneously into splenectomized calves. None of the calves showed signs of infection and proved to be fully susceptible when challenged with B. argentina.

Babesia bigemina was isolated from other bovine hemotropic agents by rapid serial passage through splenectomized calves. This isolate was compared with a laboratory strain previously isolated from a different geographic region of Colombia. Two groups of 8 calves each were inoculated subcutaneously with 10^9 B. bigemina organisms of each isolate. A third group of 8 calves remained as untreated controls. Twenty-eight days later, 4 calves in each of the 3 groups were challenged with 2×10^{10} B. bigemina organisms of each isolate. The challenge groups were homologous, heterologous and control. Both homologous and heterologous groups demonstrated immunity to challenge. No differences in the virulence of the two isolates were demonstrated.

KUTTLER, K. L.: Current Status of the Tropical Cattle Fever Tick Boophilus microplus and Texas Wildlife. Presented to the Wildlife Society, Texas Chapter, Annual Meeting - April 5, 1973, Barnet, Texas, (abstract).

The increasing presence of both Boophilus annulatus and Boophilus microplus have created considerable concern among both the Texas livestock industry and those interested in the preservation and maintenance of wildlife. Even though both ticks can complete their life cycles on deer, B. microplus appears better adapted to deer. This tick is very versatile and is capable of maintaining itself on several wildlife species. Neither B. annulatus nor B. microplus are capable of transmitting any known diseases from deer to cattle or from cattle to deer.

Eradication plans have been successful in the past, particularly where B. annulatus was present. The feasibility of B. microplus eradication by similar means was discussed.

KUTTLER, K. L.: East Coast Fever (Theileriasis, Theileriosis, Rhodesian Tick Fever, Rhodesian Red Water). Submitted for publication in the 1973 revision of the "Foreign Animal Diseases" manual, U. S. Animal Health Association, Committee on Foreign Animal Diseases.

A review of the literature with a comprehensive discussion of East Coast Fever is given. This hemoprotozoal agent (Theileria parva) is considered by many to be the single most serious tick-borne disease occurring in East Africa. The 3 host tick, Rhipicephalus appendiculatus, is difficult to control and most ranches where it occurs will dip their cattle every week. The disease organism is readily transmitted by this and other tick vectors and produces a disease which may produce mortality of over 90%. This disease is limited to the African continent; however, similar infections caused by T. annulata and T. mutans have a much broader distribution. Theileria mutans is generally considered non-pathogenic, but T. annulata is a major disease producing hemoparasite, but generally of less virulence than T. parva.

KUTTLER, K. L.: Review: Current Status of Control and Treatment With Drugs. Proceedings of the 6th National Anaplasmosis Conference, March 1973, Las Vegas, Nevada, 93-97 (abstract).

A review of the literature was given, emphasizing those treatment techniques and reports since the initial use of the tetracyclines for anaplasmosis in 1951. Two new drugs, Imidocarb and Gloxazone, were discussed. These drugs, while more effective than the tetracyclines, have not been cleared by the FDA and remain experimental. At the present time, the tetracyclines are the only effective therapeutic compounds available commercially for the treatment of anaplasmosis. Current recommendations for the elimination of carrier infections are to feed an oral tetracycline for 60 days at the rate of 5 mg/pound of body weight.

KUTTLER, K. L. and TODOROVIC, R. A.: Arthropod Borne Protozoan Infections (Affecting Domesticated, Food-Producing Animals). Submitted for publication in the 1973 revision of the "Foreign Animal Diseases" manual, U. S. Animal Health Association, Committee on Foreign Animal Diseases.

A review of the literature with a comprehensive discussion of anaplasmosis and babesiosis is given. In addition, tables of different Babesia spp., Theileria spp., Trypanosoma spp., Anaplasma spp., and Leucocytozoon spp. are given with reference to animals affected, morphology of the organism, and potential vectors. Brief descriptions of besnoitiosis and leucocytozoonosis are also given.

Despite progress in developing more effective acaracides and more efficient therapeutic agents, the arthropod borne hemoparasites remain a major disease problem in the tropics and the subject of intense research.

KUTTLER, K. L. and TODOROVIC, R. A.: Techniques of Premunization for the Control of Anaplasmosis. Proceedings of the 6th National Anaplasmosis Conference, March 1973, Las Vegas, Nevada, 106-112, (abstract).

Attempts at Anaplasma premunization in varying age groups have been reported using a virulent A. marginale of Texas origin, a virulent A. marginale of Colombian origin, an attenuated A. marginale, and A. centrale. Results of premunization response and the response to field and artificial challenge have been reported.

Premunization is a practical approach for the prevention of clinical losses associated with anaplasmosis, but a series of variables must be considered if success is to be achieved. Some of these factors are: (1) age of the animals being premunized, (2) virulence, potency, and size of the premunizing inoculum, and (3) the strain, or size, of the expected challenge exposure. In some instances, the use of a highly virulent A. marginale in adult cattle resulted in overly severe reactions even with treatment. Gloxazone (356C61) and Imidocarb (4A65) were superior to oxytetracycline in moderating the premunizing infection. Attenuated strains of A. marginale when used in young intact calves failed to produce the desired premunizing effect; however, attenuated strains were very effective in adult cattle. Premunization is dependent on establishing an active infection, and in the absence of such infection, susceptibility to field or experimental challenge occurs.

Successful premunization resulted in almost complete protection following challenge with antigenically similar A. marginale isolates. Protection was only partial, however, in instances where heterologous challenge was encountered.

MAURER, F. D.: The Need for Knowledge of Foreign Animal Diseases. Introductory chapter for the 1973 revision of the "Foreign Animal Diseases" manual, U. S. Animal Health Association, Committee on Foreign Animal Diseases.

As the introduction to a text on the diagnosis, prevention and control of diseases foreign to the United States, it is a chapter of justification for a national interest in exotic animal diseases. Justification is based upon the need to protect U. S. livestock industries, as animal diseases are major handicaps to efficient livestock production, hence, the food supply in the U.S.A. and abroad. Further, with the world's population rapidly exceeding its food supply and many people suffering from protein deficiencies, there is an urgent need to develop all sources of animal protein. Only ruminant animals are capable of converting range forages and many crop by-products into food for man.

While all animal diseases are a handicap to efficient production, the most highly fatal, infectious diseases which impose the greatest burdens are among those exotic to the United States. This results in a marked contrast in livestock productivity between developed and developing countries. With only 40% of the world's livestock in developed countries, they produce 80% of the world's meat, milk and eggs.

If we are to protect U. S. livestock against the threat of exotic disease and help developing nations feed themselves, we must have knowledge of the major diseases and know how to control them. Should we neglect opportunities to improve world food production, we increase the chances of regional starvation with the associated social, economic and political instability which lead to aggression.

MAURER, F. D.: Rinderpest. Submitted for publication in the 1973 revision of the "Foreign Animal Diseases" manual, U. S. Animal Health Association, Committee on Foreign Animal Diseases.

Rinderpest is an acute, febrile, virus disease which spreads by direct and indirect contact between ruminants, primarily cattle and buffalo. It is characterized pathologically by inflammation, hemorrhage, necrosis and erosion of the digestive tract accompanied by a wasting, frequently bloody diarrhea. Less acute forms may occur in resistant cattle. Since ancient times, Rinderpest has been the world's most devastating disease of cattle and, as such, has had a major influence on man's food supply. Prior to 1949, Rinderpest killed over 2 million cattle and buffalo per year. Losses continued until effective vaccines were developed and immunity maintained. It is only through such immunity that cattle raising is now profitable in Africa, the Middle East, and Asia. The presence of Rinderpest anywhere serves as a constant threat to the rest of the world. The U. S., like other free nations, must be alert to its recognition, and be prepared to accomplish prompt confirmatory diagnosis and control.

MAURER, F. D. and McCULLY, R. M.: African Horsesickness. Submitted for publication in the 1973 revision of the "Foreign Animal Diseases" manual, U. S. Animal Health Association, Committee on Foreign Animal Diseases.

The chapter describes the history, geographic distribution, etiology, clinical character, pathology, diagnosis, preventive immunity, epidemiology, and control of this most destructive disease of equine animals. African Horsesickness is a highly fatal, insect-borne, febrile, virus disease clinically dominated by an acute pulmonary edema or a hemorrhagic myocarditis associated with localized areas of inflammatory edema and hemorrhage. Long confined to south and equatorial Africa, in the 1960's it spread via the ubiquitous culicoides vectors throughout 11 countries of the middle east, North Africa, and Spain, killing many hundreds of thousands of equines. In view of the essentially worldwide distribution of culicoides vectors, African Horsesickness is a prevailing threat to the western hemisphere and elsewhere. With 9 known antigenically different strains of virus, polyvalent vaccines oriented to the strains involved are required to protect threatened equines. Each country, including the United States, needs to be prepared to promptly diagnose and, if need be, vaccinate against African Horsesickness.

MAURER, F. D. et al.: Livestock Production and Marketing in Pakistan. A 107 page report to AID based upon a month's survey in August 1973.

TODOROVIC, R. A.: Bovine Babesiosis: Its Diagnosis and Control. American Journal of Veterinary Research, (August 1974), 35, (8): 1045-1052.

The investigation was conducted to develop new systems and to evaluate existing ones for the diagnosis and control of bovine babesiosis in Colombia, South America. Antigens of Babesia bigemina and Babesia argentina were isolated and used in the complement fixation and rapid agglutination tests for the diagnosis of babesiosis in cattle. Three systems were evaluated for the control of bovine babesiosis: (1) vaccination of susceptible cattle with killed Babesia spp. vaccine to produce resistance based on sterile immunity; (2) premunition of cattle with virulent Babesia spp., followed by chemotherapy to produce resistance based on co-infectious immunity; and (3) chemoprophylaxis based on the activity of babesiacidal compounds with prolonged residual action. All these systems were found effective in controlling bovine babesiosis under the conditions of these experiments. The epizootiological conditions of babesiosis enzootic areas will indicate which system is applicable. In zones with a high incidence of Boophilus microplus, the premunition is indicated; in areas where the tick population is controlled, or in areas at constant risk of tick exposure, the system of inducing resistance with killed Babesia spp. or chemoprophylaxis is indicated.

TODOROVIC, R. A., GONZALEZ, E. F. and ADAMS, L. G.: Bovine Babesiosis: Sterile Immunity to Babesia bigemina and Babesia argentina Infections. Tropical Animal Health and Production, (1973), 5: 234-245

Killed Babesia bigemina and Babesia argentina vaccine was prepared from the infected erythrocytes (AG-E) and from the infected plasma (AG-S) collected from acutely infected calves with B. bigemina and B. argentina. The vaccine was tested in Colombian cattle under field conditions in the Cauca Valley. A total of 40 calves two and one-half months of age received killed-Babesia vaccine. Five calves were not vaccinated; they served as controls. Vaccinated and non-vaccinated control calves were exposed to field-borne challenge with Boophilus microplus infected ticks On the basis of the data obtained in these experiments, it was found that a high degree of sterile immunity to B. bigemina and B. argentina can be produced in calves injected with killed-Babesia vaccine. It appears that sterile immunity plays an important role in the mechanism of acquired immunity to babesiosis other then well-known co-infectious immunity known as premunition.

TODOROVIC, R. A., VIZCAINO, O. G., GONZALEZ, E. F. and ADAMS, L. G.: Chemoprophylaxis (Imidocarb) Against Babesia bigemina and Babesia argentina Infections. American Journal of Veterinary Research, (September 1973), 34, (9): 1153-1161

The chemoprophylactic effects of imidocarb (3,3'-bis-(2-imidazolin-2-yl)carbanilide dihydrochloride) against bovine babesiasis were evaluated in 29 calves. The compound had prophylactic and therapeutic properties in calves artificially or naturally infected with Babesia bigemina and Babesia argentina of Colombian (South American) origin. Administered intramuscularly at the dose level of 2 mg/kg, imidocarb suppressed the development of acute babesiasis in calves treated 46 days previously and later exposed to a lethal dose of Babesia spp.-intected blood Imidocarb failed to protect against Anaplasma marginale infection. Calves treated intravenously with imidocarb at dose level 2 mg/kg and challenge inoculated 20 days later with a lethal dose of Babesia spp -infected blood were protected For 90 days after challenge, none of the calves had Babesia spp. parasitemia, as determined by examination of stained blood films and by subinoculation of blood into susceptible splenectomized calves Calves intravenously treated 21 days previously with 3 mg of imidocarb per kilogram resisted tick-borne challenge of Boophilus microplus. This resistance was evidenced for 15 weeks of field exposure by negative results of examinations of stained blood films and death of nontreated calves from acute babesiasis. All calves treated with imidocarb and subsequently exposed to blood or tick-borne Babesia spp. responded with an increase of complement-fixing antibodies.

Imidocarb readily controlled severe acute infections with B. bigemina and B. argentina when the compound was given at dose rates of 1 mg/kg by both intramuscular or subcutaneous routes. Signs of acute toxicosis were observed in calves given intravenous injections of 3 mg/kg. Three calves died, having signs of embarrassed respiration, oral respiration, excessive salivation, muscular fasciculations, urination, defecation, incoordination, and prostration. Signs of toxicosis were milder with intramuscular or subcutaneous injections of imidocarb.

VIZCAINO, O. G. and TODOROVIC, R. A.: Produccion de Antigenos Solubles de Babesia argentina y Babesia bigemina para Pruebas de Immunodiffusion. (Soluble Antigens of Babesia bigemina and Babesia argentina and Their Application in Serologic Tests.) Proceedings of the 7th Panamerican Veterinary Congress, July 23-28, 1973, Bogota, Colombia, 38-39, (abstract).

Diagnosis of bovine babesiosis during the acute phase of infection is made by examination of Giemsa-stained blood films; however, during the chronic phase of disease, several serologic tests are used for detection of specific Babesia spp. antibodies. The purpose of the present investigation was to isolate soluble antigens of Babesia bigemina and Babesia argentina from blood acutely infected with these hemotropic parasites and use them in immunodiffusion tests for detection of specific antibodies.

Soluble antigens of B. bigemina and B. argentina were isolated from plasma collected from animals acutely infected with these parasites. By means of column chromatography (DEAE-cellulose and Sephadex-G2000), soluble antigens of B. bigemina and B. argentina were purified from host material and found antigenically specific in gel diffusion tests. Antigenic fractions obtained by above procedures were found to contain protein at 280 μw of optical density.

By means of DEAE-cellulose column chromatography, it was possible to separate host hemoglobin from soluble antigens of B. bigemina and B. argentina. Three protein peaks were recorded during fractionation, but only the second peak contained soluble antigens contaminated with host serum proteins. By means of Sephadex-G2000 column chromatography, it was possible to separate normal serum proteins from soluble B. bigemina and B. argentina antigens. When serum samples collected from cattle infected with B. bigemina and B. argentina were subjected to react with soluble antigens in the gel diffusion test a line of precipitation reaction was observed. Twenty-four or more hours of incubation was necessary for visible reaction.

Specific antibodies to B. bigemina and B. argentina were detected in sera of cattle infected with these parasites for 73 and 83 days of infection in the homologous system tested. An attempt was made to characterize these soluble antigens by means of immunoelectrophoresis. It was found that both antigens migrate a short distance to the positive pole. Antigenic reactivity of B. bigemina and B. argentina soluble antigens was preserved for 6 months at -79° C.

ADAMS, L. G.: A Study of the Toxicity of Imidocarb Dipropionate in Horses. (manuscript in preparation 1974)

An experiment was designed to study the potential systemic toxicity of imidocarb dipropionate in which 12 male and 12 female horses from 2 to 8 years of age were divided into 6 groups of 2 males and 2 females each. Five groups of 4 horses each were intramuscularly injected twice at a 24-hour interval with 2, 4, 8, 16, and 32 mg/kg, respectively. One group of 4 horses was injected intramuscularly with physiological saline solution and served as controls. Two of 4 horses injected with 16 mg/kg and 4 of 4 horses injected with 32 mg/kg died between days 2 and 6 following the first injection; therefore, the LD_{50} was determined to be 16 mg/kg at 21 days following the first injection. Increasing quantities of injected dipropionate correlated with increasing mortality rates, rapidity of mortality, systemic reaction, local injection site reactions, and increasing levels of serum urea nitrogen, increasing enzymatic activities of serum glutamic oxaloacetic transaminase, serum sorbitol dehydrogenase, serum creatinine phosphokinase, serum lactic dehydrogenase, a left shift in neutrophilic leukocytes, higher respiratory and pulse rate, and an increasing severity of hepatic renal and pulmonary lesions. The most prominent pathological lesions were an acute tubular necrosis of the proximal convoluted tubules of the renal cortex and an acute periportal hepatic lipidosis and necrosis. Death was attributed to renal and hepatic failure.

ADAMS, L. G. and CORRIER, D. E.: A Study of the Toxicity of Imidocarb Dipropionate in Cattle. (manuscript in preparation 1974)

An experiment was designed to determine the potential systemic toxicity of imidocarb dipropionate in which 20, 10 to 12 month old, calves were divided into 4 groups of 5 each. Three groups were intramuscularly treated twice at a 14-day interval with 5, 10, and 20 mg/kg, respectively, while the other group was treated only with physiological saline solution and served as a control. The LD_{50} at 14 days in calves receiving only one injection of imidocarb dipropionate was determined to be 15 mg/kg, and the LD_{50} at 67 days in calves receiving two injections was determined to be 15 mg/kg. None of the calves treated either once or twice at 5 or 10 mg/kg died, while 5 of 5 calves treated either once or twice at 20 mg/kg died within 18 days following the first injection.

No significant alterations occurred in the average daily gain, total serum proteins, total leukocytes, absolute lymphocytes, absolute monocytes, and absolute eosinophils. Increasing quantities of injected imidocarb dipropionate correlated with increasing levels of blood urea nitrogen, increasing enzymatic activity of serum glutamic oxaloacetic transaminase, and a left shift in neutrophilic leukocytes. In cattle treated with 20 mg/kg, the most prominent gross pathological lesions were hydrothorax, hydroperitoneum, pulmonary edema, perirenal edema, enlarged pale kidneys with prominent alternating red and white bands in the renal cortex, and enlarged, friable, pale livers with accentuating hepatic lobules. The most prominent histopathological lesions were acute tubular necrosis of the proximal convoluted tubules of the renal cortex and acute periacinar hepatic necrosis.

ADAMS, L. G. and TODOROVIC, R. A.: The Chemotherapeutic Efficacy of Imidocarb Dihydrochloride on Concurrent Bovine Anaplasmosis and Babesiosis. I. The Effects of a Single Treatment. Tropical Animal Health and Production, (1974), 6: 71-78.

The chemotherapeutic efficacy of imidocarb dihydrochloride [3,3'-bis(2-imidazolin-2-yl)carbanilide dihydrochloride] administered as single intramuscular doses of 1.0, 2.0 and 2.5 mg/kg, against concurrent bovine anaplasmosis and babesiosis, is reported. Dosages of 2.0 and 2.5 mg/kg of imidocarb dihydrochloride rapidly inhibited acute ascending concurrent parasitaemias of Anaplasma marginale, Babesia bigemina and Babesia argentina; however, 1.0 mg/kg had a minimal effect on A. marginale, but was very effective against B. bigemina and B. argentina. Imidocarb dihydrochloride at 1.0, 2.0 and 2.5 mg/kg inhibited the development of immunity of the acute Babesia spp. infections, making the calves more susceptible to babesiosis upon challenge.

ADAMS, L. G. and TODOROVIC, R. A.: The Chemotherapeutic Efficacy of Imidocarb Dihydrochloride on Concurrent Bovine Anaplasmosis and Babesiosis. II. The Effects of Multiple Treatments. Tropical Animal Health and Production, (1974), 6: 79-84.

Intact Anaplasma marginale, Babesia bigemina and Babesia argentina carrier calves treated intramuscularly 5 or 10 times with 2.5 mg/kg of imidocarb dihydrochloride at 48-hour intervals eliminated the Babesia infections, but not Anaplasma infections. The parasitaemias became microscopically undemonstrable within 4 days following the first treatment, and the packed cell volumes increased significantly within 18 days. Intoxications resulting in fatalities occurred in 5 of 6 calves given 10 intramuscular treatments of 2.5 mg/kg of imidocarb dihydrochloride at 48-hour intervals.

ALIU, Y. O.: Absorption, Distribution, and Excretion of Imidocarb Dipropionate [3,3'-bis-(2-imidazolin-2-yl)carbanilide] in Sheep. Ph.D. Dissertation, Department of Physiology and Pharmacology, College of Veterinary Medicine, Texas A&M University, August 1974, (106 pages).

Spectrophotometric and thin-layer chromatographic methods for quantitative and qualitative determination of Imidocarb in biologic specimens are described. Imidocarb was extracted under basic conditions from plasma, urine, milk, bile, and homogenized tissue samples in organic solvents. Following extraction and concentration in 0.82 N HCl, the drug was quantitatively identified by spectrophotometry. The limits of accuracy are estimated to be 1.0 µg/ml in plasma and other body fluids and 5.0 µg/gm in tissues.

High plasma levels were reached in 4 hours after the intramuscular injection of 4.5 mg/kg Imidocarb. This was followed by rapid decline initially but later the rate of decline was reduced so that trace amounts were still present weeks after the injection. High and persistent tissue residues were characteristic of this drug. Approximately 11-17% of the administered drug was excreted in the urine within 24 hours, but thereafter the excretion rate was low. The relatively high concentrations of the drug found in the bile suggests that biliary excretion is an important route of drug elimination. High concentrations were found in the milk of lactating ewes. When the milk was fed to nursing lambs, no drug could be detected in their plasma.

BISHOP, J. P. and ADAMS, L. G.: Babesia bigemina: Immune Response of Cattle Inoculated with Irradiated Parasites. Experimental Parasitology, (1974), 35: 35-43.

Effects of various radiation dosages on the infectivity and immunogenicity of Babesia bigemina were studied. Calves infected with 1 X 10^{10} B. bigemina parasitized erythrocytes exposed to 24 krad developed progressive parasitemias. Some calves receiving 1 X 10^{10} parasitized erythrocytes irradiated at 36 krad did not develop progressive infections. Progressive infections were prevented by exposure to irradiation at 48 and 60 krad. A degree of acquired resistance to infection with B. bigemina developed in calves after inoculation with parasites irradiated at 48 and 60 krad. The resistance developed was sufficient to suppress multiplication of the Babesia and to permit calves to survive otherwise severe clinical infections due to challenge with nonirradiated parasites. Irradiated parasites were frozen without apparent loss of immunizing properties.

CORRIER, D. E.: A Clinical, Histological and Ultrastructural Study of the Toxic Effects of Imidocarb Dipropionate in Goats. A Dissertation submitted to the Graduate College of Texas A&M University in partial fulfillment of the requirement for the degree of Doctor of Philosophy, August 1974.

The toxic effects of imidocarb dipropionate were studied in adult goats following the intramuscular injection of a lethal dosage of the drug. The acute clinical signs of toxicosis were transient and included excessive salivation, diarrhea, dyspnea, anorexia and inactivity. Significant increases in the mean serum urea nitrogen concentrations, serum glutamic oxaloacetic transaminase activities, and absolute neutrophilic leukocytes occurred. The most prominent gross pathological lesions were enlarged, pale kidneys with the presence of alternating red and white streaks in the renal cortex, hydrothorax, hydropericardium, ascites, and pulmonary edema. The histological alterations included severe acute tubular necrosis of the proximal convoluted tubules of the renal cortex beginning as early as 6 to 12 hours post-injection and massive pulmonary edema. Ultrastructural lesions were observed at 3 hours and progressed rapidly in the next 24 hours to include disruption of plasma membranes, dilation and proliferation of the endoplasmic reticulum, swollen electron dense mitochondria, and rarefaction of the cytoplasmic ground substance. Finally, complete disruption of the plasma membrane with fragmentation of the microvilli, loss of junctional complexes and cullular disjunction became evident from 12 to 24 hours post-injection.

Progressive decreases were observed in succinic dehydrogenase and adenosine triphosphatase activities beginning at 12 hours and 24 hours post-injection, respectively. The loss of ability of the epithelial cells of the proximal convoluted tubules to regulate cell volume was considered to have been the initial event responsible for the subsequent ultrastructural, histological and histochemical changes observed following the injection of imidocarb dipropionate.

GUZMAN, V. H., ADAMS, L. G. and GALVIN, T. J.: Verminosis Laringea Bovina Producida por Mammomonogamus laryngeus en Colombia. Revista ICA (accepted for publication).

Eight cases of bovine laryngeal verminosis were diagnosed in Valle del Cauca, Colombia, and confirmed by parasitological studies. Macroscopic and microscopic descriptions were made of the lesions caused by Mammomonogamus laryngeus.

KUTTLER, K. L.: Use of Imidocarb to Control Anaplasmosis. The Southwestern Veterinarian, (1975), 28, (1).

A field trial was conducted on 469 cattle to determine the effectiveness of imidocarb [3,3'-Bis-(2-imidazolin-2-yl)-carbanilide dipropionate] which was injected intramuscularly 2 times 14 days apart at a level of 5 mg/kg body weight. Treatment was therapeutically effective, but these methods failed to produce the desired control. An initial drop in positive serum response as measured by the complement-fixation test was noted after treatment. This was followed by a gradual increase, thought to be due to reinfection. One year after treatment the rate of positive serum tests was essentially the same as before treatment.

Even though effective drugs are available to treat anaplasmosis, caution is indicated in those herds in which the infection rate is high and transmission is active.

KUTTLER, K. L. and CRAIG, T. M.: Isolation of a Bovine Theileria. American Journal of Veterinary Research , (March 1975), 36, (3): 323-325.

Dual infections of Anaplasma marginale and a Theileria resembling T. mutans were reproduced in splenectomized calves inoculated with pooled blood samples from east Texas cattle. Theileria can be obtained in pure form by treating cattle, with dual infections, with Gloxazone and imidocarb which eliminated Anaplasma but not the Theileria. These Theileria infections were responsible for mild, transient reductions in packed red cell volume.

KUTTLER, K. L., GRAHAM, O. H. and TREVINO, J. L.: The Effect of Imidocarb Treatment on Babesia in the Bovine and the Tick (Boophilus microplus). Research in Veterinary Science (accepted for publication).

Treatment of calves with 5 mg/kg imidocarb as dipropionate given intramuscularly 14 days before and 14 days after exposure to Babesia infected Boophilus microplus larvae rendered the next generation larvae incapable of transmitting Babesia infection. The drug, when administered to calves 14 and 28 days before tick exposure, prevented the development of clinical babesiosis, but the larval progeny of ticks reared on the calf treated 28 days before infestation were infective for Babesia. Treatment of a calf 42 days before exposure to infective larvae did not prevent the development of a Babesia parasitemia but appeared to reduce the severity of infection.

MAURER, F. D.: Support for Research in Animal Health. Journal of the American Veterinary Medical Association (accepted for publication).

The principle source of funds for research in the colleges of veterinary medicine has long been from agencies of the Federal government. In general, Federal agencies have placed emphasis upon human health related problems even though experimental animals and veterinarians were involved. As a result, there has been a relative neglect of those diseases of livestock which reduce U. S. production by 11 to 15% per year.

Rather than for the livestock industry to wait for government assistance, it is urged that livestock associations support research toward the solution of their own problems. Other industries find it economically profitable to plow back some 15% of annual profits into research and development; this could apply to livestock as well.

MAURER, F. D. et al.: African Agricultural Research Capabilities. National Academy of Sciences, Washington, D. C., 1974. A publication of 221 pages.

The work of an international committee, of which F. D. Maurer was the veterinary member. The report constitutes a review of the needs, opportunities, facilities and personnel for research on the major agricultural crops and livestock. Emphasis is upon research required to solve major problems which now handicap crops and livestock production. Our primary area of concern was for research on animal disease problems. The committee's work was financed by USAID

PLATT, K. B.: The Development of an Indirect Fluorescent Antibody Test for Trypanosoma vivax in Colombia. A Thesis submitted to the Graduate College of Texas A&M University in partial fulfillment of the requirement for the degree of Master of Science, May 1974.

An indirect fluorescent antibody test for Trypanosoma vivax infections was developed for a survey involving over 2,000 cattle distributed throughout 11 departments and territories in Colombia. The antigen for the indirect fluorescent antibody test was prepared from the blood of infected calves by making thin blood smears that were air-dried and fixed in acetone: methanol: 60:40 at -20° C for 30 minutes. The antigen prepared in this manner was useful up to and including 144 days when stored at -70° C. Indirect fluorescent antibody test serum titers of 1:100 or greater were considered to be positive. No cross-reactivity of the indirect fluorescent antibody test was observed between Trypanosoma vivax and Anaplasma marginale, Babesia argentina, Babesia bigemina, Eperythrozoon sp. or Trypanosoma theileri at 1:50 serum dilutions. Suspicious reactions occasionally were observed when Trypanosoma evansi positive serum was diluted 1:50 and 1:100 and used in the indirect fluorescent antibody test for Trypanosoma vivax. The indirect fluorescent antibody test could be repeated within plus or minus one serum dilution approximately 80% of the time using different antigen lots on the same and different days. Samples obtained for the indirect fluorescent antibody test by eluting serum from dried impregnated filter paper discs produced results nearly equal to those obtained by using conventional serum samples. The indirect fluorescent antibody test was up to 20 times more effective in detecting Trypanosoma vivax positive cattle than the thick blood smear technique. The indirect fluorescent antibody test demonstrated the presence of Trypanosoma vivax antibodies in cattle from 5 departments in Colombia, while antibodies were not detected in the serum of cattle from 6 other departments of Colombia.

THOMPSON, K. C.: A Comparison of the Antigenic Properties of Erythrocytic Babesia bigemina in Acute and Chronic Blood Borne and Tick Borne Infection in Cattle. A Dissertation submitted to the Graduate College of Texas A&M University in partial fulfillment of the requirement for the degree of Doctor of Philosophy, May 1974.

This study was made to determine possible antigenic differences in a Babesia bigemina isolate in acute and chronic blood borne and tick borne infections of cattle.

On the basis of the serological results, antigenic variation within an isolate of B. bigemina occurred. Antigenic variation appeared to be influenced by the mode and duration of infection. The hosts' apparent reduced response to homologous challenge and the marked response observed with heterologous systems indicated antigenic differences of B. bigemina.

TODOROVIC, R. A.: Prevention and Control of Bovine Anaplasmosis and Babesiosis (Piroplasmosis). Proceedings of the Texas Animal Production Conference for Latin American Cattle Producers, January 21, 1974, College Station, Texas, (abstract).

The purpose of this report was to discuss the epizootiological similarities between anaplasmosis and babesiosis, and to emphasize recent developments concerned with prevention and control. In addition, the mechanism of immunity of these hemotropic diseases was discussed.

TODOROVIC, R. A.: Serologic Diagnosis of Babesiosis: A Review. Experimental Parasitology (submitted).

In the last three decades some fundamental knowledge concerning the immunoserology of Babesia spp. infections has led to the development of serologic techniques which provide a means for studying the pathogenesis of babesiosis and the detection of animals with subclinical infections. The antigens used in the serologic procedures originated from the parasitized erythrocytes, plasma, and tissues of animals with acute babesiosis. Parasitic and serum soluble antigens were applied in a variety of serologic tests, e.g., complement fixation, gel precipitation, agglutination, and fluorescent antibody, for detection of Babesia spp. antibodies.

In this review an attempt was made to summarize and discuss the recent advances in the serodiagnosis of babesiosis, together with conditions where the use of serologic methods may be valuable.

TODOROVIC, R. A., GONZALEZ, E. F. and ADAMS, L. G.: Babesia bigemina, Babesia argentina and Anaplasma marginale: Co-infectious Immunity in Bovines. Experimental Parasitology (submitted).

Forty-eight intact and 8 splenectomized calves were used to evaluate different systems of co-infectious immunization against Babesia bigemina, Babesia argentina and Anaplasma marginale. Co-infectious immunity was induced by two methods: (1) blood of calves acutely infected with B. bigemina, B. argentina and A. marginale was used as the source of inoculum and the post injection reactions were chemotherapeutically controlled with Imidocarb, Ganaseg, Gloxazone or Liquamycin; and (2) by artificially inducing babesiosis with the blood of carrier calves with chronic infections of B. bigemina and B. argentina without chemotherapy. The degree of resistance was determined by blood-borne and tick-borne challenges. Ticks were collected from cattle and identified as Boophilus microplus and Dermacentor nitens. Vaccinated cattle demonstrated a high degree of resistance to babesiosis and anaplasmosis; however, cattle without co-infectious immunity were treated chemotherapeutically to prevent death losses.

TODOROVIC, R. A. and KUTTLER, K. L.: A Babesiasis Card Agglutination Test. American Journal of Veterinary Research (accepted for publication).

A babesiasis card agglutination test (BCT) has been developed for detecting specific antibodies in cattle infected with Babesia bigemina. The agglutinating antigen was isolated from the blood of a splenectomized calf having 22% B. bigemina parasitemia. The antigen was preserved with 0.02% formalin and stained with fast green dye. The BCT was performed by adding 1 drop of antigen and 2 drops of plasma or serum on a card and mixing for 5 minutes by rotation. Agglutination was visible in instances of positive reactions immediately after rotation.

In cattle intentionally exposed to B. bigemina, the BCT detected agglutinating antibodies simultaneously with the onset of first parasitemia. This reaction was observed to persist as long as 3 months, or long after the disappearance of parasitemia. Because of its simplicity and apparent specificity, the BCT may have use as a field test to aid in the diagnosis of B. bigemina infections. The BCT results showed 100% agreement with the complement-fixation (CF) test on those serums prepared from blood collected within 3 months of infection.

TODOROVIC, R. A., LOPEZ, L. A., LOPEZ, A. G. and GONZALEZ, E. F.: Control of Bovine Babesiosis and Anaplasmosis in Cauca River Valley. Experimental Parasitology (submitted).

Experiments were carried out to evaluate two systems: (1) premunition and (2) chemoprophylaxis for the control of bovine babesiosis and anaplasmosis in the Cauca River Valley. Control of these diseases was achieved by inoculating cattle with virulent Babesia bigemina, Babesia argentina, and Anaplasma marginale and subsequent treatment with Imidocarb and Gloxazone to moderate the post premunition reactions. Chemoprophylactic treatment with Imidocarb and Gloxazone was administered to cattle before and during field exposure. Premunized cattle were highly resistant to tick-borne (Boophilus microplus) challenge. Imidocarb had therapeutic and chemoprophylactic properties against babesiosis, but appeared toxic. Gloxazone moderated the A. marginale post premunition reaction, but failed to prevent clinical anaplasmosis under the conditions of this investigation.

TODOROVIC, R. A. and TELLEZ, C. H.: The Premunition of Adult Cattle Against Babesiosis and Anaplasmosis in Colombia, South America. Tropical Animal Health and Production (accepted for publication).

Twenty-five cattle (Bos taurus) between 2 and 3 years of age were premunized with virulent Babesia bigemina, Babesia argentina, and Anaplasma marginale. The Babesia spp. premunition reaction was controlled by Imidocarb or by Ganaseg therapy. The A. marginale post premunition reaction was controlled by oxytetracycline alone, or by Gloxazone (dithiosemicarbazone) combined with oxytetracycline. Systems of premunition for Babesia spp. were found effective and practical; however, systems of premunition for A. marginale were found less effective and not practical under the conditions of these experiments.

CORRIER, D. E.: The Epidemiology of Bovine Anaplasmosis and Babesiosis in the Lowland Tropics of Colombia. Presented at Hemoparasite Workshop - CIAT, March 17-22, 1975.

The prevalence of anaplasmosis and babesiosis was determined on 37 ranches in the Eastern plains, 4 ranches on the Atlantic coast, and on 6 ranches in the Cauca Valley of Colombia. A random group of cattle representing a minimum of 10 per cent of the total herd were sampled on each ranch ensuring that animals less than 1 year, 1 to 2 years and more than 2 years of age were included in the sample group. A total of 3,698 serum samples were collected and tested using the complement fixation test. Tick counts were made and ticks were collected for classification on each of the 37 ranches visited in the Eastern plains.

The prevalence of Anaplasma reactors was determined to be 75 per cent in the Eastern plains, 91 per cent on the Atlantic coast and 71 per cent in the Cauca Valley. The prevalence and even distribution of Anaplasma reactors among the 37 ranches in the Eastern plains indicated anaplasmosis is endemic within the entire study area. The prevalence of Anaplasma reactors on the 4 ranches on the Atlantic Coast, and the 6 ranches in the Cauca Valley, though based on inadequate sample sizes for the areas in general, suggests that anaplasmosis is probably endemic in both areas.

The prevalence of Babesia bigemina reactors was determined to be 42 per cent in the Eastern plains, 77 per cent on the Atlantic coast and 75 per cent in the Cauca Valley. The prevalence of infection with B. bigemina in the Eastern plains indicated the area is endemic. However, the percentage of reactors among the 37 ranches varied from 5 to 98 per cent, which indicated the disease is not evenly distributed throughout the area. The prevalence of B. bigemina reactors on the Atlantic coast and in the Cauca Valley suggests that babesiosis is probably endemic in both areas.

The high prevalence of anaplasmosis and babesiosis within the 3 areas in which the study was conducted indicates the importance of exposing calves to infection at an early age when maternal antibodies and natural resistance provide maximum protection against clinical disease.

The necessity of providing protection through immunization or other procedures to susceptible cattle which may be transferred into the areas was strongly indicated.

Boophilus microplus ticks were identified on each of the 37 ranches in the Eastern plains and were nearly equally distributed as indicated by nonsignificant differences in the tick counts. Ticks identified as Amblyoma cajennense, Amblyoma triste and Anocentor nitens were collected on 3 of the ranches indicating that their role as vectors or potential vectors of anaplasmosis and/or babesiosis is limited.

DAY, W. C. and KUTTLER, K. L.: Animal Health Considerations Involved in the Movement of U.S. Cattle to Haiti. (Accepted for publication in The Southwestern Veterinarian).

A total of 44 young Charolais cattle were moved from Texas to Haiti. They were vaccinated against anaplasmosis (1 injection only), anthrax and shipping fever. They were treated with 2.8 mg/kg body weight of Imidocarb before being exposed to infected Boophilus ticks.

Based on serologic evidence, infections with Anaplasma occurred in 90% of the calves within the first 130 days. Babesia infections apparently occurred in over 70% of the calves within this same period of time. No deaths, however, occurred during the first 130 days.

MAURER, F. D.: Livestock, a World Food Resource Threatened by Disease. Journal of the American Veterinary Medical Association, (1975), 166, (9): 920-923.

This is an editorial-type article which stresses the essential role of livestock as a world food resource and the importance of disease control for efficient livestock production; hence, man's food supply.

MILLER, R.M.: Investigations On Transstadial Transmission of Bovine Anaplasmosis and Benign Bovine Theileriosis in Cattle by Two Species of Amblyomma (Acarina: Ixodidae). Thesis, submitted to the Graduate College of Texas A&M University in partial fulfillment of the requirement for the degree of Master of Science, August 1974.

Nymphal stages of both Amblyomma americanum (Linnaeus) and A. cajennense (Fabricius) engorged either on a holstein bull calf chronically infected with Anaplasma marginale (Theiler), or on a holstein bull calf chronically infected with a Theileria organism resembling Theileria mutans (Theiler). After natural detachment and molting, the exposed adult ticks subsequently engorged on non-infected splenectomized holstein bull calves.

During the engorgement of the exposed adult ticks and for 75 days after their natural detachment, the splenectomized calves were monitored for the presence of blood parasites using both complement-fixation tests and Giemsa-stained thin blood smears. No evidence of infection was observed. After 90 days, the splenectomized calves were challenged to see if they were actually susceptible to either of the two blood parasites. Inoculations of blood demonstrating a parasitemia of either A. marginale or the Theileria resembling T. mutans were administered to the splenectomized calves which had been previously exposed to the test group of adult ticks. The splenectomized calves developed evidence of both anaplasmosis and theileriosis, suggesting that they were susceptible to the blood parasites at the time of tick infestation.

PLATT, K. B. and ADAMS, L. G.: Evaluation of the Indirect Fluorescent Antibody Test for Detecting Trypanosoma vivax in South American Cattle. Submitted for publication to Research in Veterinary Science.

The indirect fluorescent antibody test (IFAT) as used in Africa for detecting bovine trypanosomiasis was adapted for use in South America and evaluated. Antigen consisted of Trypanosoma vivax laden bovine blood fixed in a 60:40:: acetone:methanol solution. The test detected initial titers of 1:50 and 1:100 at an average of 13.1 and 15.9 days post parasitemia (PP). Maximum titers as high as 1:400 developed in 8 calves at an average of 23.4 days PP. In another calf, 109 days PP were required. Efficacy in detecting sero-positive calves throughout the course of infection was 81.1 and 96.4% at serum dilutions 1:100 and 1:50 respectively. No false positive reactions occurred when serums from 36 hemoparasite-free-calves were tested. Cross reactivity did not occur when serums from calves singularly infected with Trypanosoma theileri, Trypanosoma evansi, Anaplasma marginale, Babesia argentina, Babesia bigemina and Eperythrozoon spp. were similarly tested in the IFAT. No significant differences were found in IFAT results of surveys in which both conventional serum samples and serums eluted from dried filter paper blood samples from the same calf were used.

REYNOLDS, S. D.: Evaluation of Methods of Premunition to Anaplasma marginale. Thesis submitted to the Graduate College of Texas A&M University in partial fulfillment of the requirement for the degree of Master of Science. May 1975.

A frozen stabilate prepared from a pooled sample of blood containing red blood cells highly parasitized with A. marginale was used as the infective organism in this trial.

Twenty-five yearling crossbred heifers were divided into 4 experimental groups. Group I consisted of 7 animals which were vaccinated with 2 injections of Anaplaz vaccine at 4-week intervals prior to the first infection with live organisms. Group II, consisting of 9 animals, was designated as the untreated group. The 5 animals in Group III received oxytetracycline 11 mg/kg when their parasitemias reached 4.6%. Group IV, consisting of 4 animals, was designated the control group.

Clinical manifestations of the infection were mild. During the infection the animals had a rough hair coat and poor body condition. There was some decrease in weight gains but nothing remarkable clinically.

A complement fixation titer preceded the appearance of a parasitemia by up to a week. Associated with the appearance of a parasitemia were decreases in PCV, RBC, and Hb and a rise in MCV.

The recovery rates for the animals in each of Groups I, II, and III showed no significant differences. The animals in Group II (untreated) displayed a faster rate of recovery than either Group I or Group III for PCV, RBC, and Hb, but had a slower rate of weight gain.

THOMPSON, K. C., TODOROVIC, R. A. and HIDALGO, R. J.: Antigenic Variation of an Isolate of Babesia bigemina. (Prepared for publication).

The purpose of the study was to determine whether antigenic differences occurred between acute and chronic, blood borne and tick borne, infections of Colombian cattle derived from a single purified isolate of Babesia bigemina.

Antigens were characterized by means of the complement fixation (CF), gel diffusion (GD), agar gel immunoelectrophoresis (AGI) and the indirect haemagglutination tests (IHA).

Differences were detected between the four sources of antigen.

THOMPSON, K. C., TODOROVIC, R. A. and HIDALGO, R. J.: Immune Response of Cattle to Babesia bigemina Isolated from Acute and Chronic Blood and Tick Borne Infections. (Prepared for publication).

Four Babesia bigemina stabilates were used to determine the immune response of cattle to acute and chronic blood and tick borne infections.

Thirty-six intact calves were divided into 16 groups of 2 (or 3) and each group inoculated with infective Babesia bigemina erythrocytic stabilates. Twenty-eight days later they were homologously and heterologously challenged with the original stabilates, and monitored for an additional 20 days. The host's apparent reduced response to homologous challenge and the marked immune response observed with heterologous systems indicated antigenic differences of the B. bigemina and confirmed the serological data under the experimental conditions used in the investigation.

THOMPSON, K. C.: The Maintenance, Life Cycle and Experimental Infection of the South American Boophilus microplus Tick. (Prepared for publication).

Techniques were evolved for the establishment and maintenance of a colony of Boophilus microplus free of infection with Anaplasma marginale and Babesia spp., and for their subsequent infection with a pure isolate of Babesia bigemina. Confirmation was obtained that the ticks are infected normally during the last 24 hours of attachment on the host. The life cycle of Boophilus microplus was described for a single situation on the Atlantic Coast of Colombia.

TODOROVIC, R. A. and LONG, R. F.: Comparison of Indirect Fluorescent Antibody (IFA) with Complement Fixation (CF) Tests for Diagnosis of Babesia spp. Infections in Colombian Cattle. (Prepared for publication).

A total of 372 serum samples were collected from Colombian cattle before and during the course of natural Babesia spp. infection on the North Coast of Colombia. The serum samples were used to compare indirect fluorescent antibody (IFA) with complement fixation (CF) tests for diagnosis of babesiosis. The IFA technique detected Babesia argentina antibodies an average of 4.0 weeks earlier than the CF test and Babesia bigemina an average of 2.5 weeks earlier. Both IFA and CF were capable of differentiating B. argentina and B. bigemina infections, however, in some cases cross reactions were observed. In general IFA titers were at relatively high levels of 1:640 to 1:5120 in comparison with CF titers of trace to 1:80. In cases of mortality due to babesiosis, both IFA and CF serologic techniques were very useful in indicating the cause of death. Although both IFA and CF are laboratory tests, the IFA technique had advantages over the CF in simplicity, economy and speed of performance.

TODOROVIC, R. A. LONG, R. F. and McCALLON, B. R.: Comparison of Rapid Card Agglutination Test with the Complement Fixation Test for Diagnosis of Anaplasma marginale Infection in Colombian Cattle. (Prepared for publication).

A total of 342 serum samples were collected from Colombian cattle before and during natural infection with Anaplasma marginale on the North Coast of Colombia. The serum samples were used to compare the complement fixation (CF) and rapid card agglutination (CT) tests for the diagnosis of anaplasmosis. On the basis of the results with CF and CT tests, both were found to be in agreement in detection of anaplasmosis infected cattle. It appeared that the CF and CT can detect Anaplasma marginale specific antibodies at approximately the same time after exposure, however, the positive agglutination reaction of the CT occasionally developed several days after the first CF reaction. The positive CT reaction persisted once it had become positive in contrast to the CF reaction which fluctuated between trace and 1:80 titers. The advantages of the CT test for the diagnosis of Anaplasma marginale infection under field conditions are simplicity, economy and speed of performance.

WYSS, J. H. and GALVIN, T. J.: A Standardized Simultaneous Immunization Procedure for Anaplasma marginale, Babesia argentina, and Babesia bigemina. (Submitted to Tropical Animal Health and Production).

A 42 day standardized simultaneous immunization procedure for Anaplasma marginale, Babesia argentina and Babesia bigemina using stabilates and drug moderation is described. The reactions of eight calves to the procedure are presented and the weights, packed cell volumes and temperatures of the immunized calves are compared to control calves during the 42 day period. All eight calves responded to the injection of stabilates, as evidenced by parasitaemia and sero-conversion from negative to positive, for each of the three organisms. Although expected significant differences in packed cell volumes and temperatures did occur during the immunization period all calves were successfully immunized and in good condition for transportation to the field by the end of the period.

WYSS, J. H., MATEUS, G., GALVIN, T.J. and ZARAZA, H.: Evaluation of Immunization Versus Imidocarb Chemoprophylaxis of Susceptible Calves Introduced Into an Enzootic Zone of Anaplasmosis and Babesiosis. (Submitted to Tropical Animal Health and Production).

Results of a 392 day field trial comparing two different haemoparasite control procedures on susceptible calves introduced into an enzootic area of anaplasmosis and babesiosis are presented. One group of calves was previously immunized by a standardized simultaneous procedure for Anaplasma marginale, Babesia argentina and Babesia bigemina; a second group received Imidocarb chemoprophylaxis, and a third group was maintained as untreated controls. During the field challenge there were no deaths in the immunized group in contrast to 12.5 per cent mortality in the chemoprophylaxis group and 50 per cent mortality in the control group due to haemoparasites. In addition, the two groups which received some type of treatment for haemoparasites did significantly better in respect to weight gains and showed much less evidence of anemia than the control group. An economic comparison of the three groups is presented.

MILLER, R. M., PRICE, M. A. and KUTTLER, K. L.: Investigations on Transstadial Transmission of Bovine Anaplasmosis and Benign Bovine Theileriosis in Cattle by Two Species of Amblyomma (Acarina: Ixodidae). (Manuscript prepared for publication).

Amblyomma americanum and A. cajennense nymphal stages were fed on Anaplasma and Theileria infected cattle. Following molting, the adult ticks were fed on non-infected fully susceptible splenectomized calves in an effort to demonstrate transmission. In no instance was an infection of either Anaplasma or Theileria produced by either of the ticks tested.

Draft Proposal for a 211(d) Program in Kenya with emphasis on those diseases and parasites of sheep and goats which are major handicaps to efficient production.

Several years of personal and staff experience in Kenya doing research on livestock diseases has provided an awareness of the importance of sheep and goats to the local people --- particularly to the small farmer.

Kenya has a sheep and goat population in excess of 15 million animals which is roughly twice that of the cattle population based upon 1969 figures. Sheep and goats play the major subsistence role as an animal food resource for the majority of the local people. Sheep and goats make it possible for large numbers of the people to live in vast areas of rough hill country and on rangelands where sheep and goats thrive on sparse grass and browse which is inadequate for the support of cattle. Because sheep and goats have not played as important a marketing role as have cattle, and because their ownership is so diverse, they have not received the attention for research or extension as have cattle. As relatively neglected species there is much to be done which can enhance the productivity of sheep and goats in Kenya.

The improved control of disease and parasites could make marked differences in productivity. The indigenous breeds - through generations of exposure to a diseased environment - have become genetically adapted more for survival than for productivity. The creation of a relatively disease-free environment through prevention and control would increase local production and greatly facilitate the development and successful importation of more productive breeds of sheep and goats. The greater productivity of individual animals would reduce some of the pressure for ever greater numbers which has led to over-grazing and destruction of rangelands. The improvement of quality will facilitate the exportation of sheep and goat products thereby generating purchasing power which can be used in part for improved pastures and water resources which are also needed.

What would our 211(d) program provide that would be helpful to Kenya? We would propose to do the following:

1. Conduct a survey of sheep and goat diseases and parasites to determine incidence and severity as handicaps to production.

We envision this would be done largely through review of reports and interviews with personnel of the Kenya veterinary services, diagnostic laboratories, EAVRO, the Kabete laboratories, the College of Veterinary Medicine at Kabete, Extension Services, field stations and meat inspection service personnel as at the Athie River abattoir.

2. Having conducted the above survey and having selected the most important disease handicaps to production, we would do the following for each disease of justifiable priority.

a. Prepare a summarizing paper of information from the world's literature and current research workers on the diagnosis, control and prevention of that disease, thereby determining whether improved field control requires the application of what is already known about the disease or whether research for better control methods is still needed.

b. Prepare a library of current information. Through contacts established under 1. above, obtain access to case material, take colored pictures of clinical cases and gross lesions and, when appropriate, collect tissues for pathologic study. From these, prepare sets of colored pictures with commentaries as training aids.

3. Make all of the above information available to the Kenya Government for the training of veterinarians, extension personnel, and the veterinary college faculty.

This animal health-related information and the effect of disease upon efficient, profitable production would be incorporated into the overall consortium model. Through the model the relative role of disease could be envisioned in relation to the influences of nutrition, water supply, management and the many aspects of marketing.

The model will serve to point up areas of opportunity wherein Kenya can most readily effect significant improvements in the sheep and goat industry - an industry which has great potentials as a food resource and for economic profitability.

Our requirements from the Kenyan Government for these health studies would be minimal.

We would need permission to contact personnel and review public records and annual reports which would provide incidence figures for the disease problems of Kenyan sheep and goats. Permission would be sought to interview staff members who are best informed on sheep and goat diseases at EAVRO, Muguga; the Kabete Veterinary Diagnostic and Research Laboratories; the Veterinary College at Kabete; the meat inspectors at the major abattoirs such as at Athei River, the Hides and Skins Department, and at any field stations which are currently actively engaged in sheep and goat work.

We envision that some diseased animals and their tissues could be photographed and sampled at the abattoirs and at research stations.

Fred D. Maurer
16 April 1975

ANIMAL SCIENCE DEPARTMENT, TEXAS A&M UNIVERSITY

Faculty And Graduate Students Whose Activities Were Partially Supported Under the AID 211d Consortium Grant

T. C. Cartwright, Professor
J. C. Miller, Professor Emeritus
G. E. Joandet, Visiting Professor
A. W. Qureshi, Visiting Consultant from Uganda
A. J. Dye, Assistant Professor
J. O. Sanders, Research Associate
F. G. Gomez, Graduate Fellow
T. S. Stewart, Graduate Fellow
D. Perotto, Graduate Fellow
J. M. Davis, Graduate Fellow

Title: "Expanding Competence in the Design & Execution of Livestock Development Program in the Tropics, Emphasizing Ruminant Livestock Production Systems Through Improved Breeding & Disease Control" AID/csd-3675

Grantee: Texas A&M University
College Station, Texas
1/2 to Institute of Tropical Veterinary Medicine
College of Veterinary Medicine and
1/2 to Animal Science Department

This 1/2 of the report is for the Department of Animal Science

Director: T. C. Cartwright

A. Statistical Summary:

Period of Grant: 1 July 1972 to 30 June 1977
Amount of Grant: $250,000. to the Department of Animal Science

Expenditures:	For current year 1974-75	$ 56223
	Accumulated,	151107
	Anticipated for next year, 1975-76,	40600

B. Narrative Summary:

The basic beef cattle production model at the herd level has been considerably refined, written in FORTRAN and partially validated. The reproduction component has been essentially completed and validated. The other components have been partially validated and appear to respor well. Efforts to develop an integrated forage model were begun but hav not been continued because it has become evident that the lack of infor mation and background research in this area are such that a separate full time effort will be required. A modified forage component which does not have a feedback component from cattle to forage will be used instead. This modification is not considered a serious handicap in simulating cattle responses to a given set of resources, but it has not provided a basis for simulating forage response. To date no effects of variables in the veterinary area have been included except as assumed percentage death losses.

Simulation from the herd model will be used as a method of developing various production alternatives for specific situations first in Guyana and then in other LDC's and will be used to develop herd production data for use with the macro model developed by Purdue. At present there does not appear to be a need to interface the two models; i.e. data independently generated in one are used in the other. However, they may be combined as one interacting model in the future if a need for this becomes evident.

Data collected from herds in Guyana and Brazil were edited, punched and are in the process of being summarized. These voluminous data will be used for validating the model, generating production parameters for use in the macro model, devising production system alternatives to best cope with area constraints, and thesis and dissertation material for graduate students.

The syllabus and teaching aids for the comprehensive college level course in Tropical Beef Production have been further extended and edited. Arrangements have been made for publication of this material which has now been put in book (text) form. Fifteen seminars were presented by invited guest speakers and staff to support this activity as well as the modeling effort. Also, the staff presented papers at six national or international conferences directly relating to tropical beef production systems. In addition to being an invited speaker, Dr. A. W. Quershi spent eight weeks on this program interpreting data from tropical Africa and critiquing the beef production model and the draft of the book on tropical beef production.

C. Detailed Report:

I. General Background and Purpose of the Grant

The application of improved techniques and methods of ruminant livestock production in developed countries have evolved over a period of time and have usually been based on research conducted within the context of prevailing conditions. The adaptation of these techniques to LDC's has proven to be a complex problem because of the inter-relationships which exists among the various subdisciplines within animal science and because social, economic and climatic constraints not common to developed countries often significantly and unfavorably alter outcome projected on a series of ad hoc considerations. Technical developments within these subdisciplines must be applied within the context of prevailing conditions and with simultaneous consideration of other inter-related effects. A systematic, organized method of examining these effects at the herd level and application of this method to tropical settings is the primary objective of our efforts.

II. Objectives of the Grant

1. Objectives restated

The broad objective of the consortium is to strengthen capabilities through an integrated multidisciplinary approach to:

a) identify opportunities for significant ruminant livestock production.
b) analyze constraints to such development.
c) design programs to overcome constraints and exploit opportunities for developing the ruminant livestock industry.

The objectives for the Animal Science Department at Texas A&M University are to improve competency relating to livestock breeding and selection as a component of livestock production and marketing in LDC's and to develop and evaluate livestock production systems within the constraints and potentials of tropical environments, particularly those of alternating wet and dry seasons at low altitudes. This objective includes the evaluation of different systems which are intuitively designed based on existing knowledge and in consultation with members of the consortium and to identify the major constraints at the herd level to increased production. The Animal Science Department will develop its capability of teaching undergraduate and graduate students beef cattle production which is directly applicable to tropical LDC's. Adult education will be included.

2. Review of Objectives

The third year of the grant was very active and major contributions toward accomplishing the objectives were made; most significant was establishing the herd modeling concept as sound and useful. Only operational adjustments in emphasis, rather than changes in objective, were made or are anticipated One change was to simplify the forage component of the herd model. A change anticipated is to more directly orient simulations to supply data for the macro model.

III. Accomplishments in our 211(d) Program include the following:

1. Information Exchange

T. C. Cartwright presented invited papers on tropical beef production systems at four conferences. (See Appendix I)

a. The 1st World Congress on Genetics Applied to Livestock Production - Madrid Spain, October 11-15, 1974.
   Title: Efficient Breeding Systems For Commercial Beef Production
b. The Annual Meeting Of the Mexican Society Of Animal Production, Tuxtla Gutierez, Chiapas, Mexico, November 15 and 16. Title: Use Of Zebu for Crossbreeding for Milk and Beef Production In The Tropics.
c. International Stockmens School, San Antonio, Texas, January 6-8, 1975.
   Titles: Double Muscling In Beef Cattle
   Crossbreeding Systems
   Cow Size
d. II International Conference On Tropical Cattle Breeding, Tampico, Mexico, March 18-20, 1975.
   Titles: Principles Of Selection And Breeding Beef Cattle For The Tropics
   Methods And Goals In Selecting Beef Cattle With Emphasis On The Zebu.

G. E. Joandet presented two invited papers on beef production systems at two conferences:

a. North Central Regional Beef Cattle Breeding Project, East Lansing, Michigan, July 23-24, 1975.
   Title: A Model For Simulation Of Beef Production
b. American Society of Animal Science, Symposium of International Animal Agriculture, College Park, Maryland, July 30-August 1, 1974.
   Title: Programming Beef Production Systems.

Seminars were presented by invited outside speakers and staff as follows. (See Appendix II)

Grassland Beef Production In The Humid Tropics
Dr. A. W. Qureshi, Kampala, Uganda

Grassland Ecology and Ranch Development In Uganda, East Africa
Dr. A. W. Qureshi, Kampala, Uganda

Economic And Biological Returns To Beef Production Using The Guelph Linear Programming Model.
Dr. C. A. Morris, Guelph, Ontanio

An Examination of The Relative Efficiency Of Cattle With A High Production Potential vs. Cattle With A Linear Production Potential Under Conditions Of Limited Availability Of Nutrients.
Dr. G. E. Joandet, Balcarce, Argentina

Future Trends In Body Composition Research.
Dr. Roger Seebeck, Rockhampton, Queensland, Australia.

Simulation Of Animal Functions In Models Of Production Systems: Ruminants On The Range.
Dr. R. W. Rice, University of Wyoming

The Cattle Reproduction Research Program at MARC
Dr. Dan Laster, Clay Center, Nebraska

The Effect Of The Draught On The Livestock Industry In The Sahel.
T. C. Cartwright

Problems In The Sahel
T. C. Cartwright

Economic Evaluation Of Heterosis
Fernando Gomez, Bogata, Colombia

Recent Developments In Dairy Sire Evaluation.
Fernando Gomez, Bogata, Colombia

Pre- And Post-Analysis Of Selection Results In Beef Cattle.
T. S. Stewart

Animal Breeding Applied To The Sahelian Region Of Africa
T. C. Cartwright

Simulation Of Forage Based Beef Cattle Production Systems To Evaluate Biological Efficiency And Economic Viability.
T. C. Cartwright

Selection Limits As A Function Of Fecundity.
T. C. Cartwright

2. Modeling beef production systems

The development of a model to simulate beef production under tropical conditions has been one of the major objectives of the Consortium. This responsibility was taken by Texas A&M University. After three years of development, the model is now operative. It has been written in fortran and transmitted to Purdue for use with the macro model. Validation is not complete, except for the reproduction component, but the model appears to respond well in simulating real life production as indicated by comparison with intuitive expectations. The next step is to validate the model using extensive data collected from commercial herds and research herds in Brazil and Guyana.

The model was divided into submodels for the developing process. The submodels are: (1) composition and dynamics of the herd, (2) flow of nutrients (3) nutrient production of forages, (4) reproduction and (5) economics. The submodel (3) on forage production was not fully developed because the information and time required were lacking. In order to construct a forage model which would interact with grazing pressure, it appears that at least as much effort would be required as was required to develop the components for nutrition, reproduction and herd composition. The alternative of simply utilizing data on available forage during a span of a year was decided upon. This approach should not compromise the results of the herd production model under stable, or closely definable, forage conditions but does not allow any prediction of forage response.

The economic component has not been approached but it may be added without affecting the present components. The model objective is to simulate the production of beef for a defined set of environmental conditions and for given levels of resources. The primary objective of the simulation will be the physical relationships between input-out variables that will allow the economic evaluation as a second step. No veterinary inputs have been considered to date. Presently, intuitive mortality data

are utilized. It is anticipated that to add an interacting component which considered disease organisms and parasites as part of the ecological system, as they are in real life just as the forage plants are part of the ecological system, would require an effort similar to that projected for developing an interacting forage component. Again, similar to forage components, effects of veterinary considerations will be input in the form of noninteracting mortality and production coefficients as available or estimated.

The herd composition submodel that describes the dynamics of herd composition has been completed. It is possible to predict the age structure of the herd given the initial composition and a set of parameters related to fertility, survival rate and management policy. Decisions such as numbers of animals to be sold, which ones to sell, culling practices, terminal age, etc. can be evaluated by use of this submodel. This submodel is particularly useful in predicting possibilities of cattle population growth for areas to be developed for beef production. The simulation procedure of herd structure has been written so that it is very general and may be used with any set of environmental conditions. However, it will interact with the other parts of the model which will have influence on some of the constants used by this submodel and is a direct function in many ways of the reproduction component.

This nutrient or nutrition submodel has been completed and describes the use of nutrients of each of the individuals that compose the population; requirements have been defined on a prioritory sequence according with different biological functions of the individual under consideration. Requirements to fullfill those functions are based on present knowledge and therefore they were computed on the basis of current recommendations. This submodel allows the system to store and withdraw nutrients of the body as a dynamic process. It is designed for use under a wide set of environmental conditions.

A reproduction model has been completed and validated with two sets of independent data. Further minor modifications are planned in order to accomplish further "fine tuning." The present stage of development is reported in detail in Sanders, J. O. 1974. A Model Of Reproductive Performance In The Bovine Female. M. S. Thesis, Texas A&M University, College Station. This model is based on nutrient quality and availability as reflected in weight change and characterization of age, time lapse and weight potential. (See Appendix IV.)

3. Syllabus For Course On Beef Production In The Tropics.

The progress through the first two years of the grant were reported in detail in the last annual report. All activity in this area for the past year has been devoted to writing and re-writing earlier drafts into the form of a text-reference book. Arrangements and tentative commitment have been made with the Texas A&M University Press to publish the book.

A course on "Beef Production in the Tropics" must of necessity place considerable emphasis on developing an appreciation for and hopefully some understanding of the many and complex problems of the tropical environment, its peoples, their culture and traditions. The problems are not only climate, but the effect of climate on soils, vegetation, animals and man himself. In addition, the wide variety of tropical environments affected by temperature, rainfall, altitude, prevailing winds and land masses create specific problems peculiar to a given area. The tropical environment is much more varied and complex than is the temperate climate environment.

Animal characteristics which enable them to tolerate the tropical environment with emphasis on the physiology of body temperature regulation must of necessity be stressed. Methods of improving the environment by providing supplemental feed, improving pastures, reducing losses from parasites and diseases will be included but will vary with the specific environment. Genetic improvement of native cattle by selection, introduction of new stock or by AI offer avenues of progress and are included, with use of examples where such data are available. Surveys of available tropical feed stuffs, and evaluation of native and adaptable introduced forage have been reviewed. Problems of credit, transportation, communication, lack of refrigeration, dietary habits and traditions will be discussed. Liberal use will be made of visual aids showing climates, soils, vegatation and cattle of the tropics. A substantial reference list which has been developed will be included.

It is impossible to predict at this time the number or background of students who will be enrolled in this course. The syllabus has now been completed but it should be updated annually. (See Appendix II.)

4. Training

T. T. Voelkel has essentially completed all requirements for a Master of Science in Animal Science in the area of tropical beef production. He is currently employed on a livestock development project in Botswana.

J. O. Sanders has completed work toward a Ph.D. through preliminary examinations (in July 1975) and has only his research in developing the beef cattle system production model to complete.

F. Gomez, formerly National Director of Programs for Beef Cattle, Ministry of Agriculture, Colombia, has completed 2 years of Ph.D. training in systems livestock production. His research problem will deal with the use of cows to produce both calves and milk (for human consumption) as in typically done with the majority of cattle in the tropics.

J. Mallory Davis has completed work toward a Ph.D. through preliminary examinations (in July 1975) and has only his research in examining alternative beef cattle production systems in Brazil and Guyana remaining to complete.

T. S. Stewart has completed one year past the Masters working toward a Ph.D. degree. His research area will be related to tropical beef production but has not been specifically determined.

D. Perotto has completed one year on a Master of Science degree, nonthesis, in the area of tropical beef production. He is obligated to return to Brazil after his masters.

5. Expenditures July 1, 1974 to June 30, 1975

Salaries	$41228
Graduate Assistantships	7550
Travel and Allowances	3789
Communications, Library, etc.	228
Equipment	84
Data processing, publication, etc.	3344

IV. Impact of Grant Support Activities in Developing Institutional Capabilities

The development of a systems model for beef production in the tropics has had the effect of bringing together the various subdisciplines in Animal Science to provide input information. In the process, a greater appreciation has developed in the staff for the various interactions among the areas of their expertise and the effect of these interactions on production especially as the peculiar qualities of the tropics are improved along with other constraints common to LDC's.

Because of our development in the area of systems beef production, we were invited to present a special seminar for the U.S. Meat Animal Research Center (MARC) Clay Center, Nebraska. As a result, a formal, cooperative agreement between MARC and the Texas Agricultural Experiment Station was initiated and signed in May 1974.

This agreement entitled "Simulation Of Beef Cattle Production Systems" is a substantial spin-off benefit of this 211(d) grant. The intense beef production problems of the LDC's which are compounded by additional problems of a tropical climate in the past have been almost impossible to bring into focus for application of technilogy and have forced a more formal, organized consideration of the system. A systems approach would not likely have developed independently in the U.S. at this time.

This grant has specifically allowed staff to travel to tropical countries to observe, to participate in conferences directed toward tropical livestock production, to develop a comprehensive course specifically on tropical beef production, and to attract students with experience and interest in tropical countries.

V. Utilization of Institutional Resources in Development

The expertise of the Data Processing Center, Operations Research Group, and Institute of Statistics were necessary for model development. Data from the Texas Agricultural Experiment Station (TAES) were necessary for validation. The direction and objectives of the TAES research project entitled "Evaluating Hybrid Systems For Total Efficiency Of Beef Production" have been revised in some instances to supply data and information specifically required for the model development.

VI. Other Resources For Grant Related Activities

The physical facilities including office space and equipment for staff and graduate students, telephones, data processing center, secretarial staff, library, etc. have all been contributed without reimbursement (except for computer time). However, the major contribution has been the availability of staff for consultation with sponsored graduate students and personnel working an systems model development. For example, it is estimated that personnel in the ruminant nutrition section contributed the equivalent of about 1/2 professional man year to our model development. The animal breeding and genetics section has contributed a similar or greater amount. The reproductive physiology, meats, dairy and management sections of the Animal Science Department have contributed lesser amounts. Operations Research, Range Science and Agricultural Economics have also participated and aided our efforts.

VII. Next Year's Plan of Work and Anticipated Expenditures

The beef production systems model is operational and major effort will be directed toward completing validation. The next step will be to simulate production conditions in Guyana, along with alternative production systems, to supply appropriate data for the macro model. In addition to supplying these data, a number of changes in production systems will be simulated. Any simulated systems significantly improving production efficiency will be relayed to other consortium members for review and evaluation and then, if considered appropriate, relayed to responsible authorities in Guyana. Similar simulation are planned for Brazil and other tropical countries from which data are available, other tropical settings anticipated (i.e. from which data are available to us) include Uganda, Mexico, Rhodesia and Texas.

It is anticipated that the draft of the manuscript for the Text-reference book on tropical beef production will be completed and submitted to the publishers.

Activities similar to those during the past year will continue in publication, presentation at seminars, sponsored visiting lectures, graduate students and the Latin American Symposium on Livestock Production will be continued.

The budget for July 1, 1975 - June 30, 1976 is:

Salaries	$20,000
Graduate Assistants	12,000
Travel and Allowances	3,000
Communications, Library, etc.	200
Equipment	400
Data Processing, publications etc.	5,000
TOTAL	$40,600

TABLE 1

Distribution of 211(d) Grant Funds and Contributions From Other Sources of Funding[a] for Animal Science

Review Period 1 July 1974 to 30 June 1975

(List all grant related activities	211(d) Expenditures				Non 211(d) Funding[a]
	Period Under Review	Cumulative Total	Projected Next Year	Projected to end of Grant	Amount
Research[b] (Development)	$41400	$106444	25000	$153500	44200
Teaching	10000	27503	12000	69500	8000
Libraries	228	477	200	1000	6000
Consultation[c]	2000	11290	1000	16000	
Publication	2550	2650	2000	5000	10000
Other	45	2743	400	5000	22000
TOTAL	$56223	$151107	$406000	$250000	$90200

[a] These figures are best estimates

[b] This research category relates more to developing competence and is not research in the usual proper sense

[c] Some teaching and other activities have been changed to this category from earlier budget - this is only a classified change.

TABLE II

Expenditure Report (Animal Science)*

(Actual & Projected)

Under Institutional Grant #AID/csd-211d 3675
Review Period 1 July 1975 to 30 June 1975

Budget Items	Expenditures to date		Projected Expenditures		Total Budget
	Period under Review	Cumulative Total	'75-'76	'76-'77	
			4	5	
Salaries	$41228	$94544	$24000	$45956	$164500
Travel	3789	27778	3100	3122	34000
Equipment	84	1329	700	471	2500
Libraries	228	476	400	124	1000
Supplies, data processing, publ.	3344	8357	4400	2243	15000
Graduate Assistantships	7550	18623	8000	6377	33000
TOTAL	$56223	$151107	$40600	$58293	$250000

APPENDIX I

Summaries Of Invited Talks Presented On Beef Production Systems In The Tropics.

PRINCIPLES OF SELECTING AND BREEDING BEEF CATTLE FOR THE TROPICS

T.C. Cartwright, Texas A&M University

The principles of selecting and breeding livestock have been developed since the re-discovery of the basic genetic mechanism in 1900. Even after this knowledge was established, several decades past before an understanding of quantitative characters such as gain of weight, milk production, size, etc. was developed. Then, more time elapsed before these principles were interpreted and put in useful form for application by livestock breeders. These developments brought us up to about mid-Century. However, since that time a sweeping improvement of our breeds has not occured as some predicted. In fact in the United States there is a great amount of talk from some breeders about the advantages of returning to the Texas Longhorn which we inherited from Mexico which you in turn inherited from Spain. Still more extreme reversionist insist we should go back further to our inheritance from the American Indian, the American Bison or Buffalo.

There are at least two conclusions to which we might arrive.

One is that the application of genetic principals has not been successful in changing cattle. That is not the correct conclusion as there are ample well-documented data which show change, for example, the data show consistent selection programs have increased weaning weights as much as 2 kilograms a year for 10 to 15 years. Feedlot gain, yearling weight, milk production and mature size have been similarly increased.

---

*Presented at II Ciclo International de Conferencias Sobre Ganaderia Tropical, Tampico, Mexico, March 18-19, 1975.

PROGRAMMING BEEF PRODUCTION SYSTEMS [1]

G.E. Joandet and T.C. Cartwright

Summary

A discussion about the concept of systems and its origin is followed by the definition and types of general systems. The use of systems approach and application to beef production is discussed. The possibilities of describing beef production systems at different hierar chial levels going from the elements that compose an individual to the system of production of the whole area; passing through the level of an individual and a herd. The choice of the level at which the system is going to be described is important at the beginning of the process and the successes of the description might be based on that decision. One way of describing systems is with a model, usually a mathematical model, that allows the performance of different types of manipulation in order to evaluate decision making processes and/or to obtain the optimal combination of variables with the purpose of optimizing a given objective function. Comparison of different models developed for beef cattle will be given and their uses. Examples are given of applications of models for the developing of beef production systems based on different alternatives for specific areas and possibilities of genotypes combinations in order to optimize the system under a given set of environmental conditions.

---

[1] Presented at the Annual Meetings of the American Society of Animal Production, Symposium by the International Animal Agriculture Committee, College Park, Maryland, August 1, 1974.

Another conclusion is that these changes are not necessarily improvements. I believe that this is the correct conclusion, within limits of interpretation for some but not all characters. A number of considerations enter in deliberations over this conclusion.

One consideration is that an animal which is reproducing and producing reasonably well in a given environment can not be taken and changed in only one part. The balance or relationship of one part or function to another part or function is a necessary part of all living creatures. These relationships are often genetically tied together. The tie may be loose or it may be a close tie.

Let me illustrate such a tie with some obvious, but sometimes overlooked, relationships of size as illustrated in figure 1. A relatively large individual is represented by the top curve and a relatively small individual by the lower curve. Several points of relationship become obvious:

1. The larger individual is heavier at any point in his life from birth to maturity and has a higher rate of gain at any age up to maturity.
2. The larger individual reaches any stage of maturity (such as puberty) or level of finish at a heavier weight and older age.
3. The larger individual requires more feed (or acre s of pasture) at all ages and requires a higher quality for a longer period of time.

These points illustrate that weights at any age tend to be positively correlated; that is, a bull heavier as a yearling will likely be heavier at maturity. Stated differently, selecting for increased daily gain will also tend to increase mature size. If we selected for higher rates of gain we also tend to get slower maturing cattle which do not grade as well at any given young age and which mature at heavier weights and require more feed for maintenance. The trade offs must be considered.

Another consideration relating to the conclusion that all changes brought about by selection may not have been improvements is that we tend to generalize in our thinking about what is a desirable trait. For example, if cattle with a high rate of gain and slow rate of finishing are desirable for intensive grain feeding when cattle prices are high and grain prices are low, it does not necessarily follow that big, fast growing, slow maturing cattle are best for every set of conditions.

Successful cattle breeding requires that the management (including skills of labor), nutrition, market, and climate all be considered simultaneously. In tropical areas temperature is an important factor for a large ruminant animal, but the indirect effects of the tropical climate on the forage is probably an even more important effect. I shall address this topic more later and in the second paper.

The basis for selection rests on the premise that progeny tend to resemble their sire and dam and that each has equal influence except for those characters affected by the maternal influence, such as weaning weight. The cause for the likeness, of course, is that a sample half of the sire's genes are transmitted to the progeny in the spermatozoa from the sire that fertilizes the ovum. Also a sample half of the dam's genes are transmitted to the progeny in the ovum. These two "half sets" of genes make up the progeny's inheritance. These genes guide the development and maturity of the individual from conception until its death. However, these genes, or genotype as it is called, operate only in an environment favorable to sustain life. Some traits, or genetic characters as they may be called, are more sensitive to the environment - thinking now of the environment in the broad context of any factor affecting the individual (weather, disease, nutrition, etc.) other than its genes.

For example, mature height at withers is affected only little by differences in environment - mature weight is almost the same. Weaning weight and yearling weight are affected more by environment. Even more affected by environment is fertility of the cow.

For convenience we define the characters little affected by environment and under to close guidance of genes as high in heritability. Those affected an intermediate amount as intermediate in heritability and those very sensitive to environment as low in heritability.

Differences in cattle for characters of high heritability tend to accurately reflect differences in their heredity; where as differences in cattle for characters low in heritability do not tend to accurately reflect differences in heredity. For example, two bulls of different heights tend to be different because of their genes and therefore since their genes are transmitted to their progeny, the progeny tend to closely resemble their sires in height.

At the other hand, the difference in fertility of two cows is often a poor reflection of their genotype for fertility. A heifer from a cow with high fertility is not expected to be much different, on average, from the heifer from a cow with a poor record. This is not surprising when you consider how very much the estrous cycling and conception of a cow depends on nutrition, diseases, and the fertility (and amour) of her mate. We correct weaning weights of calves for age of calf, age of dam and season of birth in order to increase the heritability of their character (that is, we correct for these environmental differences, so that the genetic differences are clearer). For cow fertility, we don't correct for anything (because of our ignorance) so it is not any wonder that heritability of this sensitive character is low. This does not mean that heredity is not important in cow fertility,* rather it means that in order to accurately assess genetic differences in cow fertility, we must resort to more careful observation; also

---

* See the article in the appendix entitled: Heredity Must Be Important In Fertility Of Cows by T.C. Cartwright

indicated is placing more empahsis on pedigree, progeny and families. I shall return to this point.

Before discussing heritability any further, I shall clarify one point which is more technical but necessary for accuracy. There are two kinds of heritability. One is a broad definition which includes all hereditary causes of differences among individuals. However, because genes condition the effect of one another, and because genes are in a different combination in the progeny than in the sire and dam, there is some "genetic slippage" from parent to progeny (due to dominance and epistatic interactions); therefore the breeding value of a sire or dam is a function of a more restricted or narrow definition of the genetic differences (only additive genetic effects are included in the more narrow definition of heritability).

Selection is chosing which males and females are to become sires and dams of the next generation; also selection includes how many progeny they leave. For example, more selection emphasis is placed on a sire which leaves 40 progeny than one which leaves only 20 progeny.

The intensity of selection depends upon the level of discrimination in chosing sires and dams. For example, if in selecting for weaning weight, if the average of the bull calves in the herd was 200 kg., and a bull calf selected from this herd was required to be among the heaviest 10% of the bull calves, the selected bull calf would be expected to weigh about 244 kg or about 44 kg

above average at weaning. However, if the selected bull was only required to be in the heaviest 50%, he would be expected to weigh, on average, about 220 kg or about 20 kg above average. The 44 kg superiority of the first bull selected to be a sire represents more intense selection than the 20 kg of the second bull.

Selection intensity for each character depends on how much the selected individuals are above average. Most of the selection or improvement must come through the sires because a large percentage of the cows must be kept as replacements. However, selection among the cows is important especially for maternal traits which are not expressed in bulls. The selection intensity possible in cows depends on the fraction which must be replaced each year; this fraction depends on the age at first calving of heifers, their average annual fertility and productive longevity. I shall discuss this point more in the second talk.

The average general levels of heritability (high, medium, low) of some characters are given in table 1. These levels should serve as guidelines.

The second major point of my topic is breeding in the sense of which bull should be mated to which cow. Four general categories should be considered. The first two are based on either the performance, conformation or other individual characteristics. The second two are based on pedigree or ancestry.

First, consider matching sires with the cow herd so that he is selected to be especially strong where the cow herd is weak. This procedure is called corrective mating and is widely practiced. It tends to keep herds close to the breed average.

Second, is mating extreme sires with extreme dams for the same characters. This is practiced to shift cattle toward some maximum goal such as breeding larger cattle, thicker cattle, higher milk producing cattle, higher gaining cattle etc. This procedure is quite effective for character of medium to high heritability.

Thirdly, cattle can be matched so that the sire and dam are definitely unrelated. This can be done within breeds by out-crossing families or lines. It can also be done on a more extreme basis by crossing breeds. Crossing lines gives a small amount of ourcross vigor. Crossing breeds gives a large amount of vigor called hybrid vigor or heterosis. This type of mating avoids low productivity and generally promotes a high level of variability.

The fourth method is breeding cattle with at least some ancestors which are in common; that is, mating relatives. This is inbreeding and the intensity of the inbreeding is proportional to the closeness of relationship. If there is no particular consistency to which relatives are repeated in the pedigree the inbreeding is limited to one or few individuals it is linebreeding; that is, the inbreeding is directed in a line to an individual.

Linebreeding is practiced for the purpose of intensifying a particularly desirable individual. Linebreeding involves identifying an ideal, or near ideal individual, one which it is considered can not be improved upon by other breeding, and then duplicating the genetics of that individual as closely as possible while keeping the intensity of inbreeding at a relatively low level.

The reason for keeping inbreeding at a low level is that inbreeding tends to depress production levels especially fertility.

In summarizing this first talk principles of selection and breeding cattle, I would like to make several points about the topics, especially the tropical conditions of the area in which you breed cattle.

It is often noted that the nutritional, climatic and disease conditions which usually prevail in the tropics stress cattle to the extent that selection is not effective. Another way of saying this same thing is that heritability of characters is lower in the tropics than in temperate zones. Also fertility is usually low and selection intensity is also low. I do not believe that either of these are necessary. I believe that the purebred breeder can fulfill an even more useful and important role in the tropics. It is necessary to provide the nutrition, sanitation and management which will allow expression of genetic potential. Especially important is the necessity for the purebred breeder to provide uniform conditions for all individuals in his herd so that differences among them tend to reflect their genetic differences and not the fact that one bull had good treatment and the other one poor treatment. Providing a good, uniform environ-

ment has the effect of increasing heritability. At the same time the cattle are selected in the same general area and climate under which their progeny are required to produce beef.

I do not intend to suggest that purebred cattle be pampered, but they should be given an opportunity to produce if they have the genetic potential. Because of the conditions that prevail in the tropics, selection in commercial beef production herds is generally of little avail because of the generally low heritability and small selection differential possible. Therefore the purebred breeder must fulfill this function; that is, improvement by selection must be accomplished in the well-managed purebred herds and passed through bulls to the commercial producer. The burden is placed on the purebred breeder to select effectively for the kind of cattle needed in beef production.

For most breeders I do not believe that sophicated breeding programs are justified. When a breeder reaches the point that he can only decrease the quality of his cattle from any available outside breeding is linebreeding an approach I would recommend.

Generally speaking, most cattle improvement has been in temperate zones and we have directed more attention to changing the tropical environment to fit the cattle. Surely we must continue to improve nutrition, management and sanitation for profitable production. We can not expect breeding to overcome poor nutrition or poor management. But also we should put more emphasis on selecting

the cattle to fit the tropical environment because cattle that are poorly adapted to the tropics; cattle that have a low inherent ability to grow, reproduce or produce milk; can severely limit production even if we provide well for the cattle. Genetic improvement must be matched with, and indeed a part of, other improvements of beef cattle production.

TABLE 1. SIMULATED AGES AT FIRST ESTRUS OF HEIFERS OF THE SAME MATURE WEIGHT (480 kg), WITH DIFFERENT WEIGHTS AT 240 DAYS AND DIFFERENT RATES OF GAIN AFTER 240 DAYS OF AGE.

Weight at 240 days of age, kg	Daily weight gain, kg						
	.1	.2	.3	.4	.5	.6	.7
150	-	1335	834	553	465	423	397
160	-	1266	727	502	436	403	383
170	-	1191	601	461	412	385	372
180	-	1066	512	425	389	370	363
190	2007[a]	819	449	394	369	361	355
200	1728[a]	548	399	372	359	353	349
210	1321	435	376	359	352	347	343
220	875	387	360	350	345	341	338
230	548	363	349	343	340	336	334
240	393	350	342	338	335	333	332

[a]Based on heifers that reached puberty by 2250 days of age.

TABLE 2. SIMULATED WEIGHTS AT FIRST ESTRUS OF HEIFERS OF THE SAME MATURE WEIGHT (480 kg), WITH DIFFERENT WEIGHTS AT 240 DAYS AND DIFFERENT RATES OF GAIN AFTER 240 DAYS OF AGE.

Weight at 240 days of age, kg	Daily weight gain, kg						
	.1	.2	.3	.4	.5	.6	.7
150	-	369	328	275	262	260	260
160	-	365	306	265	258	258	260
170	-	360	278	258	256	257	262
180	-	345	262	254	254	258	266
190	367[a]	306	253	252	255	263	270
200	349[a]	262	248	253	260	268	276
210	318	249	251	257	266	274	282
220	283	249	256	264	272	281	289
230	261	255	263	271	280	288	296
240	255	262	271	279	288	296	304

[a]Based on heifers that reached puberty by 2250 days

TABLE 3.. SIMULATED FERTILITY OF TWO-YEAR-OLD COWS DURING A 180 DAY BREEDING SEASON, BEGINNING IMMEDIATELY AFTER CALVING, WHERE ALL COWS ARE OF THE SAME GENOTYPE (WMA =480 kg), BUT HAVE DIFFERENT POSTPARTUM WEIGHTS AND RATES OF WEIGHT GAIN.

Postpartum weight, kg	Daily gain, kg	Estrus during first 90 days, %	Conceived during first 90 days, %	Estrus during breeding season, %	Conceived during breeding season, %
335	-.4	20	11	20	11
	-.2	38	23	44	31
	0	56	38	83	71
	.2	73	53	98	93
	.4	86	67	100	99
360	-.4	52	35	58	44
	-.2	68	49	85	75
	0	82	63	98	94
	.2	92	75	100	99
	.4	97	84	100	100
385	-.4	73	52	88	79
	.2	88	71	98	95
	0	96	81	100	99
	.2	99	89	100	100
	.4	99	89	100	100
410	-.4	93	78	99	96
	-.2	98	85	100	99
	0	99	88	100	100
	.2	99	89	100	100
	.4	99	89	100	100
435	-.4	98	85	100	99
	-.2	99	88	100	100
	0	99	89	100	100
	.2	99	89	100	100
	.4	99	89	100	100

TABLE 4. SIMULATED CONCEPTION PERCENTAGES DURING AN 80 DAY BREEDING SEASON, BEGINNING AT 370 DAYS OF AGE, WHERE ALL GROUPS OF HEIFERS ARE OF THE SAME GENOTYPE (WMA=480 kg).

Daily weight gain, kg	Weight at 360 days of age, kg					
	220	230	240	250	260	270
0.0	11	26	45	65	78	87
.1	15	32	52	71	83	90
.2	20	39	59	77	87	92
.3	27	47	67	83	91	94
.4	35	56	74	88	93	95
.5	45	65	81	91	94	95
.6	55	74	87	92	94	95
.7	65	80	89	92	94	95

MODELING BEEF PRODUCTION SYSTEMS[1]

G.E. Joandet[2] and T.C. Cartwright

Texas A&M University, College Station

Summary

Systems analysis techniques may be applied to modeling beef production at many different hierarchical levels. Beef production systems may be modeled from the level of the cell to the level of a region or country; choice of the proper level is critical to the attainment of objectives. A system may be described with a mathematical model that may be used to examine effects of alternative practices or inputs on a given objective function. Maximization techniques may be applied to simulate optimal breeding or management systems for a specific set of production, economic and social conditions. The modeling exercise is a systematic method of applying segmented knowledge to specific dynamic production situations. Modeling also brings areas of insufficient but important knowledge into focus. Even though mathematical models have long been used in animal science, only recently have they been applied to production systems, but the present models are limited in scope and not suitable for wide use. Further development of systems models will add substantially to our applied and scientific capabilities, especially as the body of knowledge related to beef production continues to increase.

Key Words: Beef Production, Systems, Modeling.

---

[1]Invitational paper presented at 66th Annual Meeting of the American Society of Animal Science, College Park, Maryland, July 28-31, 1974.

[2]Present address: Instituto Nacional Tecnologia Agropecuaria, Balcarce, Argentina. Formerly Visiting Associate Professor, Texas A&M University.

Introduction

The components of beef production are inter-related often in a cryptic, nonlinear manner and, therefore, must be studied simultaneously as integrated effects in order to evaluate the effect of different alternatives for a given component on final outcome. The study of integrated processes of production requires an interdisciplinary effort both within the field of animal science and between animal science and other disciplines. Production efficiency is a function of factors traditionally studied in nutrition, physiology, genetics, range and forage sciences, production economics and marketing. Animal scientists have long recognized this concept and have intuitively accounted for the various trade-offs and interacting effects. However, the complexity of beef production is such that an informal, undisciplined approach cannot be expected to yield outcomes which are consistently optimal. Techniques described by Forrester (1968) have provided a basis for systematic, orderly evaluation of complex systems and have been successfully applied in such fields as ecology, sociology, plant sciences, physical sciences and engineering. Computing capabilities which are now widely available make the application of these techniques feasible for simulation of beef production.

Simulation of beef production opens new avenues for more effective research and its application. The effects of the application of newly developed or anticipated technology may be evaluated over a wide range of conditions rather than in isolated situations to which we may be limited because of facilities, personnel or funds. General recommendations are too often inefficient but persist because they are conven-

ient; these should be replaced with those that more adequately fit the local environment, better utilize resources and/or conform more realistically to economic or sociological constraints.

The aim of most scientific endeavor has been analytical; i.e., the goal has been to decompose complex situations into smaller components in order to understand them. The success of this approach in gaining knowledge is well known and appreciated. However, knowledge about the components *per se* has proven insufficient for the understanding of the effects of their interactions in complex systems (Bertalanffy, 1951; Ashby, 1958) such as beef production. Those concerned with applying knowledge gained through the scientific approach to beef production must become complexifiers - systematic, organized synthesizers of complex events. The application of techniques of mathematical modeling of systems to production science, is a more objective, quantitative approach than has been traditional but should have a stimulating effect on both experimental and applied animal science.

Review Of Systems

A system may be defined in general terms as a set of objects together with relationships between the objects and between their attributes (Hall and Fagen, 1956). The need for integration of elements of complex structures led Bertalanffy (1951) to the formulation of the "General System Theory" based on previous work (Bertalfanffy 1940, 1944; Donnan 1936, 1937); Ashby (1952, 1958) arrived at almost the same concept. General systems theory is considered the skeleton of the sciences; it provides the basic structure by which different disciplines contribute in an orderly and coherent way to the corpus of knowledge (Boulding, 1956).

By means of a hierarchical organization, Boulding (1956) classified systems into 10 different levels ranging from the anatomy of the universe to transcendental systems which he considers the ultimate and absolute. In this 10-step organization, plants are at the fifth level and animals at the sixth. As biologists, our interests range from the third level of self-controlled systems (such as homeostasis) to the tenth level.

Systems may be classified as open or closed depending upon whether or not there is interaction with the environment; environment is defined as effects extraneous to the system. We deal with open systems since they respond to changes in the environment; inputs come in from the environment and outputs go out to it. A designer or planner must construct a system that not only operates harmoniously internally and in tandem with other systems, but also in harmony with the environment it is intended to match (Hall and Fagen, 1956).

The husbandry and production aspects of animal science attempt to integrate the knowledge generated by the others. Similarly, a system analysis has an organized set of objectives, is a methodological arrangement, involves a synthesis or summarizing process, and ties disciplines together in a meaningful way. Description of a beef production system which is adequate for evaluating a complex function such as net efficiency requires an interdisciplinary effort; i.e., the work of a team (Witz, 1973; Klir, 1965). In practice there are some difficulties of communication between disciplines even though all the work is based on the scientific method (Frosch, 1969; Caws, 1968; Toda and Shuford, 1965). Biologists often have an aversion to the use of numerical methods applied to study relationship among biological components. Mathematicians, on the other hand, tend to work in a more abstract manner and often are not interested in applying mathematics to inexact sciences; therefore biologists and mathematicians do not often work toward the same objectives as equally motivated members of a team. Similar situations are also found among other disciplines.

Modeling Beef Production Systems

A system may be described at various levels. The basic element or unit of beef production system may be considered as one individual; however, modeling at this level does not assure that the system will be properly described because individual effects may not be additive in the system. For example, different types of individuals have different nutrient requirements (for growth, reproduction, milk production) which interact at the herd level. It might be necessary for the description to be at the organ level in order to specify physiological functions. In other cases, even the cell level or single metabolic pathways may be appropriate.

A beef production system may be considered as a portion of the overall ecosystem (Hammond, 1972; Swartzman and Van Dyne, 1972; Brennan et al., 1970; Van Dyne, 1966) where cattle would be included as a consumer subsystem. Under some circumstances cattle will be the predominant consumer while in others they will compete with other species, wild or domestic, as a consumer.

As the level of description of a system is refined, precision is gained, but restraints due to lack of knowledge become more serious. As the level becomes higher, the relationships used between the variables become more and more empirical, and there is no biological explanation of the functions used to relate them. As biologists, our confidence is enhanced if we are able to explain the process along with the description. The level of description will then depend on:

a) the goals of the intended use,

b) the amount of available information,

c) the degree of precision required for the answer.

The first step in describing a system is to recognize the frame of reference within which the system is defined such as an individual, a herd, a region or a country. The frame of reference determines the degree of resolution required (error tolerable) for the output and therefore the level, or detail, of description. When working with a complex system, it is convenient to recognize logically separated portions of the system and to divide the problem into less complex subsystems so that it might be more easily conceived and developed.

Each subsystem can be defined in terms of explanatory variables, each of which might be exclusive to the subsystem or common to several. The next step is to describe the relationships in terms of the variables that compose the subsystem and mediate the inputs and outputs. In order to find how variables produce an effect, the description may have to be taken to a lower level. For example, it may be necessary to relate feed intake to nutrient requirements and availability, and therefore to include a description of the digestive processes (Rice et al. 1973) which may, in turn, require use of metabolic pathways (Paine et al., 1972; Baldwin and Smith, 1971a, b; Smith, 1970). Once the relationship is clarified, the higher level may be used.

When an explanation has a biological basis, a known relationship from previous experimental work, it is called a "sharp law" (Innis, 1972). The relationship then is known with a high degree of accuracy or confidence. Sometimes the explanation or the basis for the relationship is not known so that approximations based on intuition are employed in order to complete the subsystem. Under these circum-

stances the relationship is usually known within a certain range, so that it is possible to develop a "fuzzy law" in order to describe that part of the system. It is not always necessary to have a high degree of accuracy, and usually a "fuzzy" portion can be sharpened or improved with time. However, by working with "fuzzy" parameters, inconsistencies may be found and the limits of application are more restricted. This approach is made more acceptable because of two properties which characterize beef production systems. One is equifinality; the same final output can be reached with many different initial conditions. The second is that they have self-control mechanisms which tend to make them fairly stable.

After the system has been conceptualized it is described either verbally or by a set of equations, in which case the description is called a model. A model, then, is a description of a system and may be demonstrative, scale or analogue (de Wit, 1969); the analogue is of interest for describing beef production systems.

Models are based on the relationships between their components; mathematical expressions are used to interrelate these components. In biology, many of the mathematical relationships are not known or do not exist as such and must be developed. This development usually requires the application of knowledge from different disciplines; developing a beef production model may involve nutrition, reproduction, genetics, forage production, management, operational research, economics, mathematics, and possibly other fields. Mathematics is required since differential, or difference, equations are usually utilized in the description of dynamic processes.

Restrictions, limitations or constraints imposed by the environment should be considered in model construction or be part of the frame within which the system is defined. Economic and social constraints are not commonly included in models even though they may impose serious restrictions on the system. Ecological factors may not be considered in model construction but should be if they affect the long term input-output relationships of the system.

Models are constructed to simulate real life; therefore, a sample of their performance should be compared with independent data from real life as a method of validation. Validation of components rather than the entire system has the advantage of more ease in finding the causes of discrepancies between the simulation and real-life results. Nonetheless, validation of large portions of the model should be done in order to test interactions among the parts; however, explanation of a discrepancy might be very difficult if the behavior of the components is not well known. When the values obtained from the model do not agree reasonably well with those from experiments, changes in the model are necessary; therefore there is a type of feedback mechanism or self-control inherent to the process. After validation, models may be utilized to:

a) optimize some kind of objective function,

b) determine the effect of changes of some specific variables on the final output,

c) gain insight into the relationship among the components, (usually gaps or inadequacies in knowledge become evident),

d) simulate experiments.

Models are usually specific for a given situation (Paine et al., 1972; Teter et al., 1972), but if the model is constructed in components, it is more flexible and can be tailored to more specific sets of conditions; in fact, one of the advantages of modeling is that many particular situations can be examined rather than one general situation. However, it is important not to violate the assumptions inherent in the model or, at least, to beware of the consequences if the assumptions are violated.

Models provide a logical and systematic way to examine a complex problem, but an understanding of the system is necessary for the proper interpretation of the simulation output. If the input values are not outside the range for which the model was constructed and the assumptions are not violated, output may be expected to closely correspond to that found in real life, and, as such, models provide the opportunity to examine different combinations of values of the explanatory variables. Models by no means answer all questions or replace common sense and experience; they profit from them. The process of constructing a model for simulating a system is valuable in conceptualizing the system (Innis, 1972). Also, during the process of developing the model, inconsistencies in concepts are eliminated and the need for specific data is discovered.

Models Developed

Models have a long precedent in representing biological phenomena. In statistics, a mathematical model is used to represent a single observation, which is the elementary unit of the outcome of an experiment. Animal scientists have applied mathematical models to describe cause and effect relationships; examples are phenotype of progeny as a function of phenotypes of parents, nutritional requirements as functions of body weight, and carcass value as a function of carcass measurements. The theory of path coefficients (Wright 1921 a,b, 1934) uses a model to describe a closed system; it has been used to relate genotype of sires with production of daughters (Lush, 1931), to evaluate breeding values of individuals (Lush, 1935), and to construct selection indices (Hazel, 1943). Multiple regression techniques use a set of variables to predict or explain a dependent variable. A bio-economic definition of animal improvement was proposed by Dickerson (1970) to integrate breeding methods with production systems. The use of models in the development of animal science has steadily increased during the past few decades. This trend has been stimulated by current interest in systems analysis which has encouraged the use of models to more effectively integrate knowledge from the subdisciplines.

Production of nutrients, particularly forage production, has been described with a fair degree of accuracy. A number of different models have been developed (Bravo, 1973; Smith and Williams, 1973; Hart, 1972; Patten, 1972; Vickery and Hedges, 1972; Goodall, 1971; Freer, et al., 1970; Wright, 1970; Brockington, 1969; Wright and Dent, 1969). Some models describe the production of forage based on one

species while others are based on several species, and some include the effect of grazing (Christian et al., 1972; Paltrige, 1972; Rose et al., 1972; Vickery, 1972; Cooper, 1970; Van Dyne, 1970; Byrne and Tognetti, 1969; Cooper and Tainton, 1968; Morley, 1968; Arcus, 1963). Proper description of the interaction between animal consumption and forage growth is one of the difficulties of modeling pasture production (Vavra et al., 1973; Krueger, 1972; Young and Corbett, 1972; Hodgson and Wilkinson, 1968; Arnold and Dudzinski, 1967; Goodall, 1967; Baker, 1966) and utilization by the animal (Vickery and Hedges, 1974; Donnelly et al., 1970; Jones, 1969; Morley and Spedding, 1968). When this interaction has been included in the description it has been based on a relatively simple set of assumptions not consistent with most real life situations. Simulation models have been developed at a lower level to study rumen fermentation (Baldwin et al., 1970), animal energetics (Baldwin and Smith, 1971a; Reich and Baldwin, 1970) and intermediate metabolites (Baldwin and Smith, 1971b).

There are a number of models that simulate partial phases of production systems with ruminants. The energy metabolism of the steer under feedlot conditions between 250 kg and 475 kg live weight was simulated by Paine et al. (1972). The model gives growth responses to energy intake and takes into consideration heat exchange and body composition. The authors proposed to use the model for economic studies of expected profit from different rations, taking into account final weight and market price of beef. The use of the model for research in animal physiology and as a teaching tool was also proposed.

A systems model of sheep production (Wright, 1970) was developed

to show the feasibility of simulation for use in decision making analysis. The use of a weather simulator (Dumont and Boyce, 1974; Jones et al., 1970; Fitzpatrick and Niz, 1969) utilizing a randon variable that affects forage production was proven to be effective in this study. By using a similar forage model for forage growth, a beef cattle simulation model was developed with a steer fattening and a breeding herd component (Bravo, 1973). Both models were used to make economic comparisons of different production alternatives.

A model for comparing different genotypes was developed in order to compute efficiency of nutrient utilization (Joandet, 1967). Differences in fertility, longevity, milk production, mature size of cows and growth characteristics of their progenies were shown to affect efficiency of feed use. Different optimum slaughter weights were found for each breeding system, and the use of small cows and large bulls in a crossbreeding system was proposed to maximize beef output per unit of energy consumed. The study showed that selection to increase mature size and milk production did not necessarily lead to increased efficiency.

Based on a similar type model which included additive and non-additive genetic effects on the determination of growth, different combinations of mature size of parents under two feeding regimes were evaluated with linear programming techniques (Long et al., 1975). Under the assumptions made, the model showed an interaction between genotypes and feeding regime, based on net return comparisons. Cattle of large mature size gave the highest return under intensive systems (feedlot) while there were only small differences among small, medium and large size

cattle under extensive conditions (pasture regime). Crossing cows of small breeds with bulls of large breeds gave the highest return in either feeding regime as shown in table 1 (Fitzhugh et al., 1975). Rotational and two-breed crossing yielded very similar returns and three breed crossing exceeded two breed systems (Cartwright et al., 1975).

Models have been developed for studying different production alternatives from the economic point of view (Shumway et al., 1974; Anderson, 1972; Trebeck, 1972; Crabtree, 1970; Baab and French, 1963). Some of them are based on simplified assumptions of the biological processes. They have shown, however, that optimization procedures and operational research techniques can be applied to evaluate production alternatives and to optimize different types of objective functions (Barlett et al., 1974; D'Aquino, 1974; Woodworth, 1973).

Suggestions And Conclusions

Beef production systems are dynamic from the point of view of the individual as well as the population; changes take place through time. Models for studying beef production alternatives have not included population dynamics, and it is difficult to draw conclusions from results based on partial representation of the population. Models presently reported have considered only one or a few types of individuals, such as growing steers, which represent only a portion of the total inputs-outputs of the system. Recommendations developed from such a subsystem would be useful only for the restricted finishing subsector. A cow-calf operation model which assumes only mature cows is also unrealistic because mature cows do not usually represent more than 50% of the total female population of the herd. Models developed for equilibrium conditions where the proportion of different age groups are maintained constant through time give more realistic approximations but still do not closely emulate real situations. Steady state of the herd structure is reached when the reproductive performance, mortality rates and management are kept constant for a long periods (15 to 20 years). This is not often the actual case; e.g., if nutrients are entirely from grazing, variation of nutrients available through time (Sims et al., 1971; Pino, 1972) will affect the reproductive performance of females, and, since this effect is age dependent, fertility rates will change during a cow's lifetime. Incidence of diseases differ from year to year due to differences in climate and management practices. Changes in market conditions due to commercial or political reasons are expected to change over time so that management decisions

could not be expected to remain constant.

Results of simulation should be carefully interpreted because they are consequences of the functions built into the model. That is, results from models must be interpreted as being caused either by model artifacts or real life functions (or the interaction between them) whereas outcomes of experiments result only from real life (including errors of recording, etcetera) causes; either result is subject to erroneous interpretation.

The effects of alternative production practices can be determined experimentally only through a narrow range of practices and locations, whereas these effects could be simulated over very wide ranges. Examples of production questions which might best be examined by use of simulation are:

1. Optimal allocation of nutrients for a breeding herd where quality, quantity, and costs of nutrients vary seasonally.
2. Optimal herd structure for different sets of production conditions as affected by alternative ages for slaughtering (selling) steers, excess heifers, and culled cows.
3. Optimal growing rate, maturing rate, milk production and mature size for given sets of production conditions and breeding systems.
4. Optimal stocking and supplemental feeding rates for sets of pasture or range and market conditions.

Given a large number of possibilities of combining variables in a beef production system, there are a large number of responses or outputs. The combination of variables which best accomplishes objectives,

such as maximizing profit, may be established by means of some optimization procedure. In order to be most useful, the optimization procedure should give a region (rather than one point) within which optimal solutions fall. It does not seem logical to seek a single, narrow optimal solution with beef production models since they are based on a series of assumptions difficult to closely meet in practice. The most likely situation is that the values of the variables put into a model will not be exactly the same as those in real life, since those affected by risk factors, such as weather conditions, can not be exactly predetermined (McInerney, 1969). Therefore, regions of optimal solutions subjected to parametric and sensitivity studies would be more helpful and certainly more flexible for the decision making process. Decisions may modify some of the structures of the model so there is a self-induced change or feedback to the model. However, when the process has been repeated several times the solution should, hopefully, converge toward an optimal region.

The effect on the objective function of changing a variable may be used to establish the relative importance of that variable and, therefore, aid either in management or research priority decisions. Examples of knowledge that is important to beef production but lacking, and therefore deter modeling (and other approaches to understanding) of beef production, are:

1. The relationships between nutritional level, hormonal production and the onset of estrous cycling in heifers and postpartum cows.
2. The energetic efficiency of fat deposition, maintenance

and mobilization for utilization.

3. The genetic variability of growth curve parameters.

4. The effect of ambient temperature, body composition and physiological state (especially weight loss) on nutrient requirements.

5. The effect of disease at sublethal levels on growth, reproduction, etcetera.

Beef cattle production modeling is an especially appropriate activity at this stage of the evolution of animal science. First, it requires following through a production process in all its components in a logical, ordered manner. This process has a powerful integrating effect on the subdisciplines in which the pace of ad hoc developments is increasing. Second, it brings to our attention the more pressing needs for research information and provides a basis for a more orderly and specific inventory of research needs and priorities. Third, responses or recommendations can be made which are more current with dynamic production and market conditions. Developing strategy to best cope with change is especially important in beef production since some elements of production can be changed only slowly or expensively. Fourth, and perhaps the most important concern, is that modeling systems tends to direct research philosophy and activity toward a more basic level of investigation. In order to effectively model systems it is necessary to understand basic principles and relationships which hold in general and do not change over time and space. Then, with effective models, simulating production can replace the need for conducting production research in each geographical area. Thus, the

expenditure of the financial and scientific resources available for animal science research tends to be of greater and longer lasting benefit.

LITERATURE CITED

Allden, W.G. and I.A. McD. Whitaker. 1970. The determinants of herbage intake by sheep: The interrelationship of factors influencing herbage intake and availability. Australian J. Agr. Res. 21:755.

Anderson, J.R. 1972. Economic models and agricultural production systems. Proc. Australian Soc. Anim. Prod. 9:77.

Arcus, P.L. 1963. An introduction to the use of simulation in the study of grazing management problems. Proc. New Zealand Soc. Anim. Prod. 23:159.

Arnold, G.W. and M.L. Dudzinski. 1967. Studies on the diet of the grazing animal. II. The effect of physiological status in ewes and pasture availability on herbage intake. Australian J. Agr. Res. 18:349.

Ashby, W.R. 1958. General systems theory as a new discipline. General Systems 3:1.

Ashby, W.R. 1952. Design for a Brain. Chapman and Hall, London.

Baab, E.M. and C.E. French. 1963. Use of simulation procedures. J. Farm Econ. 45:876.

Baker, H.K. 1966. The experimental development of systems of beef production from grassland. Proc. X Int. Grassld. Congr. 10:483.

Baldwin, R.L. and N.E. Smith. 1971a. Application of a simulation modeling technique in analyses of dynamic aspects of animal energetics. Fed. Proc. 30:1459.

Baldwin, R.L. and N.E. Smith 1971b. Intermediary aspects and tissue interactions of ruminant fat metabolism. J. Dairy Sci. 54:583.

Baldwin, R.L., H.L. Lucas and R. Cabera. 1970. Energetic relationships in the formation and utilization of fermentation end-products. In A.T. Phillipson (Ed.). Physiology of Digestion and Metabolism in The Ruminant. Oriel, Press, Newcastle upon Tyne, England.

Barlett, E.T., G.R. Evana and R.E. Bement. 1974. Serial optimization model for range management. J. Range Manage. 27:233.

Bertalanffy, L. von. 1940. Der Organismus als physikalisches System betrachtet. Die Naturwissenschaften. 28:521.

Bertalanffy, L. von. 1944. Bemerkungen zum Modell der biologischen Elementareinheiten. Die Naturwissenchaften. 32:26.

Bertalanffy, L. von. 1951. General System Theory: A new approach to unity of science. Human Biol. 23:303.

Boulding, K.E. 1956. General systems theory. The skelton of science. Manage. Sci. 2:197.

Bravo, B.F. 1973. Beef Production Systems: A Simulation Approach. Ph.D. Thesis. University of New England, Armidale, N.S.W., Australia.

Brennan, R.D., C.T. de Wit, W.A. Williams and E.V. Quattrim. 1970. The utility of a digital simulation language for ecological modeling. Oecologia (Berl.) 4:113.

Brockington, N.R. 1969. Herbage Growth. In J.G.W. Jones (Ed.) Use of Models in Agricultural and Biological Research. G.R.I., Hurley, Berks., England.

Byrne, G.F. and K. Tognetti. 1969. Simulation of a pasture-environment interaction. Agr. Meteorol. 6:151.

Cartwright, T.C., H.A. Fitzhugh, Jr. and C.R. Long. 1975. Systems

analysis of sources of genetic and environmental variation in efficiency of beef production: mating plans. J. Anim. Sci. 40:433.

Caws, P. 1968. Science and systems: on the unity and diversity of scientific theory. General Systems. 13:3.

Christian, K.R., J.S. Armstrong, J.R. Donnelly, J.L. Davidson and M. Freer. 1972. Optimization of a grazing management system. Proc. Australian Soc. Anim. Prod. 9:124.

Cooper, J.P. and N.M. Tainton. 1968. Light and temperature requirements for the growth of tropical and temperate grasses. Herbage Abstr. 38:167.

Cooper, J.P. 1970. Potential production and energy conversion in temperate and tropical grasses. Herbage Abstr. 40:1.

Crabtree, J.R. 1970. Towards a dairy enterprise model. In J.G.W. Jones (Ed.) Use of Models in Agricultural and Biological Research. G.R.I., Hurley, Berks., England.

D'Aquino, S.A. 1974. A case study for optimal allocation of range resources. J. Range Sci. 27:228.

de Wit, C.T. 1969. Dynamic concepts in biology. In J.G.W. Jones (Ed.) Use of Models in Agricultural and Biological Research. G.R.I., Hurley, Berks., England.

Dickerson, G.E. 1970. Efficiency of animal production-modeling the biological components. J. Anim. Sci. 30:849.

Dickerson, G.E. 1972. Inbreeding and heterosis in animals. In Proc. of the Animal Breeding and Genetic Symp. in Honor of Dr. J.L. Lush. A.S.A.S., Champaign, Ill.

Donnan, F.G. 1937. Integral analysis and the phenomena of life.

Acta Biotheor. 2:1.

Donnan, F.G. 1937. Integral analysis and the phenomena of life. II. Acta Biotheor. 3:43.

Donnelly, J.R., Axelsen, A. and Morley, F.H.W. 1970. Effect of Flock size and grazing management on sheep production. Australian J. Ex. Agric. Anim. Husb. 10:271.

Dumont, A.G. and D.S. Boyce. 1974. The probabilistic simulation of weather variables. J. Agric. Eng. Res. 19:131.

Fitzhugh, H.A. Jr., C.R. Long and T.C. Cartwright. 1975. Systems analysis of sources of genetic and environmental variation in efficiency of beef production: heterosis and complementarity. J. Anim. Sci. 40:421.

Fitzpatrick, E.A. and H.A. Niz. 1969. A model for simulation of soil water regime in alternating fallowcrop systems. Agr. Meteorol. 6:303.

Forrester, J.W. 1968. Principles of Systems. Wright-Allen Press Inc., Cambridge, Mass.

Freer, M., J.L. Davidson, J.S. Armstrong and J.R. Donnelly. 1970. Simulation of summer grazing. Proc. XI Int. Grassld. Congr. 11:913.

Frosch, R.A. 1969. A new look at systems engineering. I.E.E.E., Spectrum 6(9)24.

Goodall, D.W. 1967. Computer simulation of changes in vegetation subject to grazing. J. Indian Bot. Soc. 46:356.

Goodall, D.W. 1971. Extensive grazing systems. In J.B. Dent and J.R Anderson (Ed.) Systems Analysis in Agricultural Management.

J. Wiley & Sons, New York.

Hall, A.D. and R.E. Fagen. 1956. Definition of Systems. General Systems 1:18.

Hammond, A.L. 1972. Ecosystem analysis. Biome approach to environment research. Science 175:46.

Hart, R.H. 1972. Forage yield, stocking rate, and beef gains on pasture. Herbage Abstr. 42:345.

Hazel, L.N. 1943. The genetic basis for constructing selection indexes. Genetics 28:476.

Hodgson, J. and J.M. Wilkinson. 1968. The influence of the quantity of herbage offered and its digestibility on the amount eaten by grazing cattle. J. British Grassld. Soc. 23:75.

Hodgson, J., J.C. Taylor and C.R. Lonsdale. 1971. The relationship between intensity of grazing and the herbage consumption and growth of calves. J. British Grassld. Soc. 26:231.

Innis, G.S. 1972. Simulation of ill-defined systems: some problems and progress. Simulation 19(6) Center Section.

Joandet, G.E. 1967. Growth patterns and efficiency of TDN utilization in beef cattle. Ph.D. Dissertation. Texas A&M University, College Station.

Joandet, G.E. and T.C. Cartwright. 1969. Estimation of efficiency of beef production. J. Anim. Sci. 29:862.

Jones, J.G.W. 1969. Lamb production. In J.G.W. Jones (Ed.) Use of Models in Agricultural and Biological Research. G.I.R., Hurley, Berks., England.

Jones, J.W., E.D. Threadgill and R.F. Colwick. 1970. A simulation

environmental model of temperature, rainfall, evaporation and soil moisture. Am. Soc. Agr. Engin. Paper 70-404.

Klir, J. 1965. The general system as a methodological tool. General Systems 10:29.

Krueger, W.C. 1972. Evaluating animal forage preference. J. Range Manage. 25:471.

Long, C.R., T.C. Cartwright and H.A. Fitzhugh, Jr. 1975. Systems analysis of sources of genetic and environmental variation in efficiency of beef production: cow size and herd management. J. Anim. Sci. 40:409.

Lush, J.L. 1931. The number of daughters necessary to prove a sire. J. Dairy Sci. 14:209.

Lush, J.L. 1935. Progeny tests and individual performance as indicators of an animal's breeding value. J. Dairy Sci. 18:1.

Minson, D.J. 1972. The digestibility and voluntary intake by sheep of six tropical grasses. Australian J. Exp. Agr. Anim. Husb. 12:21.

Morley, F.H.W. 1968. Pasture growth curves and grazing management. Australian J. Exp. Agr. Anim. Husb. 8:40.

Morley, F.H.W. and C.R.W. Spedding. 1968. Agriculture systems and grazing experiments. Herbage Abstr. 38:279.

McInerney, J.F. 1969. The treatment of variability in programming models. In J.G.W. Jones (Ed.) Use of Models in Agricultural and Biological Research. G.R.I., Hurley, Berks., England.

Paine, M.D., J.A. Witz, A.F. Butchbaker, C.M. Bacon and J.E. McCroskey. 1972. Mathematical simulation of energy metabolism in beef animals. Am. Soc. Agr. Engin. Paper 72-510.

Paltridge, G.W. 1972. Experiments on a mathematical model of a pasture. Agr. Meteorol. 10:39.

Patten, B.C. 1972. A simulation of the shortgrass prarie ecosystem. Simulation 19:177.

Pino, J.A. 1972. Animal breeding and climatology, beef cattle production in the tropics in Latin America. World Rev. Anim. Prod. 7:45.

Reichi, J.R. and R.L. Baldwin. 1970. Computer simulation of feed energy utilization in ruminants. In 5th Symposium on Energy Metabolism of Farm Animals. European Ass. Anim. Prod.

Rice, R.W., J.G. Morris, B. Maeda and R.L. Baldwin. 1973. Simulation of animal functions in models of production systems, ruminants on the range. Fed. Proc. 33:188.

Rose, C.W., J.E. Begg, G.F. Byrne, B.W.R. Torsell and J.H. Gonoz. 1972 A simulation model of growth-field environment relationship for Townsville stylo (Stylosanthes humiles H.B.K.) pasture. Agr. Meteorol. 10:161.

Shumway, C.R., E. Bentley and E.R. Barrick. 1974. Economic analysis of beef production innovation: dairy-beef crossbreeding. North Carolina State University Economic Res. Rep. No. 26.

Sims, P.L., G.R. Lovell and D.F. Hervey. 1971. Seasonal trends in herbage and nutrient production of important sandhill grasses. J. Range Manage. 24:55.

Smith, N.E. 1970. Quantitative simulation analysis of ruminant metabolic functions: basal; lactation; milk fat depression. Ph.D. Dissertation, University of California, Davis.

Smith, R.C.G. and W.A. Williams. 1973. Model development for a deferred grazing. J. Range Manage. 26:454.

Spedding, C.R.W. 1970. The relative complexity of grassland systems. Proc. XI Int. Grassld. Congr. 11:A126.

Swartzman, G.L. and G.M. Van Dyne. 1972. An ecologically based simulation-optimization approach to natural resource planning. Ann. Rev. Ecology and Systematics 3:347.

Teter, N.C., J.A. DeShazer and T.L. Thompson. 1972. Operational characteristics of meat animals. II. Beef. Am. Soc. Agr. Engin. Paper No. 72-447.

Toda, M. and E.H. Shuford, Jr. 1965. Logic of systems: introduction to a formal theory of structure. General Systems 10:3.

Trebeck, D.B. 1972. Simulation as an aid to research into extensive beef production. Proc. Australian Soc. Anim. Prod. 9:94.

Van Dyne, G.M. 1966. Application and integration of multiple linear regression and linear programming in renewable resource analyses. J. Range Manage. 19:356.

Van Dyne, G.M. 1970. A systems approach to grasslands. Proc. XI Int. Grassld. Cong. 11:A131.

Vavra, M., R.W. Rice and R.E. Bement. 1973. Chemical composition of the diet, intake and gain of yearling cattle on different grazing intensities. J. Anim. Sci. 36:411.

Vickery, P.J. 1972. Grazing and net primary production of a temperate grassland. J. Appl. Ecology 9:307.

Vickery, P.J. and D.A. Hedges. 1972. A productivity model of improved pasture grazed by Merino sheep. Proc. Australian Soc. Anim. Prod.

9:16.

Vickery, P.J. and D.A. Hedges. 1974. Simulation in animal-pasture ecosystem research. Simulation 22(3) Center Section.

Witz, J.A. 1973. Integration of systems science methodology and scientific research. Agr. Sci. Rev. 11(2):37.

Woodworth, B.M. 1973. Optimizing the calf mix on range lands with linear programming. J. Range Manage. 26:175.

Wright, A. 1970. Systems Research and Grazing Systems. Management Oriented Simulation. Farm Manage. Bull. IV, University of New England, Armidale, N.S.W. Australia.

Wright, S. 1921a. Correlation and causation. J. Agr. Res. 20:557.

Wright, S. 1921b. Systems of mating. Genetics 6:111.

Wright, S. 1934. The method of path coefficients. Annu. Math. Statist. 5:161.

Wright, A.B. and J.B. Dent. 1969. The application of simulation techniques to the study of grazing systems. Aust. J. Agr. Econ. 13:144.

Young, B.A. and J.L. Corbett. 1972. Maintenance energy requirements of grazing sheep in relation to herbage availability. II. Observations on grazing intake. Australian J. Agr. Res. 23:77.

TABLE 1. PERCENT RETURN ON INVESTMENT[a] FROM COMBINATIONS OF MAT RE SIZE FOR TWO BREEDING SYSTEMS AND FEEDING REGIMES

Size of sire	Pasture regime, Size of Cow			Feedlot regime, Size of Cow		
	Small	Medium	Large	Small	Medium	Large
Crossbreeding						
Small	15.9	15.9	15.0	6.8	7.0	7.0
Medium	16.7	16.6	15.4	7.7	7.8	7.7
Large	17.7	17.4	16.0	8.8	8.7	8.4
Straightbreeding	14.8	14.9	14.9	5.6	6.6	7.4

[a] Return on investment is defined as total income less expenses, other than interest, expressed as a percentage of total expenditures other than interest.

[b] Adapted from Long et al. (1975) and Fitzhugh et al. (1975).

A Model For Simulation Of Beef Production[1]

Guillermo E. Joandet[2]

During recent years several models for describing total of partial aspects of beef production have been used. The objectives of developing models are wide; in general they are constructed to increase the understanding of a given system and to evaluate the effect of individual variables in the final output. Models can be constructed at different levels, going from cell components to biological systems, all of them however do share a common element, that is the need for a logical and systematic description of the process one is dealing with. Such descriptions force those who are building the model to search for all available information on each of the steps and therefore to be aware of the lack of it whenever it is not present. It is a synthesis process and as much the end product is a consequence of the inputs. The more detailed and accurate the information we feed the model, the closer to reality is the answer we obtain. Theoretically it might be possible to describe a system of beef production with a model starting from very basic elements at the molecular level going into all the biochemical reactions that take place in the process and taking into consideration effects of the environment. Unfortunately such a model is almost impossible to construct nowadays, because of lack of knowledge and operational costs.

---

[1] Presented at the Annual Meeting of the NC-1 Technical Committee July 23-24, 1974, East Lansing, Michigan.

[2] Research worker of INTA, Balcarce Exp. Stat., Argentina. At present time: Visiting Assoc. Prof. of Animal Science at Texas A&M University.

Acknowledgement: The valuable discussions and encouragement of Dr. T.C. Cartwright during the construction of the model is greatly appreciated as well as for his critical review of the manuscript. Sincere appreciation to Mr. J.O. Sanders for his comments on the manuscript.

Therefore we have to think of describing the system at a much higher level where we might be able to deal with variables that make the system react and also that would be operationally feasible.

The Animal Breeding Group at Texas A&M University has been working on models of beef production for the last 8 years. Models for describing partial aspects of beef production have been used, all of them were entirely deterministic; that is, no variation due to chance was allowed. In general, stochastic variables have not been included in models of beef production.

The work that we are doing at the present time is directed toward the description of the system at the herd level. In order to do that we have to build the model at the individual or organ level. The relationships used are the ones found in the literatur and whenever there is a lack of them we are developing equations, usually empirical, to describe the process following some kind of logical procedure.

Conceptual Development - The first step that was taken was to describe the herd itself. A herd is composed of cows and bulls that through the function of reproduction have offspring. The calves by the function of growth reach weaning time (age at this time is a variable). Weaning time is important to describe because decisions usually are made then: selling policy of calves, growing of those that remain in the herd, etc.

After weaning, through growth again, we reach the age where decisions are made about the future of the animals; some of them are used as replacements, others are sold for reproduction or as slaughter animals. Possible outputs of the herd are animals that have reached reproductive or slaughter age. Losses due to death might occur at any age.

As mentioned there are two functions that make the dynamics of the herd possible: reproduction and growth. Growth can be divided into preweaning and postweaning phases since some of the variables that are involved in one period are not necessarily present in the other. With the same criterion, postweaning growth can be divided into different phases to take care of the possible steps that the growing animal follows after weaning and before it leaves the herd or is used as a replacement.

If we now take both of these functions, it might be possible to make a list of the most important variables that modify or have an influence on them. Let us consider reproduction, first.

The level of reproduction of the herd depends on the reproductive performance of females and males. Female reproductive performance is influenced or determined by: age of cow, genotype, age at which puberty is reached, presence of calving difficulties, stage of lactation, incidence of diseases, level of nutrition, use of artificial insemination, other environmental effect, etc. The male reproductive performance will be related to age, genotype, use of artificial insemination, level of nutrition, presence of diseases, number of females per male and other environmental variables. Some of the variables will have direct effects, some of them will interact in order to modify reproductive performance, some of them are related with one sex and some with both. Considering preweaning growth we might list the following variables: sex of calf, birth weight, dam's milk production, age of dam, maternal ability, dam's genotype, sire's genotype, level of nutrition, presence of diseases, other environmental effects. For the postweaning growth we might

As mentioned there are two functions that make the dynamics of the herd possible: reproduction and growth. Growth can be divided into preweaning and postweaning phases since some of the variables that are involved in one period are not necessarily present in the other. With the same criterion, postweaning growth can be divided into different phases to take care of the possible steps that the growing animal follows after weaning and before it leaves the herd or is used as a replacement.

If we now take both of these functions, it might be possible to make a list of the most important variables that modify or have an influence on them. Let us consider reproduction, first.

The level of reproduction of the herd depends on the reproductive performance of females and males. Female reproductive performance is influenced or determined by: age of cow, genotype, age at which puberty is reached, presence of calving difficulties, stage of lactation, incidence of diseases, level of nutrition, use of artificial insemination, other environmental effect, etc. The male reproductive performance will be related to age, genotype, use of artificial insemination, level of nutrition, presence of diseases, number of females per male and other environmental variables. Some of the variables will have direct effects, some of them will interact in order to modify reproductive performance, some of them are related with one sex and some with both. Considering preweaning growth we might list the following variables: sex of calf, birth weight, dam's milk production, age of dam, maternal ability, dam's genotype, sire's genotype, level of nutrition, presence of diseases, other environmental effects. For the postweaning growth we might

Herd Structure - The herd structure submodel describes throughout time the number of different individuals present in the herd at a given time. The composition depends on fertility levels, mortality rate and policy of selling or buying (migration).

At breeding time there are lactating and nonlactating females for which there is a probability attached to each individual to come into heat; this of course is not a random process.

The submodel describes the female population, since males are assumed not to be a limiting factor.

Those not coming into heat will be dry next year, those that showed heat will be mated; of these some are going to get pregnant the others will be dry. Of those pregnant, some will abort and will be dry; the others will give birth. From these, some will loose the calf and be dry; the rest of them will be nursing calves during the breeding season. The probability at each of these steps is associated with the age, genotype and past and present nutrition of the cow. Decisions on selling policy can be applied on the dry cows or nursing cows so that they may be bred or may be sold; calves can be weaned at variable ages, and after weaning they can be sold, kept so they reach reproductive age, or sold as steers or replacement heifers or bulls. Probabilities after weaning are independent of age of dam. Different weaning ages can be considered as well as age at which females have their first and last calf.

Originally the model was considered for a three-month breeding season, but later it was extended to any length between three and twelve months. For the three-month situation, a probability distribution of birth was developed, based on observed data. The corresponding

cumulative distribution shows that by 30 days of the calving season 52% of the calves are born; by 60 days, 86% and by 90 days 100%. These figures are very close to what one might expect them to be.

For a fixed set of probability figures and a given policy of management, if the model is run for a long enough period it will reach a steady state of equillibrium situation. The equillibrium situation can be computed using a Markov's process of the probability of a female of a given age to be in the herd next year. We will use this approach to validate the submodel.

Nutritional Submodel - Under the assumption that energy will be the limiting factor it was decided to use the energy system in order to establish requirements of the animals. Requirements were divided into: vital activity; pregnancy; milk production; maintenance and gain of weight. Vital activity was defined as the energy requirement in order to keep the animal alive; this will be equivalent to basic metabolic needs plus the energy required to obtain that amount. Maintenance will be the energy required besides that for vital activity, in order to maintain constant body weight.

The vital activity portion was included in the model since we know that some production functions (milk and pregnancy) are carried below maintenance levels; that is with females loosing weight. The traditional way of defining maintenance is to have both things together which is an instantaneous concept; however, from an operational point of view we have to divide it. By separating the requirements this way we will be able to establish priorities for the use of energy for the different functions. Let us say we have a milking

pregnant cow gaining weight and we start decreasing the amount of energy intake. The reaction of this individual as intake is lowered will be to stop gaining weight, to start loosing weight, to stop milk production, to abort (these last two might be in the reverse order) and finally to die. If this sequence is true there is a priority for the use of energy and the model should account for it.

A fairly large amount of time was spent on the discussion of what energy system to use (*); even though the net energy system might be the ideal one, the metabolizable energy system could be more practical. Since there is almost a constant relationship between metabolizable and digestable energy both systems can be considered equivalent so we are using either one according to the information abailable.

For growth and maintenance requirements, the National Research Council (1963) recommendations are used. Some work has been done on determining the requirements of milk production and pregnancy. For milk production requirements, data from the Agricultural Research Council (1965) recommendations were used. The amount of milk produced in these tables is a function of metabolizable energy consumed. It is recognized that the function is different for different energy concentration in the diet and also varies with genotype. Three genotypes are presented with different levels of milk production and fat content of the milk. If the regression of energy consumed on milk produced is studied, it is possible to see that variation between diets within genotypes and between genotypes is not too large. Therefore

---

* The participation and suggestions of Dr. W.C. Ellis in these discussions is appreciated.

it is possible to conceive that an intermediate value could be a good approximation for beef cattle; particularly if we think that a wide range of genotypes were represented (this goes from a 363 kg live weight Jersey producing milk with 4.89% fat to a 590 kg Friesian cow producing milk with 3.58% fat). The average metabolizable energy required to produce 1 kg of milk is close to 1400 kcal. Daily milk production requirements can be computed with this relationship. It seems that milk production declines from shortly after birth according to most estimates in beef cattle; it seems reasonable to think that the decay follows an inverse exponential function. Such a function was fitted to experimental data from McGregor and a similar exponent for Angus x Jersey cows and Hereford cows were found. The function was of the type:

$$MP\ (kg/day) = ke^{-bt}$$

where k is the value of maximum milk production and t is the time after that maximum was reached. The constant b was 0.087 in the first case and 0.081 in the second, which are very close.

Milk production is affected by age of the cow, having its maximum some way between 5 and 9 years of age. The correlation factor could be obtained with a quadratic equation that gives a parabola. The equation we found was:

$$CF = 1 + 0.002166\ (A-7) - 0.004034\ (A-7)^2$$

it is not intended to be used beyond 13 years of age.

I do not think it is necessary to go into detail of all of the steps in the development of the pregnancy requirements. Where we started, a total given by the NRC was considered; but since it was necessary to have monthly requirements, first an expotential function

of birth weight and time was used and finally by adapting recent work done on sheep (Rattray et al., 1974) it was possible to develop a growth function for the concepts. The integral of that function between any given period gives the pregnancy requirements. One interesting (and somewhat controversial) observation which has resulted from using this function is that requirements for pregnancy during the last week are higher than those for the production of 6 kg of milk/day. The type of function and the low efficiency of energy utilization for pregnancy purposes are the explanation for this. The function is behaving as expected and I believe would be verified as correct if it could ever be measured. Any way it is during a very short period of time and it does not represent a large amount, particularly if it is considered relative to the total requirements.

Requirements for change of weight are established following the NRC formulas. Maintenance was divided in two portions as was explained earlier: vital activity which represents 63% of the total usually recommended as maintenance and a portion which is considered to be the true maintenance for any given live weight represents the remaining 37%.

With all these elements in the herd structure submodel it is possible to compute the requirements of the herd throughout the years given a fixed set of parameters. The distribution of requirements will depend on decisions of management such as selling policy of calves at weaning, heifers, dry cows and old cows. By changing these type of decisions, requirements of the herd could be influenced or changed so that maximal amount of beef (or $) is produced from the

nutrients available is achieved. Nutrient requirements will depend on rate of growth of young individuals and change of weight of the adults. An equation to describe rate of growth of different genotypes was derived; it is a function of age, mature weight and degree of heterosis. Hybrid vigor is maximum around weaning and minimum as maturity is approached. Since rate of growth depends also on growth during preceding periods, adjustment for this factor should be necessary in the future.

Production of Nutrients

A submodel on forage production will take into consideration the production of nutrients since the model was developed to include beef production under grazing systems. The forage production must be an integral part of the model because its production and quality is a function of the amount and pattern of grazing; i.e., beef production and forage production are interdependent, interacting variables. Dr. A.J. Dye of the Range Science Department at Texas A&M University will be responsible for this portion of the model. It will describe the amount and quality of forage available through the year based on rainfall, temperature, daylight, etc. Rainfall and probably temperature will be determined by a stochastic approach.

Other nutrients supplements to forage could be utilized and taken into consideration whenever they are available.

Reproductive Performance

A model that predicts reproductive performance of females has been developed recently (Sanders, 1974). The model could be used to predict the expected values for some of the rates utilized in the herd structure submodel. This model uses as inputs variables

such as: actual and expected weights and gains of females, age, lactational status, time after parturition, etc. Most of the inputs for this model are given by the herd structure and nutritional submodels. The outputs are the probabilities of estrus and pregnancy; that is, the information needed in order to establish the herd dynamics Therefore, in the future, it might be possible to use this model of reproductive performance as a portion of the overall model.

Application of Decision Analysis with the Model

The model was developed with the help of the Texas A&M Bioengineering Group of which Dr. D.W. DeMichele is the leader. This group was responsible for the decision of the language to be used and the programming of the model. Mr. Joseph B. Humber, graduate assistant, did the programming part on DYNAMO and he will use the model in order to optimize profit following decision analysis techniques and probably other methods utilized in the field of Operational Research.

Uses of the Model in the Future

In order to be completed the model should have a portion that will evaluate different alternatives and maximize or minimize different objective functions subject to a given set of constraints.

The work done at Texas A&M University is part of a project to increase competence in livestock development programs in the tropics. The project involves three other U.S. institutions working in the fields of Economics, Extension and Sociology, Forage and Nutrition and Diseases (this also at Texas A&M). The overall project is financed through an AID (section 211d) grant to each of these institutions. When a particular situation is undertaken, in the future,

each of these fields will impose restrictions or will fix goals that should be taken into consideration by the model and therefore work out the way, or to establish the system that will assure that restrictions are not violated and that the goals are met. Techniques such as linear programming, dynamic programming or others might be used for that purpose.

The model could be useful to evaluate different breeding alternatives or combinations of genotypes. Comparisons of genotypes can be made with different systems of production such as cow-calf operation or a fattening operation or any combination of these two.

Portions of the model, the herd structure submodel for instance, could be useful for animal breeding studies. Possibilities of selection based on different levels of reproductive performance and replacement policies and feasibility of crossbreeding programs in a self contained system are examples to which the submodel could be applied.

In order to have the model working it was necessary to make assumptions that simplified the problem. However, as such assumptions are reviewed, it will become obvious that further research is needed in many of the fields which the model is intended to be covering. This is particularly true whenever we try to explain some of the relationships used on the model; some of them are based on empirical functions rather than on known biological explanations and certainly these are fields for future research. Model building is a synthesis type process and as such those who are associated with this step by step process probably are the ones who gain the most; this gain is in knowledge and a better understanding, within and across disciplines, of the overall problem.

Literature Cited

Agricultural Research Council. 1965. The Nutrient Requirements of Farm Livestock. N°2 Ruminants ARC. London.

National Research Council. 1963. Nutrient requirements of beef cattle. National Academy of Sciences. Pub. 1137.

Rattray, P.V., W.N. Garrett, N.E. East and N. Hinman. 1974. Efficiency of utilization of metabolizable energy during pregnancy and the energy requirements for pregnancy in sheep. J. Animal Sci. 38:383-393.

Sanders, J.O. 1974. A Model of Reproductive Performance in the Bovine Female. M.S. Thesis. Texas A&M Univ., College Station, Texas.

Methods And Goals For Selecting Beef Cattle With Emphasis On The

T.C. Cartwright, Texas A&M University

Introduction of Zebu into tropical America was probably the most useful and logical of all the past importations since the original introductions from Spain. The Zebu provides a very useful genetic resource for beef production in the tropics which is unique in several ways.

First, the Zebu tend to complement European breeds rather than being in competition with them; that is, the usefulness of Zebu is enhanced by other breeds and the usefulness of other breeds is enhanced by Zebu.

A second uniqueness is the fact that in crossbreeding, Zebu are used as both a sire line and a dam line; that is, they are used as the first choice of breed to produce brood cows and to produce slaughter cattle. Few, if any, other breeds share this distinction.

The crossing ability of the Zebu is now becoming recognized in the temperate zones. We documented this combining ability in Central Texas in the early 1960's. More recently similar reports, though not yet published, are coming out of more temperate climates such as the INTA Station, Balcarce Argentina and the U.S. MARC, Clay Center, Nebraska. The crossing ability of the Zebu is further enhanced in the Tropics by the high level of adaptability it confers

---

Presented at II Ciclo Internacional de Conferencias Sobre Ganaderia Tropical, Tampico, Mexico, March 18-19, 1975

on other breeds which are not so well adapted. This high level of adaptability to tropical condition is a most valuable characteristic and should not be diminished through misdirected selection emphasis. To assure that adaptability is not diminished, Zebu should be kept and selected in a tropical setting.

Determining logical selection criteria is difficult for any breed, but the multiple role of sire breed - dam breed - crossing breed - tropically adapted breed adds to the complexity for Zebu. As a beginning let's consider traits I consider desirable in beef production. It is convenient to divide cattle into two phases of the production system:

Phase I Reproduction - Increasing Numbers
Cow Herd Calf Production

Phase II Production - Increasing Weight
Slaughter Cattle Weight Production

In the brood cow herd the following traits are desired:

Low feed maintenance requirements
Early maturity
High fertility
Mothering ability
Productive longevity
Soundness
Adaptation

For the animal destined for slaughter rather than reproduction, A different set of traits is desired:

High rates of gain
Efficient feed conversion
Finishing ability at desired weight
A muscular carcass with a high cut out
Tender, palatable beef

The traits which are desired in the brood cow are quite different for those desired for the cattle being finished for slaughter. However, production efficiency is important in both and one should not predominate at the expense of the other.

The economic efficiency of Phase I herd production in registered as well as commercial cattle depends largely on net lifetime fertility of the cow and net fertility of the bull; that is, the number of sale calves produced per cow. These fertility characters have little direct sales value in the purebred market, but they are extremely important in establishing the reputation of the breed as a whole. Since fertility is so very important to the individual breeder and to breed reputation, it deserves major consideration, even though heritability for the trait is low.

The contribution of the bull to fertility of a herd (or of a breed) is usually overlooked except in cases of complete or nearly complete sterility. Hormonal production and balances and other qualities of a highly fertile bull have their counterpart in highly fertile females. Thus, it is logical, though untested by research, that highly fertile bulls tend to sire highly fertile daughters. Because of this relationship and the importance of cow fertility, bull fertility will be included in the selection goals.

The demand for a breeder's cattle, largely depends upon the reputation of the breed, the reputation of the breeder and the performance, conformation and pedigree of his cattle. Objective per-

formance records have been marketed very successfully by some breeders in some breeds, but not generally within the Zebu breeds. The reason is related to the fact that Zebus are very effective for crossbreeding, and the crossing performance of the breed, rather than individual merit, has often been relied upon by commercial buyers. However, continued emphasis on increased efficiency makes performance testing - though a special brand of performance testing - desirable for Zebu breeders.

The results of breeding programs for registered cattle quickly filter down to the commercial level. For the Zebu, most use at the commercial level is in production of crossbred brood cows and crossbred slaughter calves. The reputation of Zebu hybrids for high levels of general combining ability primarily reflects a general breed characteristic. The pedigree is useful in evaluating combining ability but the level of hybrid vigor in Zebu crosses is not generally associated with particular bloodlines. The fact that the Zebu does have a very high level of general combining ability is a valuable, merchandizable characteristic, which should be given increased consideration in Zebu selection programs. In other words, some selection should be based on progeny testing crossbred offspring for performance.

Complementarity is another advantage gained from crossbreeding that is only now becoming recognized and appreciated. Complementarity adds to efficiency of beef production largely through mating cows that are especially efficient as brood cows to sires that have the

characteristics desired in steers - growthiness and meatiness. The economy results from lower costs required to maintain the brood cow that still produces a calf with good growth potential because of his growthy sire plus hybrid vigor. The ability of the brood cow to calve without assistance when mated to a large sire assumes primary importance. Zebu and Zebu cross cows have this ability well established so selection for calving ease is probably not necessary; however, this trait should be constantly kept in mind so that calving ability is not inadvertantly lost as a result of selecting some other character.

Zebu breeders should give a major portion of their selection consideration to brood cow efficiency and thereby avoid the sort of selection that leads to disproportionate increases in mature size relative to rate of gain at young ages. At the present point in time there is no apparent need to increase average mature size in the Zebu cow. This could change if larger carcasses were in strong demand. If breeds which are already quite large continue to select for increased size and the very large breeds, such as the Chianina, continue to be introduced, then the industry may adapt to larger cow sizes and create some need for the Zebu to increase in size. Nevertheless, as long as Zebu cross cows can deliver calves sired by the growthiest, largest sires available, there is no reason to increase their size. This point may be difficult to appreciate and accept when there is so much interest and demand for size and gaining ability. However, recall that

selection and breeding practiced at this time will not begin to show effect for several years, probably five to ten years. There can be little question that beef cattle producers in general have already begun to realize the false economy of unqualified selection for size. The value of the well-balanced, medium size cow will become increasingly appreciated during the next few years.

Also, Zebu breeders should always be conscious of the fact that their cattle are highly unique in their adaptability to tropical, and subtropical beef production conditions. Since efficient heat dissipation, one of the aspects of tropical adaptability, is impaired as body size increases, an additional caution about increasing size in the Zebu is warranted. The number and availability of very large, growthy breeds of cattle have rapidly increased while cattle which have the qualities of good brood cows have not.

These general comments which have preceded should be considered along with more specific recommendations given below for Zebu breeds.

Breed Characters and Adaptability

The Zebu is quite different from other cattle of European origin. Since the Zebu is used widely in crossbreeding, one might conclude that breed character is not as important in the Zebu as in other breeds. However, just the opposite is true because their uniqueness is largely responsible for it's high level of general combining ability. It would be an error for breeders to consume too much of

their selection opportunities with breed type, but selection should definitely not be directed toward European breed standards. The Distinctive Zebu breed characters are quite well established and individuals not reasonably meeting those standards should be culled. This is more a question of culling or eliminating a nonconforming individuals rather than selecting the top end.

Even though a part of the Zebu adaptability is associated with its physical appearance, this trait is much more complex. Selecting for just one of the many components of adaptability, such as ear length or heat dissipating ability, would create more problems than benefit and, would waste valuable selection opportunities. If concerted selection effort was based on adaptability, it would be more effective to use a character which reflects the summation of adaptability features. Longevity is one of the better, if not the best, indicators of adaptability; lifetime fertility is another.

Conformation

The conformation of Zebu breeds contributes to breed characters and adaptability. In addition, it is often implied that conformation is associated with production and somewhat more directly with carcass characteristics. There is no question that conformation has definite value - justified or not - when selling registered cattle. However, the Zebu pioneered in educating the U.S. cattle industry that there are many variations in conformation and quite wide limits within which conformation can vary in sound, productive cattle. Selection for production traits should be directly based on well-taken records of production rather than using conformation as an indirect indicator of production.

Conformation is a subjective (judgement) evaluation in the main and is not highly heritable. There is no definite yard stick for conformation and consequently, standards vary from one individual to another. The low heritability of the trait indicates that altering conformation is a relatively slow, unsure process and that variability will remain in a herd even after being closed to outside breeding for many generations.

Specific points of conformation that relate to soundness fall into a different category. Cattle with obvious unsoundness - distinctly abnormal feet and legs, toes that grow out in a foundered condition, retained testis, etc. - should definitely be culled.

Individual breeders are going to place emphasis on conformation according to their own ideas and therefore there is little that should be said additionally except to repeat that it would be a mistake for any Zebu breed to emulate European breeds and that the heritability for the character is relatively low.

Cow Fertility

It is well established that the Zebu cow is slow to cycle when under nutritional stress, especially if she is under the additional stress of nursing a calf. A fact that is a great deal less widely appreciated is that the sensitivity or responsiveness of the Zebu cow to nutrition works both ways; that is, the valuable survival mechanism that prevents her from cycling during stress also operates promptly to initiate cycling when nutrients are plentiful. From the selection standpoint, it is obviously poor procedure to cull a cow which does not conceive under

nutritional stress and select one which does conceive because of nutritional plenty. One of the chief reasons that heritability of cow fertility is low is that the environmental factors such as seasonal differences, age, disease and a host of other factors, obscure the true genetic differences among individuals for fertility.

A well-managed breeding herd assures that all cows are provided the opportunity to express their genetic ability to conceive. This is an economically sound practice even without considering the genetic aspects. (See tables 1, 2, 3 and 4).

Following conception, the second component of net fertility is the ability of the cow to deliver a live calf and the ability of the calf to survive. There is little need for concern about the Zebu cow delivering a calf; however, survivability of the calf is a different matter. First consider the calf aspect of survivability. At the present time there is little definite knowledge about the problem of postnatal survival of Zebu calves. However, since cross-bred calves from either Zebu sires or Zebu dams are especially vigorous, it indicates a within breed problem that may be thought of as opposite to heterosis. Selection against this effect opposite to heterosis is no more likely to succeed than selection for heterosis or hybrid vigor. The best advice is to avoid close matings (unless there is very good reasons for inbreeding) and to always mate a cow to a different bull if she produces a weak calf that doesn't live. Sires or dams which produce a distinctly higher than average percentage of calves that die shortly after birth, should be culled. More research is needed before a better recommendation can be offered.

The other aspect of calf survival is the ability of the cow to properly mother the calf. This ability includes her physical as well as behavioral characteristics. Replacements should not be saved from any cow, which under normal circumstances, can not or does not mother her calf without assistance.

The milking ability of the Zebu cow is about ideal on average for raising beef calves except that her relatively high milk yield does tend to place nutritional stress on her unless she has access to excellent nutrition for several months following calving. Once the cow has conceived, the nutritional stress is not as critical. Just as the Zebu cow is responsive to either nutritional stress or plenty, as noted above, the Zebu heifer responds in a similar manner. Zebu heifers should have optional nutritional opportunities if they are to be expected to reach puberty, cycle and calve before 30 months of age.

Bull Fertility

Some Zebu bulls limit the fertility of the cow herd. There are two aspects of the limitation placed by the bull: (1) his libido or mating aggressiveness and (2) the quality of his semen. Brahman breeders are well aware that observation of a Zebu bull during a limited portion of the day may give a poor indication of his breeding activity. A number of easily observed characteristics should be required of a bull. These include well-developed, firm, symetrically suspended testes and a generally masculine appearance with darker pigmentation around the shoulders and quarters.

After initial screening on appearance, the semen should be tested and evaluated by a qualified person. The standards required of the semen should be that the bull is not only fertile, but highly fertile. Again, even though there is no rigorous research data to substantiate the opinion, it is logical that even for bulls in natural service, semen should be of the volume, density and motility suitable for commercial AI collection and that it should be able to withstand the freezing and thawing required. This rigorous standard should be taken into consideration in the selection process; the closer a bull comes to meeting these standards the more desirable he is. Certainly those bulls which miss the mark by quite a margin should be culled. As mentioned above, this selection is practiced to improve cow fertility, not only from the standpoint of providing fertile bull mates, but also the replacement heifers sired by this type of bull would be expected to have fewer fertility problems.

Rates Of Gain And Maturing

Rate of gain (sometimes equated with performance testing) has gained considerable popularity among registered and commercial beef cattle breeders in the U.S. However, changing rate of gain in a more or less stable, well-adapted breed or herd of cattle should not be taken lightly because there are correlated or "spinoff" effects. The major concern is that selecting for increased rate of gain, particularly during a five or six month interval around 12 months of age, will have a strong tendency to increase mature

size and delay age at which puberty is reached. Increased rate of gain to slaughter weight does tend to increase efficiency of feed conversion of slaughter cattle. However, as pointed out a number of times, the delayed maturity and increased mature weight will decrease efficiency in the brood cow herd, other things being equal.

The major advantage in breeders selecting for increased average daily gain would be to increase gainability in Zebu crossbred steer progeny. Even though the Brahman sired steer has an excellent reputation for finishing, the Zebu sire is a sire for adapted, productive, hybrid cows - and most Zebu cross cows are already large enough. Indicated for the Zebu, then, is a more comprehensive approach to selection for increased average daily gain. Performance data should be used to increase rate of gain, but without increasing mature size.

The soundest approach is to give preference to those individuals which have higher rates of gain but mature at medium sizes. If progeny data are available, sires which have higher gaining progeny but are themselves average size should be given selection preference.

At the present time and with the current state of accumulated data in breeder's performance files, performance testing of only bulls for rate of gain appears to justify the effort and expense. However, it is recommended that heifers be weighed at 12 months and 18 months. Heifers should be developed normally, without effort to achieve maximum gains, to avoid the detrimental effect of early fattening on later fertility as a cow.

Temperament

The temperament of the Zebu is even more famous than its hybrid vigor. The athletic performance of "professional" rodeo bulls which have some Zebu "blood" has contributed to this reputation. Even though it may be unfair, they do have a poor image and the fact must be faced. Zebu and Zebu crosses can be worked without undue difficulty (actually more easily in some cases) by experienced cattlemen with proper facilities.

Temperament is conditioned by both heredity and treatment. It is difficult to separate these effects, but the hereditary effect in temperament can be improved by selection. Cattle which are wild or unmanageable should be culled. However, culling them from a herd in which the cattle have not been given proper management or treatment is not effective. Cattle must be given the change to exhibit their inherent temperament, good or bad, under comparable conditions. After culling out the "trouble makers", gentleness should be favored, other characters being equal, in selecting among the top end.

Summary

The continued development and improvement of the Zebu centers around its valuable genetic combining ability in crossbreeding and its adaptability. Performance of its crossbred progeny is more important than its purebred performance. As with any breed, the effective or distinctly undesirable animals (retained testis, wild, etc.) should be culled. Development of the Zebu breeds is to the point at which selection should be intensified. A summary of some of the more important selection and mating considerations for the Brahman is given in Table 1.

Summary Points For Selecting And Breeding Zebu

General

Do not diminish valuable Zebu uniqueness,
The value of Zebu breeds lie not only in breed traits but also in their distinctiveness from other breeds.

Establish definite goals and concentrate on them.
Brood cow traits are most important; do not select for size (gain) indiscriminately.

Limit goals to important traits and keep records on them.
Record crossbred performance as well as purebred performance; include fertility and survivability.

Provide good, uniform management and nutrition.
Genetic potential can be expressed and selection becomes effective only in proper environment.

Test young sires freely on commercial cows and look to them for improvement.
A test must include old sires to be useful. Don't replace proven sires until young ones prove better, but remember that use of a sire for long periods of time tends to maintain status quo.

Be objective, consistent and persistent.
Genetic improvement tends to be cancelled when goals change.

Be direct, keep records.

Mating Plans

Evaluate a wide outcross cautiously.
Increased performance may result because of outcross vigor but breeding value may not be improved.

Avoid inbreeding except to linebreed to a truly superior sire.
Little is gained by fixing mediocrity.

Selection

Emphasize high level of fertility in bulls.
The objective is to increase cow fertility - directly and indirectly.

Do not cull cows for long calving intervals in poor environment.
Good nutrition for heifers and nursing cows in especially important.

Cull defective cattle.
Also cull their sire and dam if the trait is a genetic recessive.

Cull wild or nervous cattle.
Also, favor gentleness, other traits equal.

Cull sires and dams with low progeny survival.
Keep records and cull those much below average.

CROSSBREEDING SYSTEMS

By
Dr. T. C. Cartwright, Professor
Department of Animal Science
College of Agriculture
TEXAS A&M UNIVERSITY
College Station, Texas

Crossing breeds of cattle is a practice as old as the breeds themselves; but its use as the primary method of producing beef, such as with swine, has been approached only in recent years. There are different purposes for crossing breeds and different systems of crossing. The system should be matched to fit the purpose and the prevailing production and market conditions.

The reasons for crossbreeding are:

1. To combine the traits of two or more breeds in a more favorable blend either as a base for new breeds or to create a type fitted for a specific purpose;

2. to create hybrid vigor or heterosis;

3. to utilize the desired production traits of two or more breeds in such a way that they complement each other;

4. to grade up to a purebred.

Creating a new breed or type which is more useful is often a matter of choosing a breed which is extreme for one or more characters of concern in order to improve a breed deficient in that character. Of course, if the second breed has traits which tend to overcome some deficiency in the first breed, then the combination becomes more attractive. In the case of breed formation, the initial crossing must be followed by selection and an appropriate breeding plan. An example is crossing Brahman with a British breed to gain a more favorable blend of adaptability to subtropical areas, growth rate, and finishing qualities. A breed such as the Santa Gertrudis illustrates combining desirable traits of two pre-existing breeds. Each breed was chosen because it possessed in strong measure one or more desirable traits which could not be gained in the other breed by selection over a reasonable length of time or perhaps not at all. "Synthesized" breeds differ from crossbreds when the desired characteristics have been genetically bound together in a reasonably stable form and the unwanted characteristics have been sorted out and reasonably well eliminated. An example of crossing for a specific purpose, which is currently popular, is combining the "meatiness" of Limousin with the marbling and finishing qualities of the Angus in an effort to gain an optimal combination of characters according to current vogue in steer shows.

Hybrid vigor is created in the offspring resulting from mating one breed with another. The hybrid is, of course, an admixture of the parental breeds, but its traits of physiological fitness (generally including hardiness, fertility, growth, and overall productivity) tend to be enhanced. The genetic explanation for the extra vigor of the hybrid is basically the same as that for hybrid corn, hybrid sorghum, coastal bermuda, hybrid poultry, hybrid hogs, etc. Crossing two breeds (or two inbred lines, or even two species) gives an added boost because the new gene combinations created possess a greater total number of possible gene forms and because there is increased masking of undesirable recessive genes.

Percent hybrid vigor for each trait is inversely related to response from selection (percent heritability). Those traits high in heritability which respond consistently to selection (e. g., 18 mo. weight) have little hybrid vigor response. And, vise versa, traits low in heritability (e. g., cow fertility), usually have high hybrid vigor percent.

Matching two or more breeds to take advantage of the different production qualities of each breed or cross has been termed complementarity. A demonstration of complementarity was carried out at the Texas A&M University Research Center at McGregor using a Charolais sire on Angus-Jersey cows. The sire breed contributed growthiness and meatiness to the terminal progeny and the cows were relatively small and efficient to maintain. The pounds of feed required to maintain the cow for a year and creep feed her calf up to weaning was 17% less for this three breed

cross than for a straightbred.

Grading up was the principal recommended practice for many years in the United States. It faded somewhat, but is now very much back in vogue for the new breeds both domestic and exotic. The only recent development is the increased use of crossbred bulls---especially the 1/2 and 3/4 exotics.

As indicated above, the level of hybrid vigor may be different for each trait. Hybrid vigor is most pronounced in traits that are a stress or a hardship. Gestation, parturition, and lactation for the cows and survival at birth for the calf are the major stresses of beef cattle. Therefore, the most benefit from hybrid cattle will be realized in maternal ability and survival.

Also, the level of hybrid vigor for all traits depends on the breeds crossed. The greater the genetic difference between the two breeds, the greater the hybrid vigor expected. The genetic difference between a British breed and an Indian origin breed is greater than the difference between one British breed and another British breed. Hybrid vigor can be contrasted to inbreeding depression. When related animals (a half-brother and half-sister or two cousins, for example), are mated, the resulting offspring is inbred. The intensity of the inbreeding depends on the closeness of the relationship of the sire and dam. The loss of vigor tends to be proportional to the intensity of inbreeding. Mating individuals genetically diverse (different breeds), instead of genetically similar (two relatives), tends to increase vigor in proportion to the diversity. Hybrid vigor is maximum in the F_1 (first cross). The extra vigor is partially dissipated in the second cross or backcross. In general, if an F_1 is bred to an F_1 of the same type, the vigor is halved in the resulting F_2. The same halving occurs in the backcross resulting from mating an F_1 back to one of its parent breeds to get a 3/4 bred. About half of the vigor remaining in an F_2 is again lost in the F_3, and so on. In an advanced generation of mating crossbred to crossbred, none of the hybrid kick is left.

It is more beneficial to have hybrid vigor in the cow herd because of the substantial hybrid advantage in fertility and mothering ability. A hybrid cow passes on benefits to her calf through her

TABLE 1. HYBRID VIGOR IN BRAHMAN-HEREFORD AND THREE BREED CROSSES[a]

Sire	Dam	180-day wt. lb.	180-day wt. H.V.%	Feedlot av. daily gain lb.	Feedlot av. daily gain H.V.%
Hereford	Hereford	384	Base-	2.36	Base-
Brahman	Brahman	377	point	2.04	point
Hereford	Brahman	441	16%	2.43	10%
Brahman	Hereford	425	11%	2.44	10%
Third Breed[b]	F_1 HxB	460	21%	2.60	18%
F_1 HxB	F_1 HxB	443	16%	2.16	-3% (loss)

[a] These data were taken from published reports from the Texas A&M University Research Center, McGregor, involving 3145 calves over a 16 year period. Hybrid vigor (H.V.) is expressed as the percent advantage of the cross over the base point average of the Hereford and Brahman.

[b] The third breeds were Santa Gertrudis, Charolais and Brown Swiss; hybrid vigor is expressed in terms of the average of the Hereford and Brahman.

mothering ability. The calf of a hybrid mother is necessarily a crossbred of some type so it is difficult to completely separate the hybrid benefit from the dam's mothering ability and the calf's own doing ability.

A successful crossbreeding program must take advantage not only of hybrid vigor in the traits most responsive to hybrid vigor, but it must also take advantage of selection for those traits most responsive to selection. Selection is less predictable and less effective in crossbreds than in purebreds. Also, the amount of selection possible in a systematic crossbreeding plan is limited. Therefore, the major selection benefits must constantly be brought in by purebreds, especially for those traits high in heritability such as meatiness and carcass value.

However, the practical difficulties can be readily appreciated. One principal difficulty is the availability of a continuous supply of a substantial number of good purebred stock. "Good" cattle refers to those selected and bred for the economic traits important in total beef production.

The basic facts presented about hybrid vigor are backed up by substantial research from many states and various breed crosses. The research results from the Texas A&M University Research Center at McGregor are used to illustrate hybrid vigor in Table 1.

Crossbreeding cattle without considering the reasons for the initial cross and the consequences of the next step usually accumulates the disadvantages of crossing. However, a substantial body of consistent research information clearly indicates practical ways to utilize the advantage of hybrid cattle. A producer can put together a practical plan tailored to his facilities that will create and sustain a hybrid boost in his cattle. Hybrid cattle offer more advantage for some operations than for others. Hybridization offers greater possibilities in any situation creating hardships on cattle or where productivity traits---such as weaning weight, fertility, or survivability---are below the general average of cattle. However, hybridization is definitely not a practical alternative for good management. Even when conditions are good, producers of feeder or slaughter calves should consider the advantages and the increasing demand for hybrid calves.

Three basic breeding plans are outlined, but adaptations of plans to variations in existing facilities and herds are easily visualized. In each and every plan, purebred sires must be available since success depends on the breeding performance of the purebreds as much or more than on the plan. Hybrid cattle emphasize the need for productive purebred cattle---greater numbers of purebred seed-stock will be required---as utilization of hybrid vigor increases.

Plan 1. F_1 Cows X Purebred Sires

This plan (Table 2) gives the opportunity to capitalize on hybrid vigor more than any other. First, maximum vigor is retained in the cow herd where it is most advantageous. The purebred sire can be highly selected and should tend to breed uniformly. For maximum vigor, the sire should be a third breed different from the two breeds in the F_1 cows. An important advantage of crossbreeding is matching breeds. The two breeds used to make the F_1 cows should be: (1) distinctly different breeds from one another, (2) strong in the cow production traits---hardiness, fertility, and mothering ability, and (3) adapted to area. Rate of gain or growthiness should be left to the sire.

The sire, a purebred, should be highly selected for growthiness and carcass desirability. He should be a third breed in order to both sustain a high level of hybridization and to allow more discriminating matching of breeds. A backcross results if the sire breed is the same as one of the parent breeds of the cow herd and some hybrid vigor in the backcross calves is lost.

A very real and obvious disadvantage lies in the replacement of the F_1 cows. As more cattlemen enter the express business of producing F_1 heifers, purchasing replacement heifers becomes more feasible. This system encourages specialization and hopefully efficiency. First, purebred breeders have to supply purebred heifers to an F_1 heifer producer. A breeder of another purebred has to supply the bull. Second, the F_1 producer supplies heifers to the producer of slaughter-feeder cattle. The F_1 producer sells his male calves as

TABLE 2. Outline Of A Three Breed Terminal Crossing System (Plan 1)

Purebred Sires x F_1 Cows

The stocks required to maintain 100 F_1 cows for this system are shown below on an annual basis. Herd 1, Herd 2, and Herd 3 may each represent a different breeder but a large breeder could maintain two or all three herds. Herd 1 sells heifers to Herd 2. Herd 2 sells heifers to Herd 3. In Herd 1 and Herd 2 minimum numbers are shown.

Herd 1

Bulls	Cows	Calves
2 Purebred Breed A	50 Purebred Breed A	20 Bulls 20 Heifers: 10 stay as replacements 10 go to Herd 2

Herd 2

Bulls	Cows	Calves
2 Purebred Breed B	50 Purebred Breed A	20+ Bulls, market as feeders 20+ Heifers, majority go to Herd 3

Herd 3

Bulls	Cows	Calves
4-5 Purebred Breed C	100 F_1 Hybrids AxB Breed Crosses	40+ Bulls, market as feeder-slaughter cattle 40+ Heifers, market same as bull calves or sell into a rotational cross program

feeder or slaughter calves.

This system requires a large supply of purebred females. An established purebred breeder, if he has been sound and practical in his breeding and selection program, should find a developing market for his heifers. He should be encouraged to remain purebred and perhaps close his herd to much outside breeding.

This system is practical. At no point is it less efficient than a straightbred beef producing operation. Most of the selection must be introduced from the purebred sires. The plan does not permit heifer selection except for culling the tail enders. Selection for growthiness in the females is not desired in this plan; therefore, the principal reasons for culling heifers will be unthriftiness, and the reduced culling percentage will not be a serious handicap.

Plan 2. Rotational Crossing---Crisscrossing

Perhaps one of the most popular features of this system is that the producers who either are not equipped or are not included toward numbering cattle and keeping records can still improve their herd production. Improvement in their beef production will be gained from using performance tested sires and hybrid vigor in the cows and calves.

The major feature of a rotational plan is that it allows a producer to sustain hybrid vigor and to produce his own replacements. The rotation can involve as few as two herds (crisscrossing) or up to four or five; a three-breed rotation is outlined in Table 3. The limits are set first by physical facilities and second by the number of

TABLE 3. Outline Of A Three Breed Rotational Crossing System (Plan 2)

Purebred Sires x Crossbred Cows

This basic plan can be limited to two breeds or expanded to 4 or 5 breeds. The heifers saved from one herd always go as replacements to the next herd. The purebred sire is always mated to cows carrying the least amount of his blood.

Bulls	Cows	Calves	
Breeding Pasture 1			
Purebred	Crossbreds from Herd 3	Bulls:	All go to market
Breed A	14% Breed A	Heifers:	Excess go to market
	29% Breed B		Replacements to Herd 2
	57% Breed C		
Breeding Pasture 2			
Purebred	Crossbreds from Herd 1	Bulls:	All go to market
Breed B	14% Breed B	Heifers:	Excess go to market
	29% Breed C		Replacements to Herd 3
	57% Breed A		
Breeding Pasture 3			
Purebred	Crossbreds from Herd 2	Bulls:	All go to market
Breed C	14% Breed C	Heifers:	Excess go to market
	29% Breed A		Replacements to Herd 1
	57% Breed B		

different breeds of commercially sound sires which are readily available.

For each breed used in a rotational system, at least one separate breeding pasture is required. If each cow is individually identified, the cows can be combined and shifted about according to available grass, etc., and then separated for breeding, or if AI is used, they don't ever have to be separated.

The different sire breeds should be reasonably well adapted and not extreme in size. The individual sires should be performance tested and there is probably some advantage if they come from herds which are essentially closed to outside breeding. This system does not allow matching cow breeds chosen for desirable cow traits with sire breeds selected for growthiness and carcass and meats traits. Also, some hybrid vigor is lost since the cows are not a completely different breed from the sire after the first go-around.

Plan 3. Single Cross---Purebred Cows and Sires

This plan consists of breeding about half of the cows to sires of the same breed and half to a different breed. Each sire breed and their cows can be kept in separate pastures, sire breeds can be alternated every year or so, or sires can be run together in a mixed sire herd. This plan is simple and can be adapted to any size operation. This breeding plan is similar to that of Herd 2 of Plan 1, except that it allows for its own replacements.

An essential requirement for this plan to be efficient is that a breed which is well-adapted and strong in desirable cow traits be used for the cow herd. The purebred cows and their purebred calves, half of the calf crop, will not possess any hybrid advantage. Therefore, a suitable alternative to this plan should be considered, especially if the area is notable for low fertility or high calf mortality.

Getting Started and Choosing Breeds

In evaluating plans and breeds for utilizing hybrid vigor, all good practices should be observed. One is recognizing the breeds that thrive and are available in the producer's area. Objective performance records are much more available today than ever before, and should be utilized.

The future of hybrid cattle is much clearer now than just a few years ago. One important change is the general recognition by purebred breeders of the hybrid cattle potential---both their support and their cattle are essential ingredients. The most important development, however, has been a greater awareness of the advantages of hybrid vigor by commercial cattle producers.

COW SIZE

By
Dr. T. C. Cartwright, Professor
Department of Animal Science
College of Agriculture
TEXAS A&M UNIVERSITY
College Station, Texas

Beef cattle producers understand a great deal about cow size and its relationship to efficiency of production for their operation, yet there is still a difference of opinion and controversy about the best cow size. This enigma results, I believe, from several reasons. One is our inability to allow for all the positive and negative influences of size because of the very complex accounting required to properly evaluate efficiency through all stages of production. Another reason is our failure to properly define our terms of reference; that is, we may talk to another about different segments of production and think we are talking about the same thing, but they may be quite different. Also, we may have personal biases about size not related to efficiency of production.

Commercial beef production is usually divided into segments with respect to ownership or management-ship; for example, one owner maintains a cow herd and sells calves at weaning, while a second owner grows the calves for a period and then a third owner finishes them for slaughter. The interests of the several owners are not necessarily identical, especially if the market rather imperfectly reflects the true relative value of different cattle. The market is not usually highly discriminating of value of cattle and the only creditable information transmitted from the seller to the buyer is the weight and appearance of the cattle. The calf producer is interested in minimizing maintenance costs for his cow herd and may choose a type of cattle with small mature size if the market tends to recognize numbers of calves rather than gain potential of calves.

Efficiency of production takes on different meaning if it is considered as if the production operation was integrated (one owner) from calf production, through finishing, to slaughter. All of the inputs and outputs of the production system which may affect efficiency should be considered; these include production of replacements, maintenance of the cow herd, and salvage value of cull cows.

The term cow size probably became established to designate size characteristics of cattle of both sexes and all ages because size is most important in the cow. Size is most important in the cow because (1) she is more numerous, about 2 to 1, and is kept longer than either bulls or slaughter cattle, and (2) the amount of feed (or acres of pasture or range) required to grow and maintain her is proportional to her body size. For example, it takes about 1/3 more feed to maintain a 1,200 lb cow than an 800 lb cow. On the other hand, cattle which gain faster tend to be more efficient feed converters than cattle of the same weight which are slower gaining. In fact, the desirable traits of brood cows are quite different and often opposing to those of feeder and slaughter cattle, as seen in Table 1.

Before going further, cow size should be defined. A great deal has been learned about size and growth during the past few years. The aspect of size, or differences in size, that I refer to is the genetic component. The genetic effect on size is illustrated by the differences between two breeds for average weight. Of course, the difference must be between cattle given relatively equal nutrition and of the same stage of maturity such as cows at maturity. Cow size is a term used to refer to differences in size of all ages and sexes. See Figure 1.

Absolute and relative measures of weight are probably the most important characters to consider in setting selection and breeding criteria for beef cattle. Selection for increased rate of gain at any age tends to increase mature size. The closeness of the correlation between rate of gain and mature size has not been exactly established, but it is usually considered to be high; that is, there is a strong tendency for cattle to follow a pattern of growth. The patterns of growing and maturing of a large and a small size individual given relatively

Table 1. Desired Traits Of Brood Cows And Feeder And Slaughter Cattle

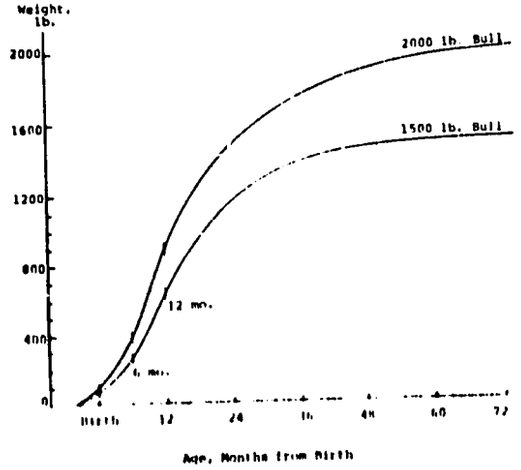
Brood cows	Feeder and slaughter cattle
Small size, efficient maintenance	High gaining ability, efficient feed conversion
Early puberty	No puberty
Highly fertile	Zero fertility
Long lived	High cutability
Hardy and adaptable	Tender beef

equal opportunities are shown in Figure 1. The essential points brought out by these two growth curves are that the larger mature individual tends to: (1) have a higher rate of gain from birth up until mature size is reached, (2) reach puberty at an older age and heavier weight and (3) would reach some specific finish level at an older age and heavier weight.

This last point is especially overlooked when we compare cattle which have high cutability---usually we are comparing cattle which are of the larger type with cattle of the smaller type at the same weight. If we compare them at the same degree or stage of maturity (and therefore different weights) the difference in cutability tends to disappear.

FIGURE 1. Examples of growth curves illustrating the genetic potential of a small and a larger bull.

Mature size	Birth wt.	6 mo. wt.	Yr. wt.	Postweaning ADG	Maturity at 1000 lb.
1500 lb.	62	330	700	2.1	67%
2000 lb.	78	400	850	2.5	50%



Direct selection for large mature weight is widely recognized as an effective means of increasing growth rate. Heritability of average daily gain (ADG) at 1 year of age is about 40% and mature weight about 70%. The genetic correlation between ADG and mature weight is about 70%. The estimated increase in ADG resulting from a reasonable, specified level of selection[1] for mature size alone is about 0.25 lb/day. At the same time, mature size would be expected to increase approximately 116 lb. Conversely, selecting for ADG alone would increase mature weight about 61 lb and increase ADG 0.27 lb/day. Because of these so-called correlated or multiple effects of selection, the effect of selecting for ADG on production efficiency becomes complex. In order to get realistic answers to this problem, we began several years ago to apply some techniques of operations research utilizing data from our studies of rates of growing and rates of maturing (growth curves) in beef cattle. We simulated the production and efficiencies of cattle taking into account the input and output variables of the entire system of the production of beef up to slaughter.

The inputs and outputs may be converted to dollars and cents terms and include cash flow and interest on capital in order to compute economic as well as biological efficiency. Economic efficiency may be defined as follows:

Profit - the net monetary return of a complete beef production operation; that is, all returns less all expenses including interests on capital, or

Return to investment - profit divided by capital investment. If capital is borrowed from an extraneous source it must be included as indicated under profit. If capital is all from one source, the investor, then it may not be appropriate to include interest as an expense; whether it is or is not included must be specified.

Biological efficiency must be defined as follows:

Liveweight produced per unit of physical input - lb of liveweight sold per acre of per lb of TDN are examples. If quality of nutrients and of liveweight produced are to be included in the efficiency measure, economic efficiency may be more suitable as quality of a unit of input or output can be weighted by costs or selling price.

When a breeder talks about production, he usually thinks about the type of climate, management, nutrition, breeding system, and market product most familiar to him; even though he does recognize that there are vast differences in these factors from area to area and that they do affect the efficiency of beef production. However, we may not fully consider that these factors may in turn affect the efficiency of production of different size cattle differently. For an example that may be current, consider a market which pays a premium for steers finished to the equivalent of the USDA Choice quality grade. The most efficient size for rate of gain may be quite different if the steers are fed in feedlots when grain is economically available around the year, versus steers that are finished largely by grazing on forage which is highly seasonal in quality and quantity and grain is relatively expensive. In the first case, a genotype for a large, growthy type may be most efficient for the finishing phase. In the latter case, a genotype for a smaller, quicker finishing steer may be a distinct advantage if the steer can be finished during two seasons of abundant forage (usually spring and early summer) and carried through only one season of poor forage production (usually winter).

My point will be made, I believe, if it is recognized that evaluation of efficiency of beef production from different sizes of cows should not be applied to different sets of conditions without determining if it is justified.

One of the simulation studies was on the effect of cow size on overall efficiency of production in an integrated operation. We assumed no differences in fertility or milk production, but that growth and maturing rates were determined by genotype for mature size under a fixed environment.

The same fixed amount of resources were allocated for nutrients for each herd so that comparisons could be made on the basis of liveweight produced from a given amount of resources for nutrients. A number of other assumptions were made and programmed into the deterministic model which included a linear program for maximizing profit. The production efficiencies for straightbreds of small and large size, typified by mature cows weighing 950 lb and 1,325 lb respectively, were simulated for two sets of environmental (management-nutrition) conditions for the cow herd: (1) fed all harvested feed in confinement which is referred to as feedlot and (2) pasture as available plus harvested supplements which is referred to as a pasture. All males and surplus females were fed for slaughter in a feedlot after weaning.

These results illustrate several points. One is that there are no very large differences in the overall efficiency of the different sizes. The advantages in efficiency of one size for one segment of production (e.g., lower per head maintenance requirements for the cows of small genotype) tend to be offset by lower efficiency for another segment of the production unit (e.g., lower rates of gain in the feedlot for the progeny from the herd of small genotypes). About 56% more small cows were supported than large cows in the simulated cow size study; i.e., where one large cow and finished calf could be supported over 1 1/2 small cows and finished could be supported. However, there were some differences which were not readily predictable. For the fixed input of resources for nutrients for sustaining the cow herd and finishing the slaughter cattle, larger numbers of smaller cattle were possible and the smaller cattle consistently returned more total liveweight for their fixed nutrient input. Increasing size tended to increase economic efficiency in the feedlot while it tended to increase profit and increase return to investment in pasture. Effects of size were less pronounced in the pasture regime.

It appears that current selection trends tend to favor traits useful in feeder and slaughter cattle for all breeds rather than being limited to the few which already best fit the criteria. The results of these selection practices has been to create more variability, and consequently less predictability, within breeds and, therefore, to diminish the utility of breeds as maternal lines in crossbreeding. For straightbreeding, size has little effect on efficiency if cattle are taken to their best slaughter weights. Selection based on increasing weights reflects a move toward more objectivity among breeders in selection but combined perhaps with less understanding or concern for the total production system.

Cow size, along with its correlated effects, is probably the most important character in beef cattle. Fortunately, we have a wealth of genetic variability in size thanks largely to the exotics and AI. I believe that the possibilities for beef cattle producers to increase efficiency of production and profit are enhanced if we retain this variability. It gives him greater opportunities and greater flexibility over a wider range of production conditions. However, this variability can be more sensibly and productively used if it is ordered into breeds. Every breed should set criteria---standards---for its most important characters. What is more important to know with assurance about a breed than its size?

DOUBLE MUSCLING IN BEEF CATTLE

by
Dr. T. C. Cartwright, Professor
Department of Animal Science
College of Agriculture
TEXAS A&M UNIVERSITY
College Station, Texas

Beef cattle are produced primarily for their muscle and, logically, the rationale for selection criteria is often centered around muscularity. There is little wonder, then, that cattle with "double muscles", or even these tendencies, have appeal and, in fact, have increased in frequency in the United States during the past decade. However, the disadvantages outweigh the advantages for most U. S. producers and any beef cattle breeder should be familiar with the characteristics and the genetics of double muscling and its side effects.

The term "double muscling" is descriptive of the appearance of fully affected animals but it is an incorrect term in that they have only one set of muscles as does any other animal. The muscles are enlarged over the normal and these cattle deposit very little fat so that the muscles tend to stand out and have creases between them. Other names, often similar, have been coined in other countries: doppellender (double rump, Germany), groppa doppia (horse rump, Italy) and culard (France). The scientific name that often applies is muscular hypertrophy, but it is also, in fact, a misnomer as it implies increased size of fibers in each muscle which is not the case. Instead, it has been shown (Swatland and Kieffer, 1974; Butterfield, 1966), that there are more fibers, not larger fibers. The proper term would be muscular hyperplasia, but it is not used so that it is just as well to accept the term "double muscling" and understand what it means.

Double muscled cattle have been observed in many breeds and described in historical accounts at least since 1807 (Culley, 1807; Weber and Ibsen, 1934; Mason, 1963). The reason this condition can be retained in many breeds for generations is because it is a single gene recessive (Kieffer, Cartwright and Sheek, 1972). The recessive gene tends to be "masked" by the dominant gene in the heterozygous carriers. (Polledness and hornedness, for example, is a character controlled by one pair of genes. Dwarfism is another example.) The genetics, therefore, are relatively simple. Since each animal has two genes for such characters, all cattle can be classified as follows:

DM DM	Homozygous normal; two dominant normal genes. Normal animal
DM dm	Heterozygous; one dominant normal gene (DM) which tends to cover up the one recessive gene (dm); these are called carriers. This cover up is not complete so that there is a tendency toward double muscling.
dm dm	Homozygous recessive; two recessive double muscle genes. Double muscle animal.

The progeny from a sire and dam of all these three genotypes are predictable, on average, but not necessarily for any one offspring. The possible matings and progeny are:

Sire		Dam	Progeny
DM DM		DM DM	DM DM All normal.
DM DM DM dm	or	DM dm DM DM	1/2 DM DM, 1/2 DM dm All normal but 1/2 carriers.
DM dm		DM dm	1/4 DM DM, 1/2 DM dm, 1/4 dm dm Of the 3/4 normal, 2 out of 3 are carriers, the remaining 1/4 are double muscled.
DM DM dm dm	or	dm dm DM DM	DM dm All carriers.
DM dm dm dm	or	dm dm DM dm	1/2 DM dm, 1/2 dm dm One-half carriers, 1/2 double muscled.
dm dm		dm dm	dm dm All double muscle.

The problem is, obviously, determining if an animal is DM dm, a carrier, rather than DM DM. There are two ways to do this: appearance and breeding tests. The appearance is not 100% but for the experienced observer few mistakes will be made. However, it will be best to describe the homozygous double muscle (dm dm) animal first and then the

Special recognition is accorded to Dr. Nat M. Kieffer, a colleague at Texas A&M, for his assistance and the use of his research data in preparing this talk.

carrier (DM dm).

The double muscle character is really a syndrome of many characteristics. The key characteristics of a full double muscled animal are summarized below for each separate characteristic, but all of these may not be present to the same degree in any one animal:

1. Increased development of the hindquarter, accentuated in appearance by a groove between the major muscles (the vastus lateralis and semimembranosus), and a rounded "ham" appearance from the side.

2. Thick, open shoulders.

3. An unusually wide, stretched stance with the front and hind legs extended, generally creating a swayback appearance.

4. Lean, trim appearance often with a cylindrical middle and tucked up flank.

5. General lack of masculinity, other than muscularity in bulls, and lack of femininity in heifers and cows.

6. Heavy birth weight, good early growth, but growth markedly slower by one year and small mature size.

7. Fine bone.

8. Short tail.

9. Small vulva or testes.

10. Tail head set forward on top of rump.

11. At birth calves often have enlarged tongues, crooked legs, and are weak.

The DM dm carrier may show some degree of the characteristics of the full dm dm homozygous recessive, but there is a great deal of variability in the carrier; in fact, some carriers exhibit no indication of being carriers, especially as they reach maturity or are in thin condition. The general overall trim appearance, thicker quarter with a bulging, thicker round, and a higher tailhead setting are the best indicator points to observe.

Breeding tests may be designed to test if a bull is a carrier. (The same tests can be used for cows but they usually have too few progeny for progeny testing to be feasible.) These tests may use either double muscle cows, known carrier cows, or the sire's own daughters. However, test matings are not advised except for special cases and a geneticist should be consulted. The most important point is that any bull that sires a double muscled calf is a carrier (or homozygous double muscled), and the cow must also be a carrier. If a carrier DM dm sire is mated only to homozygous normal cows (DM DM) he would never produce a full double muscle calf. However, about 1/2 of his sons and daughters would be DM dm carriers. If a carrier's heifers are kept as replacements (and they are likely to have eye appeal for muscularity but not femininity), and a carrier bull is used in the herd, double muscle calves would begin to appear.

Growth and Reproduction

The double muscle calf tends to be heavier at birth, about normal from birth to some time after weaning up to about one year of age, and then tends to top out in growth and mature at a small size. Birth weights are heavier than average and the thicker calf causes a very high percentage of calving difficulty (Kieffer, 1974; Oliver and Cartwright, 1969). "Hip lock" is common. Either pulling or Caesarean is usually required for a double muscled calf even if his dam is normal. Perhaps the most practical point to make here is that in selecting sires for commercial herds, care should be taken to avoid carriers because 1/2 of their calves would be carriers. These carrier calves present more calving difficulty and, perhaps more importantly, they may be kept as replacements and later have real trouble.

The reproductive performance of the double muscle cow is usually severely impaired. First, her reproductive tract is much smaller. This fact is easily noted from the small vulva of the heifer. She likely will not conceive until much later than her normal herdmates, often calving first at 4 or 5 years of age. Second, her pelvic opening is smaller, and especially if she has a double muscle calf, she cannot usually deliver even with assistance, and a Caesarean is often

required if both cow and calf are not to be lost.

Kieffer (1972) reported that out of 25 births from double muscle cows delivering calves sired by double muscle bulls that 9 required caesareans, 10 were difficult pulls, 2 required light pulling and only 4 could deliver without assistance. Also 11 of the calves and one cow were lost. Kieffer mated cows sired by carrier bulls to carrier sires; the results are shown in Table 1. From this table note the higher than normal difficulty, especially when the calf is double muscle; about 1/2 of the non-double muscled calves are expected to be carriers which are somewhat affected. Also note in this table that out of 67 calves from carrier sired cows bred to carrier sires, 9 were double muscled: 9/67 or 13.4% is just slightly less than the expected 12.5% of double muscle calves from this kind of mating.

The double muscled bull also tends to have smaller reproductive organs, but not as consistently as the cow. Testes are usually reduced about 1/3 in size. The volume of semen is usually smaller, but the quality is not impaired.

In general, the double muscled animal is not hardy. The young calf follows its mother less closely and lies down more frequently. Walking appears to be more difficult and often labored for the mature animal. The extra muscle does not make these cattle stronger or more athletic; but just the opposite.

The reproductive performance of the carrier heifer or cow is thought to be somewhat impaired, but this has not been well established. However, the carrier cow can produce a homozygous double muscle fetus if bred either to a double muscle bull (about 1/2 of the time) or to a carrier bull (about 1/4 of the time). In the case she does produce a double muscle, she is likely to have serious calving problems especially if it is her first calf. The point should be emphasized again that the carrier varies considerably in the various aspects of the double muscle syndrome. This certainly applies to the reproductive tract. A heifer with an underdeveloped vulva should be seriously considered for culling.

The carcass of double muscle cattle is exceptional. The amount of fat deposit is reduced to only traces even though the cattle have been fed. The amount of muscle relative to bone is higher---in fact, double muscle cattle are the only kind where there is a substantial difference in the real muscularity of cattle (despite a great deal of talk about rather minute

TABLE 1. BIRTH WEIGHT, CALVING SCORE AND TYPE CALF FROM COWS SIRED BY CARRIER BULLS AND BRED TO CARRIER BULLS.[a]

Item	Doubled Muscle		Non-Doubled Muscle	
	Males	Females	Males	Female
No. calves	6	3	32	26
Av. Age of Dams (years)	2.5	2.7	3.0	3.1
Av. Birth Weight (lb.)	102.3	95.7	94.6	84.9
Av. Calving Score[b]	3.0	2.7	1.94	1.40

[a] Taken from Kieffer (1972)

[b] Calving Scores:

1 = Parturition not observed and/or no assistance given
2 = Light assistance - mechanical aids not used
3 = Mechanical aids necessary for delivery
4 = Difficult birth, lost cow and/or calf. Includes Caesarean section.

TABLE 2. SLAUGHTER AND CARCASS CHARACTERISTICS OF DOUBLE MUSCLE, CARRIER AND NORMAL CATTLE[a]

Item	Steers[b]		Bulls and Heifers[b]	
	Carrier DM dm	Normal DM DM	Double muscle dm dm	Carrier DM dm
Number[c]	15	8	10	10
Slaughter weight, lb.	954	948	973	1008
Dressing %	62.2	61.8	65.4	63.8
Conformation	Choice	Good+	Prime-	Choice+
Marbling	Slight-	Slight	Practically devoid	Trace
USDA Quality grade	Good-	Good	Standard+	Standard+
Fat Thickness, in.	.23	.38	.11	.17
Ribeye area, sq. in.	13.3	11.7	16.1	14.1
USDA Cutability grade[d]	53.6	51.4	56.2	53.8
Shear force, lb.[e,f]	10.9	16.3	13.3	13.1
Cooking loss, %[f]	31.4	33.02	31.7	33.1

[a] Adapted from West (1974)

[b] The steers were fed separately from the bulls and heifers; the data on the bulls and heifers are adjusted to equivalent sex.

[c] The number varies for some traits measured.

[d] USDA prediction equation; probably under estimated for the double muscle.

[e] Shear is an objective test of tenderness, the lower the value the more tender.

[f] Longissimus muscle.

differences). The lack of fat usually prevents the carcass from grading higher than USDA Standard even though the beef is tender. Data from cattle bred by Kieffer and their carcasses studied by West (1974) are given in Table 2; these data clearly illustrate these carcass and meat characteristics.

Some areas of France and Italy prefer the "culard", because it is adapted to their cooking which utilizes seasoned gravies very generously served on the meat. Double muscled beef cooked U. S. style, such as grilled, is dry and the reaction is usually unfavorable. The butcher of France knows he will get a very good dressing percent, no fat waste and a locally preferred type of beef, so he is willing to pay as much as a 50% premium on the hoof. In the U. S., it appears to me that there is a special market for low-fat beef which might be developed, but the market does not exist at present.

The carrier is intermediate in carcass characteristics and may be very useful in special situations for reducing fatness and increasing cutability. In fact the "modern" steer which is currently winning the carcass contents have the characteristics of double muscle carriers (and in fact many may have been just that). The gaining ability of the carrier is very acceptable; Kieffer (1974) fed a number of carriers and found that they gain as well or better than the normal steer (Table 3) and had very desirable "meat-type" carcasses with large loin eyes (Table 2). The carrier can be consistently produced by breeding (natural or AI) a homozygous double muscle bull to normal cows. Since the cows may have increased difficulty calving, easy

TABLE 1. AVERAGE DAILY GAIN OF DOUBLE MUSCLE, CARRIER AND NORMAL CATTLE[a]

No. and averages	Steers		Bulls		Heifers	
	Carrier DM dm	Normal DM DM	Double muscle dm dm	Carrier DM dm	Double muscle dm dm	Carrier DM dm
Number	14	6	5	4	4	5
Days on feed	182	200	107	138	263	194
Final wt., lb.	1018	1017	1097	1096	1019	1019
ADG on feed, lb.	2.46	2.31	3.76	3.78	2.32	2.45

[a] Adapted from data supplied by Kieffer (1974).

calving breed of cow and close supervision at calving are required. Also there is some indication that even some double muscle sires (dm dm) produce less calving problems than others. Some breeds, such as the Italian Piedmontese, which are predominately double muscle, apparently have adapted so that calving difficulty is reduced to tolerable levels.

Summary

Double muscling is caused by a homozygous genetic recessive condition. The muscles are enlarged rather than doubled and the condition has many other symptoms or effects including reduced fat deposition and increased calving difficulty. The double muscle gene is not completely recessive so that the heterozygote or carrier has tendencies toward the syndrome of effects. Because of calving difficulties associated with both double muscled cows and calves, the character should be treated as a genetic disease for extensive commercial operation; i.e., care should be taken to not introduce it into a herd and if it is found, it should be eliminated. However, a special market demanding tender beef with low fat levels could make special production feasible in herds which can be supervised by herdsmen with experience and skills in treating dystocia.

LITERATURE CITED

Butterfield, R. M. 1966. Muscular hypertrophy of cattle. Aust. Vet J. 42:37-39. (An. Breed. Abstr. 34:329).

Cully, George. 1807. Observation On Livestock: Containing Hints for Choosing and Improving the Best Breeds of the Most Useful Kinds of Domestic Animals. 4th Edition. G. Woodfall, Paternoster-Row, London.

Kieffer, N. N., T. C. Cartwright and J. E. Sheek. 1972. Characterization of the double muscle syndrome: I Genetics.

Kieffer, Nat M. 1972. Reproductive problems associated with the double muscle syndrome in cattle. Proc. 21st and 22nd Beef Cattle Short Course, Texas A&M Univ. pp 83.

Kieffer, Nat M. 1974. Personal communication.

Mason, I. L. 1963. Symptoms of muscular hypertrophy in heterozygous steers. Ani. Prod. 5:57-65.

Oliver, W. M. and T. C. Cartwright. 1969. Double muscling in Cattle. Texas Agric. Exp. Station Tech Rpt. No. 12.

Swatland, H. J. and Nat M. Kieffer. 1974. Fetal development of the double muscled condition in cattle. J. Anim. Sci. 38-752.

Weber, A. D. and H. L. Ibsen. 1934. The occurrence of the double-muscled character in purebred beef cattle. Proc. Am. Soc. Ani. Prod. pp 228-232.

West, R. L. 1974. Red to white fiber ratios as an index of double muscling in beef cattle. Ph. D. Dissertation, Texas A&M Univ., College Station, Texas.

EFFICIENT BREEDING SYSTEM FOR COMMERCIAL BEEF PRODUCTION

Effiziente Zuchtsysteme für die wirtschaftliche Produktion vom Rindfleisch

Sistemas eficaces de reproducción para la producción comercial de carne bovina

T. C. CARTWRIGHT *
H. A. FITZHUGH, Jr. **

The efficiency with which a given set of environmental resources are utilized to produce beef may vary considerably among various alternative uses of the existing genetic resources. Conversely, the efficiency of production of a given set and use of genetic resources may vary according to the environmental resources. In real life one set of resources is not fixed and the other adjusted, but rather they tend to be simultaneously adjusted. However, for this discussion, I am going to consider the environmental resources; which in this context includes management, economic and marketing considerations; to be fixed in order to examine the effect of varying the genetic resources on efficiency of beef production.

During the past decade, especially, bovine semen has been relatively widely and expeditiously distributed. This development increases the genetic variability available for use in commercial production and, hence, tends to increase the opportunities for increasing efficiency of production and the capability to adjust to changing environment through the judicious choice of breeding systems. At the same time, this availability of a large array of genotypes may compound the seriousness of imprudent choices of breeding systems.

In order to examine the efficiency of beef production, a definition of efficiency is required. Commercial beef production may be divided into segments with respect to ownership or managementship; *e. g.* one owner may maintain a cow herd and sell calves at weaning, a second owner may grow the calves for a period and third owner finish them for slaugther. The interests of the several owners are not necessarily identical especially if the market rather imperfectly reflects

* Animal Breeding and Genetics Section, Animal Science Department, Texas A & M University, College Station, Texas 77843, United States.
** Agri-Link Corp., 2192 Dupont Drive, Irvine, California, United States.

the true relative value of different cattle (HARRIS, 1970). The market is not likely to be discriminating if the only creditable information transmitted to the buyer is the weight and appearance of the cattle. For example, the calf producer is interested in minimizing maintenance costs for his cow herd and may choose to select a type with small mature size if the market tends to recognize numbers of calves rather than gain potential of calves. Even though the market conditions may have an overriding control in determining the most efficient breeding system for an individual producer, efficiency is considered here as if the production operation was integrated (one owner) from calf production, through finishing, to slaughter. All of the inputs and outputs of the system which may affect efficiency should be considered; these include production of replacements, maintenance of purebreds for use in crossbreeding and salvage value of cull cows.

The inputs and outputs may be converted to monetary terms and include cash flow and interest on capital in order to compute economic as well as biological efficiency. Both economic and biological efficiency may be of interest for use in evaluating breeding systems. The measures of production efficiency proposed are:

Profit — the net monetary return of a complete beef production operation; *i.e.* all returns less all expenses including interest on capital.

Return of investment — profit divided by capital investment. If capital is borrowed from an extraneous source it must be included as indicated under profit. If capital is all from one source, the investor, then it may not be appropriate to include interest as as expense; whether it is or is not included must be specified.

Liveweight produced per unit of physical input — kilograms of liveweight sold per hectare or per megacalory of digestible energy are examples. If quality of nutrients and of liveweight produced are to be included in the efficiency measure, economic efficiency may be more suitable as quality of a unit of input or output can be weighted by costs or selling price.

If the efficiency of breeding systems are compared within a more or less fixed set of environmental conditions, the effects of interactions between breeding systems and environment are by-passed. This approach appears to be necessary at this time because only very limited quantitative information about interactions between genotype and environment ($G \times E$) is available even though it would be quite useful to be able to approximate the limits which should be placed on generalizations about applying breeding systems. Almost certainly, serious $G \times E$ interactions occur when G varies across many breeds and breeding systems and E varies across wide climatic, nutritional, management and economic conditions. Some of these interactions, especially ones involving climatic variation, are well known if not precisely quantified. Others are less well illustrated. For example, consider a market which pays a premium for steers finished to the equivalent of the U.S.D.A. choice quality grade (1965). The most efficient genotype for rate of gain may be quite different if the steers are fed harvested feed economically available around the year than if the steers are finished largely by grazing on forage which is highly seasoned in quality and quantity and harvested feeds are relatively expensive. In the first case a genotype for a large, growthy type may be most efficient for the finishing phase. In the latter case a genotype for a smaller, quicker finishing steer may be a distinct advantage if the steer can be finished during two seasons of abundant forage

and carried through only one season of poor forage production. (This example was inspired by anticipated changes in beef production practices in some countries which will result either directly or indirectly from continued, accelerated use of a fixed supply of hydrocarbon fuels.)

Breeding systems can be classified as straightbreeding and crossbreeding. Straightbreeding designates essentially *inter se* mating within a breed or some other more or less closed population such as a local indigenous strain. It is generally recognized that selection may be employed as an important adjunct to straightbreeding, *i. e.* individual selection following breed selection. However, too often criteria for selecting individuals are established without a clear definition or understanding of the effect of the selected change, direct or correlated, on efficiency of production either for the slaughter cattle or the reproducing cattle, *i. e.* the effect on the total production unit (CARTWRIGHT, 1970).

Absolute and relative measures of weight are perhaps regarded as the most important characters to consider in setting selection and breeding criteria for beef cattle. Selection for increased rate of gain at any age up to maturity tends to increase mature size to the extent of the genetic correlation between the gain character selected and mature size. This correlation has not been widely estimated, but it is usually considered to be high (FITZHUGH and TAYLOR, 1971); *i. e.*, there is a strong tendency for cattle to follow a pattern of growth. Also, it has been suggested that both rate of maturing and rate of growing are correlated with mature size, but in this case negatively correlated (SMITH *et al.*, 1974). Also, BROWN, BROWN and BUTTS (1972) observed variation in the relationship among these rates and mature size and suggest that selection could be effectively employed to increase growth rate while at the same same time deterring proportionate increase in mature size. Selecting for increased growth rate, a trait emphasized by many breeders and encouraged by many livestock specialist and officers, without placing constraints on mature size and perhaps other correlated characters, may not have a favorable effect on efficiency. However, direct selection for large mature weight is widely recognized, intuitively, as an effective means of increasing growth rate. Heritability of average daily gain (*ADG*) at one year of age and mature weight (*MW*) may be reasonably assumed to be 0.40 and 0.70, respectively, within breeds under environmental conditions that prevail over a limited, uniform geographical area and system of management (PLITT and CARTWRIGHT, 1966). Also, it is realistic to assume a genetic correlation of 0.70 between *ADG* and *MW* under these conditions.

Estimated increase in *ADG* resulting from truncation selection with a standardized selection differential of 1.0 is 55 to 60 g based either directly on *ADG* or indirectly on *MW* assuming further that the standard deviation *ADG* is 150 g. Mature weight would be expected to increase approximately 28 to 53 Kg respectively assuming the standard deviation of *MW* is 75 Kg. The correlated response to selection for either *ADG* or *MW* for more involved characters such as herd profit are not predictable from established genetic theory. Nonetheless, decisions concerning selection are necessarily being made at the individual herd level as well as at higher levels.

The simulation of beef production reported by LONG, CARTWRIGHT and FITZHUGH (1974) illustrates the effect of size on overall efficiency of production in an integrated operation. They assumed no differences in fertility or milk production

but that growth and maturing rates were determined by genotype for mature size under a fixed environment. The same fixed amount of resources were allocated for nutrients for each herd so that comparisons can be made on the basis of liveweight produced from a given amount of resources for nutrients. A number of other assumptions were made and programmed into the deterministic model which included a linear program for maximizing profit. The efficiencies for straightbreds of small (*S*), medium (*M*) and large (*L*) size, typified by mature cows weighing 430, 500 and 600 Kg, respectively, are summarized in Table 1. The production efficiency of these three types were simulated for two

TABLE 1

NUMBERS, EXPENSES, LIVEWEIGHT PRODUCED AND EFFICIENCIES OF SELF-CONTAINED, INTEGRATED HERDS OF STRAIGHTBRED CATTLE OF SMALL (*S*), MEDIUM (*M*) AND LARGE (*L*) MATURE BODY SIZE ALLOCATED FIXED, EQUAL RESOURCES FOR NUTRIENTS
(Adapted from LONG, CARTWRIGHT and FITZHUGH, 1974)

Items compared	Drylot[a]			Pasture[a]		
	S[b]	*M*[b]	*L*[b]	*S*[b]	*M*[b]	*L*[b]
Number of cows	686	587	481	956	782	614
Sum of per cow expense, $	26754	22893	18759	37284	30498	23946
Nutritional expense, $	100000	100000	100000	100000	100000	100000
Interest, $	23880	23132	22098	31564	29511	27010
Total expense, $	150634	146025	140857	168851	160009	150959
Liveweight sold, Kg	207820	206333	202309	289789	275023	258341
Gross income, $	145401	144440	141717	202751	192525	180967
Net income or profit, $	−5233	−1585	800	33900	32516	30011
Return to investment, %	5.6	6.6	7.4	14.8	14.9	14.9

[a] *Drylot* designates the cow herd was fed harvested feeds in drylot, and *pasture* designates cow herd was grazed on pasture as available and supplemented; progeny from both drylot and pasture herds were finished in feedlot.

[b] For mature cow weight: *S* = 430 Kg, *M* = 500 Kg and *L* = 600 Kg.

sets of environmental (management-nutrition) conditions for the cow herd: (1) fed all harvested feed in confinement which is referred to as feedlot and (2) pasture as available plus harvested supplements which is referred to as pasture. All males and surplus females were fed for slaughter in a feedlot after weaning.

These results illustrate several points. One is that there are no very large differences in the overall efficiency of the different sizes. The advantages in efficiency of one size for one segment of production (*e.g.*, lower per head maintenance requirements for the cows of small genotype) tend to be offset by lower efficiency for another segment of the production unit (*e.g.*, lower rates of gain in the feedlot for the progeny from the herd of small genotype). However, there were some differences which were not readily predictable. For the fixed input of resources for nutrients for sustaining the cow herd and finishing the slaughter cattle, larger numbers of smaller cattle were possible and the smaller cattle consistently returned more total liveweight for their fixed nutrient input. Increasing size tended to increase economic efficiency in the feedlot while it tended to

decrease profit and increase return to investment in pasture. Effects of size were less pronounced in the pasture regime.

Crossbreeding designates the mating of males of one or more breeds (strains) with females of one or more breeds. Selection may be employed but, in fact, one real advantage of crossbreeding is that breed characteristics, which presumably are the result of long time selection criteria, may be exploited; that is, selection will be considered to have been employed within the purebreds and except for utilizing the purebreds, selection will not enter into considerations of crossbreeding here. Also, *inter se* mating of crossbreds will not be considered here as a breeding System as it more aptly breed formation.

The benefits which accrue from crossbreeding for a particular use may be classified into three categories: (1) additivity or a favorable blend of traits resulting from the averaging effect of each genotype (breed or strain) combined in a crossbred individual, (2) heterosis or a favorable interaction resulting from combining gametes from two or more different genotypes (breeds or strains) in a crossbred individual, and (3) complementarity or a favorable interaction resulting from combining two or more different phenotypes (breeds or strains) in a crossbreeding production unit. The benefits of crossbreeding are almost always at least partly offset by complications of maintaining a crossing system or other undersirable effects such as increased dystocia.

The additive effects of crossbreeding are largely a matter of choosing a breed which is extreme for one or more characters of concern in order to improve a breed deficient in that character. Of course, if the second breed has traits which tend to overcome some deficiency in the first breed, then the combination becomes more attractive (especially if they tend to compound to produce heterosis). An example of additivity is crossing Zebu with a British breed to gain a more favorable combination of adaptability to subtropical areas, growth rate and finishing qualities. Another example recently popular in the U.S. is combining the «meatiness» of Limousin with the marbling and finishing qualities of the Angus in an effort to gain an optimal combination of characters according to current vogue in U.S. steer shows. Heterosis levels have not been evaluated over a wide range of genotypes and environments but there is sufficient evidence in beef cattle to conclude that at least in some crosses there is substantial heterosis and that there is substantial variability in the general combining ability of different breeds not all of which are predictable from the extent of the separation of breeds over time and space (CUNDIFF, 1970; CARTWRIGHT *et al.*, 1964). Heterosis appears to be most pronounced in the maternal abilities of the cow. For example, CARTWRIGHT *et al.*, (1964) reported about 11 % heterosis for weaning weight of Hereford-Brahman calves from Hereford dams, about 15 % for first backcrosses 3/4 Hereford-1/4 Brahman calves from F_1 Hereford-Brahman dams. Utilizing the F_1 cow may further complicate the maintenance of a crossbreeding system.

Complementarity was recently described by CARTWRIGHT (1970) as the «advantage of one cross over another cross or a purebred resulting from the manner in which two or more characters combine or complement each other». FITZHUGH, CARTWRIGHT and LONG (1974) further elaborated to define complementarity as «the cumulative effect of interactions among the phenotypic effect of the three basic components of the production unit — sire (*S*), dam (*D*), and produce (*P*) — on phenotype of the production unit». Complementarity is made

up of the cumulative effect of the four phenotypic interactions $S \times D$, $S \times P$, $D \times P$ and $S \times D \times P$ on characters which are measures of the performance of the production unit such as net profit. An example of complementarity from a cross of Charolais bulls on Angus-Jersey F_1 cows, compared to straightbred Herefords, was described by ELLISON *et al.* (1974). Feed consumed by cows and calves during lactation and from weaning up to approximately one year of age were observed. The relatively low nutrient requirements for maintenance of the F_1 cows combined with a relatively high growth rate of the three-breed cross progeny so that the cross produced a pound of liveweight on 17 % less feed up to weaning and on 6 % less feed up to one year age of calf. However, this detailed study of the efficiency of cows and calves did not take into account the nutrient and other economic requirements necessary for producing herd replacements.

In order to experimentally evaluate the efficiency of total producing units for several different breeding systems using only a very small sample of the cattle breeds would require vast facilities and a long period of time; even if facilities, financing and personnel were available, problems of design and conduct would be discouraging. The development of the field of operations research utilizing modeling techniques and computer simulation (FORRESTER, 1961) offers a method of evaluating many different breeds and breeding systems. Perhaps the most useful function of simulating production of breeding systems is that a large number of input and output variables can be simultaneously considered and the complex relationships, the interacting and often nonlinear feed-back mechanisms, can be more adequately accounted for. Using these techniques, FITZHUGH, CARTWRIGHT and LONG (1974) and CARTWRIGHT, FITZHUGH and LONG (1974) evaluated the additive, heterosis and complementarity effects of several crossing systems using small (S), medium (M) and large (L) size breeds which were evaluated by LONG, CARTWRIGHT and FITZHUGH (1974) as straightbreds (see Table 1). Their results are summarized in Tables 2 and 3.

The effects of heterosis and complementarity may be noted by comparing the results of the first crosses in Table 2 with the straightbreds reported in Table 1. For example crosses between two small breeds ($S \times S$), two medium breeds ($M \times M$), and two large breeds ($L \times L$) produced returns to investment of 15.9, 16.6 and 16.0 % while S, M and L straightbreeds produced 14.8, 14.9 and 14.9 %. It is interesting to note that in these crosses, the M size was optimal even though heterosis and input variables other than mature size and related rates of maturing and growing were set equal. The effects of complementarity can be demonstrated by observing the returns to investment of 15.0 vs 17.7 % for $S \times L$ and $L \times S$ crosses respectively.

The results of crossing systems using three breeds and rotations are given in Table 3. The three-breed crossing systems utilized F_1 cows and straightbred bulls. These systems provided the opportunity to maximize heterosis and complementarity in parts of the system but in the process of producing female herd replacements, unwanted straightbred and F_1 males were produced. The rotation systems do not maximize heterosis and can not take advantage of complementarity but production of replacements is uncomplicated and all cattle except the sires are hybrids.

TABLE 2

NUMBERS, EXPENSES, LIVEWEIGHT PRODUCED AND EFFICIENCIES OF SELF-CONTAINED, INTEGRATED HERDS UTILIZING SYSTEMS OF CROSSBREEDING TWO DIFFERENT PUREBREDS TO PRODUCE TERMINAL F_1 PROGENY; EACH SYSTEM ALLOCATED FIXED, EQUAL RESOURCES FOR NUTRIENTS
(Adapted from FITZHUGH, CARTWRIGHT and LONG, 1974)

Items compared	Two-breed crossing system[a]								
	SS	*MS*	*LS*	*SM*	*MM*	*LM*	*SL*	*ML*	*LL*
Number of cows	919	870	809	801	764	713	655	627	590
Sum of per cow expense, $	35841	33930	31551	31239	29796	27807	25545	24453	23010
Nutritional expense	100000	100000	100000	100000	100000	100000	100000	100000	100000
Interest, $	30704	29304	27697	29866	28930	27348	28566	27557	26232
Total expense, $	166545	163234	159248	161105	158726	155155	154111	152010	149242
Liveweight sold, Kg	291532	288839	284846	283453	281400	277172	265790	263526	260024
Gross income, $	204548	203191	201041	198505	197549	195193	185754	184586	182655
Net income, $	38003	39957	41793	37400	38823	40038	31643	32576	33413
Return to investment, %	15.9	16.7	17.7	15.9	16.6	17.4	15.0	15.4	16.0

[a] *SS*, *MS*, *LS* etc. designate crosses, sire breed × dam breed, of two different breeds of the same or of different mature size; all F_1 progeny are sold for slaughter; each crossing system produces all purebred replacement females. Mature cow weights are: $S = 430$ Kg, $M = 500$ Kg and $L = 600$ Kg.

TABLE 3

NUMBER, EXPENSES, LIVEWEIGHT PRODUCED AND EFFICIENCIES OF SELF-CONTAINED, INTEGRATED HERDS UTILIZING TWO-BREED ROTATION OR THREE-BREED SYSTEMS OF CROSSBREEDING; EACH SYSTEM ALLOCATED FIXED, EQUAL RESOURCES FOR NUTRIENTS
(Adapted from CARTWRIGHT, FITZHUGH and LONG, 1974)

Items compared	Crisscross[a]			Three-breed cross[b]			
	(*SS*)	(*MM*)	(*LL*)	(*MS*)	*L SS*	*L MM*	*L MS*
Number of cows	893	743	573	815	781	688	744
Sum of per cow expense, $	34827	28977	22347	31785	30459	26832	29016
Nutritional expense, $	100000	100000	100000	100000	100000	100000	100000
Interest, $	30348	28680	26014	29506	27203	26870	26932
Total expense, $	165175	157657	148361	161291	157662	153702	155948
Liveweight sold, Kg	291519	281246	259632	286604	284933	277112	282077
Gross income, $	204566	197459	182390	201150	201268	195304	199200
Net income, $	39391	39802	34029	39859	43606	41602	43252
Return to investment, %	16.3	16.9	16.3	16.7	18.3	17.9	18.3

[a] (*SS*), (*MM*), (*LL*) and (*MS*) designate two-breed rotation or crisscross of two different breeds of the same or different mature size; all sires are purebred and all replacement females as well as progeny sold for slaughter are crisscrosses. Weights of mature crisscross cows are: (*SS*) = 439 Kg, (*MM*) = 510 Kg, (*LL*) = 617 Kg and (*MS*) = 474 Kg.

[b] *L SS*, *L MM* and *L MS* designate three-breed crossing systems where *L* sires are mated to F_1 dams; all progeny from these matings are sold for slaughter, but F_1 and purebred replacements are produced in each system. Weights of F_1 cows are: *SS* = 443, *MM* = 515 and *MS* = 618 Kg.

Even though the various advantages and disadvantages of each of the crossbreeding systems in integrated, selfcontained herds tended to counterbalance and equalize efficiency, there were important differences when considered as net effects. Both heterosis and complementarity consistenly added to net efficiencies. Systems using smaller size cattle in crosses produced more liveweight. Compared to straightbreds of medium size (*M*) for mature cow weight, single crosses between two breeds were always more profitable except in one case of extreme negative complementarity where sires of small size (*S*) were mated to cows of larger size (*L*). However, liveweight produced by single crosses was less than *M* in every case *L* cows were used. Two-breed rotation crisscrosses were generally comparable to the single crosses in all measures of efficiency; in fact, they were remarkably similar. However, the single crosses utilizing complementarity exceeded the most efficient rotation where complementarity can not be utilized. Three-breed crosses using *L* sires on two-breed F_1 cows, added an additional increment of efficiency. These results indicate that breeds of smaller size are more efficient under a typical Texas pasture production conditions and are especially useful in adding efficiency to crossbreeding if sire breeds of large size are also available.

It appears that the net efficiency of commercial beef production can be increased by utilizing crossbreeding which produces heterosis and provides the

opportunity for adding another increment through complementarity. In order to use heterosis and complementarity demonstrated in this paper, it is necessary to have purebreds; for example, in the three-breed systems of crossbreeding about 44 % of the calves and about 20 % of the cows are straightbred. In order to use crossbreeding effectively in a particular area, a number of different breeds with different traits, especially for size, and different genetic background are desired. These breeds, or at least some of them, should be highly adapted to the environment and possess a high level of uniformity within the breeds would also be desirable. Perhaps a real need which has been largely neglected by animal breeders, as well as livestock officers and administrators, is that of formulating incentive to breeders of purebreds to select cattle for ability to combine well and complement other breeds when crossed. That is, selection for traits which tend to increase efficiency of the breed *per se* would be secondary to selection for traits which would improve efficiency in crossbreeding systems.

The efficiency with which purebreds reproduce themselves, because of the low fecundity of cattle has an important effect on the efficiency of the crossbreeding system in which they are used. This effect is greater for breeds used as maternal lines in crosses than it is for breeds used as paternal lines; *i. e.* selection can be more intense for traits which contribute to combining ability and complementarity in paternal lines than in maternal lines. It appears from observations in the U. S. that selection emphasis has tended to favor traits useful in paternal lines for all breeds rather than being limited to the few which already best fit the criteria. The results of these selection practices has been to create more variability, and consequently less predictability, within breeds and, therefore, to diminish the utility of breeds for as maternal lines. This trend reflects a move toward more objectivity among breeders in selection but combined perhaps, with less understanding or concern for the total production system.

SUMMARY

The efficiency of breeding systems should be evaluated on the basis of the ratio of beef produced to cost of production for a herd in equilibrium rather than for an individual or for one component of a production system. Mature body size and related growth characters affect the efficiency of components of production; but, since a positive effect for one component tends to be associated with a negative effect for another component, size has a smaller affect on net efficiency of the system. Crossbreeding may be designed to utilize additivity, heterosis and complementarity and thereby more fully or profitably utilize the genetic potential of some breeds. Selection criteria for these breeds should be directed toward enhancing combining and complementing ability, especially for size, in order to specialize as either a paternal or a maternal breed. More emphasis should be placed on encouraging maternal breeds. Increased genetic variability sorted into relatively uniform breeds would provide the opportunity for more efficient crossbreeding systems; however, breed dimorphism for size may not be desirable for rotational crossing systems.

ZUSAMMENFASSUNG

Die Leistungsfähigkeit der Zuchtsysteme sollte auf der Basis eines Gleichgewichtes zwischen dem produzierten Rindfleisch und den Kosten der Herde beurteilt werden und nicht im Hinblick auf ein Individium oder eines Teils des Produktionssystems. Die Größe des ausgewachsenen Tieres und die damit in Beziehung stehenden Wachstumsparameter beeinflussen die Leistungsfähigkeit der Produktionskomponenten. Meistens ist ein positiver Effekt für eine Komponente mit einem negativen Effekt für eine andere Komponente korreliert. Die Körpergröße hat einen relativ kleinen Effekt auf die Nettoleistung des Systems. Kreuzungszucht ist geeignet, die additive Wirkung, den Heterosiseffekt und die komplementäre Wirkung des genetischen Potentials zu nutzen und kann deswegen die Vor- und Nachteile einiger Rassen besser und vorteilhafter ausnützen.

Die Selektionskriterien für diese Rassen sollten wir stärker bezüglich der Kombinations- und Ergänzungsfähigkeit, besonders was die Größe betrifft, beurteilen, um entweder eine Vaterrasse oder eine Mutterrasse zu bekommen. Mehr Gewicht sollte auf die Förderung der Mutterrassen gelegt werden. Eine größere genetische Variabilität in relativ einheitlichen Rassen würde eine Möglichkeit für leistungsfähigere Systeme der Kreuzungszucht bieten. Ein Rassendimorphismus in der Körpergröße wäre jedoch für eine Rotation in Kreuzungszucht-Systemen nicht erwünscht.

RESUMEN

La eficiencia de sistemas de mejoramiento genético debe evaluarse en base a la proporción de carne producida al costo de producción en un rebaño en equilibrio en lugar de un individuo, o un componente del sistema de producción. El tamaño adulto y los caracteres relacionados con el crecimiento afectan la eficiencia de los componentes de producción, pero dado que un componente tiende a estar asociado con un efecto negativo de otro componente, el tamaño tiene un efecto pequeño en la eficiencia neta del sistema. Los cruzamientos pueden diseñarse para utilizar aditividad, heterosis y complementariedad y, por tanto, aprovechar más o menos económicamente el potencial genético de algunas razas.

El criterio de selección en esas razas debe estar dirigido para aprovechar la capacidad de combinar y complementar, particularmente para tamaño, para especializarse ya sea como raza paterna o materna. Mayor énfasis debe hacerse para mejorar las razas maternas. El aumento de la variabilidad genética entre razas relativamente uniformes ha de brindar la oportunidad de tener sistemas de cruzamientos más eficientes; sin embargo, el dimorfismo para el tamaño entre las razas puede no ser deseable para sistemas de cruzamientos rotativos.

BIBLIOGRAPHIE

BROWN, J. E.; BROWN, C. J., and BUTTS, W. T. (1972): Relationships among weights, gains and earliness of maturing in Hereford and Angus females. *J. Anim. Sci.*, 35:607.

CARTWRIGHT, T. C.; ELLIS, G. F., Jr.; KRUSE, W. E., and CROUCH, E. K. (1964): Hybrid vigor in Brahman-Hereford crosses. *Texas Agric. Exp. Sta. Tech.*, Monograph, 1.

CARTWRIGHT, T. C. (1970): Selection criteria for beef cattle for the future. *J. Anim. Sci.*, 30:706.

CARTWRIGHT, T. C.; FITZHUGH, H. A., Jr., and LONG, C. R. (1974): Systems analysis of sources of genetic and environmental variation in efficiency of beef production: crossbreding. *J. Anim. Sci.* (In press.)

CUNDIFF, L. V. (1970): Experimental results on crossbreeding cattle for beef production. *J. Anim. Sci.*, 30:694.

ELLISON, D. R.; CARTWRIGHT, T. C.; THOMAS, R. C., and FITZHUGH, H. A., Jr. (1974): Productivity of Angus-Jersey vs. Hereford cows. *J. Anim. Sci.*, 39:144.

FITZHUGH, H. A., Jr., and TAYLOR, St. C. S. (1971): Genetic analysis of degree of maturity. *J. Anim. Sci.*, 33:717.

FITZHUGH, H. A., Jr.; CARTWRIGHT, T. C., and LONG, C. R. (1974): Systems analysis of sources of genetic and environmental variation in efficiency of beef production: heterosis. *J. Anim. Sci.* (In press.)

FORRESTER, J. W. (1961): *Industrial Dynamic*. M.I.T. Press, Cambridge, Mass.

HARRIS, D. L. (1970): Breeding for efficiency in livestock production: defining the economic objectives. *J. Anim. Sci.*, 30:860.

LONG, C. R.; CARTWRIGHT, T. C., and FITZHUGH, H. A., Jr. (1974): Systems analysis of sources of genetic and environmental variation in efficiency of beef production: cow size and herd management. *J. Anim. Sci.* (In press.)

PETTY, R. R., and CARTWRIGHT, T. C. (1966): A summary of genetic and environmental statistics for growth and conformation traits of young beef cattle. *Texas Agric. Exp. Sta. Tech. Report*, No. 5.

SMITH, G. M.; FITZHUGH, H. A., Jr.; CUNDIFF, L. V.; CARTWRIGHT, T. C., and GREGORY, K. E. (1974): A genetic analysis of maturing patterns in Hereford, Angus and Shorthorn cattle. *J. Anim. Sci.*, 39. (In press.)

U. S. D. A. (1965): *Official United States Standards For Grades Of Carcass Beef*. United States Dept. of Agriculture, Washington, D. C.

APPENDIX II

Outline Of Text-Reference Book
On Beef Production In The Tropics

Introduction

I. The Tropical Enviornment
   A. Geography
      1. Latitude and longitude
      2. Land area
      3. Altitude
   B. Climate
      1. Humid tropics
         a. Equatorial
         b. Monsoon
         c. Trade wind
      2. Dry tropics
         a. Arid
         b. Semi-arid
   C. Soils
      1. Humid tropics
      2. Dry tropics
   D. Vegetation
      1. Humid tropics
      2. Dry tropics

II. The Tropical Countries
   1. Principal cattle producing countries
   2. Human-animal unit ratio
   3. Human diet-animal protein level
   4. Present and potential cattle production

III. Cattle in the Tropics
   1. Types and breeds
   2. Numbers and distribution
   3. Systems of production
   4. Land per animal unit
   5. Levels of production

IV. Major Obstacles to Beef Production in the Tropics
   1. Environmental stress
   2. Parasites and diseases
   3. Poor Communication, roads, transportation
   4. Marketing facilities and practices
   5. Lack of refrigeration
   6. Poor management
   7. Unimproved breeding stock
   8. Socio-economic problems and traditions

V. Animal response to high ambient temperature
   A. Climate
      1. High temperature (thermal stress)
   B. Physiology if heat regulation
      1. Heat exchange (homeotherms)
      2. Heat production
      3. Heat loss
   C. Anatomical characteristics and their contributions to heat regulation
VI. Effects of thermal stress on performance
   A. Appetite
   B. Efficiency of feed utilization
   C. Growth
   D. Reproduction
   E. Milk production
VII. Tropical forages
   A. Importance
      1. Nature
      2. Distribution
   B. Problems of tropical pastures
      1. Climate
      2. Soils
      3. Biotic factors
   C. Nutritive Value
      1. Chemical composition
      2. Digestibility
      3. Animal performance
   D. Pasture improvement
      1. Plant introductions
      2. Improved grasses
      3. Culture
      4. Management
   E. Tropical legumes
      1. Need
      2. Contribution
      3. Adapted species
   F. Economics of tropical grasslands
VIII. Systems of cattle production in the tropics
   A. Asia
      1. South
      2. South-east
   B. Africa
   C. Australia
   D. Latin America

IX. Improvement of cattle performance
  A. Management
    1. Nutrition
    2. Selection and culling
    3. Reduce losses from disease and parasites
    4. Improved husbandry practices
  B. Breeding
    1. Use of adapted breeds and crosses
    2. Use of indigenous disease and parasite resistant breeds
    3. Use of environmentally adapted exotic breeds for crossing and upgrading
    4. Performance and progeny testing of breeds and crossbreeds for superior genotypes in a given environmental complex
    5. Development of new breeds

X. Animal Health
  A. Diseases
  B. Parasites

XI. General considerations
  A. Marketing of beef and beef byproducts
  B. Other sources of meat-buffalo, goats, camel, wild animals
  C. Credit
  D. Agratian reform
  E. Education
    1. Research
    2. Extension

APPENDIX III

Summaries Of Invited Talks Presented On Beef Production Systems In The Tropics

!!!!!!!ROUNDTABLE DISCUSSION!!!!!!!

on

INTERNATIONAL DEVELOPMENT

Dr. Thomas Cartwright, Animal Science Dept.

"The Effect of the Drought on the
Livestock Industry in the Sahel"

Agriculture Building, Room 300

Tuesday, July 23rd

NOON

EXPERIENCE THE TROPICS

DR. T.C. CARTWRIGHT (ANIMAL SCIENCE)

&

DR. R. STELLY (AGR. ECO.)

WILL GIVE AN ILLUSTRATED TALK CONCERNING THEIR RECENT JOURNEYS TO AFRICA

"PROBLEMS IN THE SAHEL"

THIS IS THE FOURTH IN THE EVENING SERIES ARRANGED BY THE

TROPICAL STUDIES PROGRAM
GEOGRAPHY DEPARTMENT

TIME 7:30 P.M.

TUESDAY

MARCH 25, 1975

RM. 510 J. EARL RUDDER CENTER

COFFEE WILL BE SERVED AFTER THE TALK.

THE PUBLIC IS INVITED.

ANIMAL SCIENCE DEPARTMENT

SEMINAR

ANIMAL BREEDING AND GENETICS SECTION

12:00 Noon

Friday, April 18, 1975

Room 203 AI Building

"RECENT DEVELOPMENTS IN DAIRY SIRE EVALUATION"

by

Fernando Gomez

The techniques used in the widespread progeny testing of dairy sires represents a high level of refinement in applied animal breeding. The concepts employed as well as the techniques and results should be of interest to all concerned with improvement of livestock.

ANIMAL SCIENCE DEPARTMENT

"THE CATTLE REPRODUCTION RESEARCH PROGRAM AT MARC"

Thursday, July 18, 1974

12:00 Noon

Room 203 A.I. Bldg.

by

Dr. Dan Laster

Research Leader, Reproductive Physiology

U.S. Meat Animal Research Center

Clay Center, Nebraska

Recently TAES and the U.S. Meat Animal Research Center signed an agreement to enter into a joint effort entitled "Simulation Of Beef Cattle Production Systems." This agreement calls for personnel of each organization to confer and collaborate on model development. Dr. Laster's trip to TAMU is the first of these exchanges for the purpose of conferring on model development since the agreement was signed. His particular interest will be in the reproductive component of the model in its present state and planned revisions.

Dr. Laster received the B.S. degree from the University of Tennessee, the M.S. from the University of Kentucky and the Ph.D. from Oklahoma State University in Reproductive Physiology. He was an NIH Post doctoral Fellow at Iowa State University in reproductive endocrinology and then a member of the Animal Science staff at Iowa State. He has been on the staff of the U.S. Meat Animal Research Center since 1971. Dr. Laster's research has included the study of multiple ovulation in cattle, examination of effects of exogenous hormones, characterization of reproductive abilities of several breeds and types of cattle and sheep, and determination of the effects of dystocia and early weaning on reproduction in cattle.

Dr. Laster's visit provides an excellent opportunity to learn more about the extensive reproduction research at MARC where there are now six reproductive physiologist in residence. Also, some may wish to confer individually with Dr. Laster.

ANIMAL SCIENCE DEPARTMENT

SEMINAR

ANIMAL BREEDING AND GENETICS SECTION

1:00 P.M.

Tuesday, November 5, 1974

Room 203 AI Building

FUTURE TRENDS IN BODY COMPOSITION RESEARCH

by

Dr. Roger Seebeck
CSIRO Division of
Animal Genetics Cattle Research Laboratory
Rockhampton, Queensland, Australia

Dr. Seebeck did his doctoral graduate work at the University of Melbourne on growth and development of farm animals and has continued research in this field. He is presently on a tour of a number of research institutions on his way back to Australia after a sabbatical year in France. He will be at Texas A&M Monday and Tuesday October 4 and 5, 1974 and has agreed to present a seminar. Those of us interested in research concerned with body composition are indeed fortunate to have this opportunity to have Dr. Seebeck, an authority particularly on design and analysis, on campus. (All animal breeding students are given the assignment to review the following article before the seminar: Seebeck, R.M. 1968. Developmental studies of body composition. Animal Breeding Abstracts 36:167-181. This is an invited review article; copies are in 319 AI, T.C.C.)

ANIMAL SCIENCE DEPARTMENT

SEMINAR

ANIMAL BREEDING AND GENETICS SECTION

12:00 Noon

Friday, May 2, 1975

Room 203 AI Building

"ECONOMIC AND BIOLOGICAL RETURNS TO BEEF PRODUCTION USING THE GUELPH LINEAR PROGRAMMING MODEL"

by

Dr. C. A. Morris

Dr. Chris Morris is a professor in the Department of Animal and Poultry Science, Ontario Agricultural College, Guelph, Ontario.

Dr. Morris and colleagues have been actively engaged in simulating beef production for some time and have now generated considerable output. In the process of developing the production model, various subdisciplines have contributed. Dr. Morris indicated cooperating nutritionist, especially, have contributed much to the understanding of nutrient requirements for milk production and calf growth.

ANIMAL SCIENCE DEPARTMENT

SEMINAR

ANIMAL BREEDING AND GENETICS SECTION

11:00 A.M.

Thursday, September 12, 1974

Room 203 AI Building

"GRASSLAND BEEF PRODUCTION IN THE HUMID TROPICS"

by

Dr. A.W. Qureshi

Dr. Qureshi has a B. Vet. Sci. degree from Osmania University and the M.S. and Ph.D. degrees in Animal Breeding from Texas A&M. He has served as Extention and Research Officer in Pakistan, Research Associate at Iowa State and Head, Department of Animal Breeding at the Agriculture University, Lyallpur Pakistan. Since 1964 he has been Animal Production Officer and Team Leader, successively, with FAO/UNDP in Uganda. At present he is on leave from FAO spending his accumulated annual leave time working with the AID 211(d) Tropical Beef Production program at Texas A&M.

Dr. Qureshi's high level of training and expertise reinforced with wide experience in tropical areas combines an unusual and valuable set of characteristics especially useful for advising on the Tropical Beef Production program.

ANIMAL SCIENCE DEPARTMENT

SEMINAR

ANIMAL BREEDING AND GENETICS SECTION

11:00 A.M.

Thursday, September 26, 1974

Room 203 AI Building

"ANIMAL BREEDING APPLIED TO THE SAHELIAN REGION OF AFRICA"

by

T.C. Cartwright

Dr. Cartwright spent several weeks early this summer in the area which is the southern border of the Sahara. This large land area has very limited resources other than its people and its cattle. A question which has been seriously asked is whether this area should be (a) abandoned by people, (b) returned to limited utilization by nomadic cattle tribes, (c) or "developed" to support the maximum number of people. A more limited question is what role, if any, can animal breeding play at least in alternative (c)? Other, still more limited questions, might be posed. Of what value might the "breeds" of cattle found in the Sahel be to other tropical areas? What are the genetic differences among these "breeds" in their resistance to trypanosomiasis and how is the resistance mediated?

ANIMAL SCIENCE DEPARTMENT

SEMINAR

ANIMAL BREEDING AND GENETICS SEMINAR

11:00 A.M.

Thursday, September 19, 1974

Room 203 AI Building

"PRE- AND POST- ANALYSIS OF SELECTION RESULTS IN BEEF CATTLE"

by

Terry S. Stewart

"The phenotypic and genetic relationships existing between and within traits used as criteria for selection in beef cattle must be known to maximize the rate of progress in a selection program and to devise the most efficient breeding plans." Shelby 1965.

"Animal Geneticist have been ready to support national livestock improvement schemes, without any efficient means of assessing their worth in practice." Smith 1962.

Terry Stewart completed his M.S. degree in Animal Breeding at Florida before coming here. His seminar will be based on his M.S. thesis.

The seminar originally planned will be given at a later date.

ANIMAL SCIENCE DEPARTMENT

SEMINAR

ANIMAL BREEDING AND GENETICS SECTION

12:00 Noon

Friday, January 31, 1975

Room 203 AI Building

"ECONOMIC EVALUATION OF HETEROSIS"

by

Fernando Gomez

Fernando Gomez, a native of Colombia, has an M.S. from Oregon State and is presently working toward a Ph.D. in Animal Breeding. He is on leave from his position as Director of the National Beef Cattle Program of the Instituto Colombiano Agropecuario. He is presently a fellow in the Tropical Livestock Production program. His special interest is in dual purpose of crossbreeding cattle in tropical areas. It has been estimated that one-half of the cows of the world are both milked and suckled in tropical or sub-tropical areas. This seminar will be a general treatment of the subject using cattle for examples.

NOTICE OF A SPECIAL SEMINAR
TO BE PRESENTED
BY

DR. R. W. (DICK) RICE
DEPARTMENT OF ANIMAL SCIENCE
UNIVERSITY OF WYOMING

SUBJECT MATTER:

SIMULATION OF ANIMAL FUNCTIONS
IN MODELS OF PRODUCTION SYSTEMS:
RUMINANTS ON THE RANGE

TIME: JULY 1, 1974 - 3:00 PM

LOCATION: ROOM 118, TEAGUE RESEARCH CENTER

ALL INTERESTED FACULTY AND STUDENTS
ARE URGED TO ATTEND!!

EXPERIENCE THE TROPICS

DR. A.W. QURESHI, PROJECT MANAGER, F.A.O.
BEEF DEVELOPMENT PROJECT, UGANDA, WILL
PRESENT AN ILLUSTRATED PROGRAM ENTITLED

GRASSLAND ECOLOGY AND RANCH DEVELOPMENT IN UGANDA, EAST AFRICA

This is the first in the 2nd evening series arranged by the
TROPICAL STUDIES OFFICE
GEOGRAPHY DEPARTMENT

TIME - 7:30 P.M., TUESDAY, OCTOBER 15, 1974

PLACE - RM. 302 J. EARL RUDDER CENTER

COFFEE WILL BE SERVED AFTER THE TALK
THE PUBLIC IS INVITED

ANIMAL SCIENCE DEPARTMENT

SEMINAR

Thursday

June 19, 1975

3:30 p.m.

Room 317 AI Building

"AN EXAMINATION OF THE RELATIVE EFFICIENCY OF CATTLE WITH A HIGH PRODUCTION POTENTIAL vs. CATTLE WITH A LOWER PRODUCTION POTENTIAL UNDER CONDITIONS OF LIMITED AVAILABILITY OF NUTRIENTS"

by

Dr. G. E. Joandet

Dr. Joandet is well-known to you as he was a Visiting Professor here during 1973-74 working on simulation of beef cattle production systems. He has just attended a conference in Panama on agricultural research in Latin America and is returning to Argentina via College Station. We are fortunate to have Dr. Joandet here and to have him present this seminar. In addition he will discuss the results of the carcass and meats research conducted in connection with the beef cattle crossbreeding project at Balcarce. This discussion is scheduled at the night Journal Club meeting on Tuesday, June 17, 8:30 p.m., Dr. Charles Long's house.

ANIMAL SCIENCE DEPARTMENT

SEMINAR

ANIMAL BREEDING AND GENETICS SECTION

12:00 Noon

Friday, March 7, 1975

Room 203 AI Building

I. Comments On Cattle Breeding In Some Eastern European Countries

II. A New Research Project Proposal Entitled: "Simulation Of Forage Based Beef Cattle Production Systems To Evaluate Biological Efficiency And Economic Viability"

III. Selection Limits As A Function Of Fecundity.

by

T.C. Cartwright

APPENDIX IV

Publications On Tropical Beef Production Systems

SIMULATED REPRODUCTIVE PERFORMANCE OF COWS AND HEIFERS[1]

J.O. Sanders and T.C. Cartwright

Summary

A mathematical model was developed for computer simulation of reproductive performance of cows and heifers. The effects considered in the model are age, weight, weight gain, mature size potential, lactational status, and time since last calving. All of these effects in the model interact with past or present nutritional level and genotype (breed type) for size which includes potential for rates of gain and maturing. The model was validated by comparisons with research results and was found to correspond closely in most cases. Simulation results indicated large differences in conception rates due to past and/or present nutrition and nutritional requirements. These results emphasize the reproductive performance which can be acheived by attention to the different nutritional requirements of cows and heifers due to their age and weight, and lactation and growth requirements.

Introduction

Reproductive performance of the cow and heifer is a complex, involved trait that is affected by many interacting components. The lifetime nutrition of a cow or heifer in relation to her past and potential production level is an important subset of these components. For example, conception rate during a breeding season may be related to breed type (genotype) because of its inherent milk production capabilities and growth or size potential. The nutritional requirements for milk production and growth, especially in young cows and heifers, interact with the quantity and quality of past nutrition and presently

[1] Submitted for publication June 1, 1975 for publication in the Texas Agricultural Experiment Station "Beef Cattle Research In Texas".

available nutrients to affect the age or time since calving at which estrus cycling initiates.

The effects of several given levels of nutrition on reproduction of cows of different growth patterns and lactational capabilities have been demonstrated for given conditions. The purpose of the research reported here was to systematically organize and quantitatively describe these effects in the form of a mathematical model which could be used to simulate reproductive performance over a wide range of genotypes and nutritional conditions. This computer model will be interfaced with other production components in order to examine total production efficiency. In addition to these more direct, practical applications, this research will aid in understanding the basic cause and effect relationships affecting reproductive performance in cows and heifers.

Procedures

A mathematical model was developed to simulate the occurrence of estrus and conception in cows and heifers during a specified time period. The growth potential and maturing pattern, including puberty, were considered as characteristics of or conditioned by the genotype. Effects of age, weight, rate of weight gain, time since calving, and lactational status were also included in the model. Minimum weight and minimum age at puberty, maturing rate, and condition constant weight at 8 months, 12 months, and maturity are characteristics for each genotype.

A complete model of female bovine fertility should consider the factors affecting estrus and conception in both heifers and cows. It

is important to assess the consequences of differences and similarities between the two groups. Some important considerations resulting from the differences are: (1) prepubertal heifers are not as physiologically mature as cows, (2) calving affects the physical condition of the reproductive tract in cows, and (3) lactation increases the interval to first estrus (and possibly affects conception) in postpartum cows.

Effects of the plane of nutrition before and during the breeding season have been studied in both heifers and cows. Higher planes of nutrition are associated with a decrease in both age at puberty (age at first estrus) and interval to first estrus after calving. It was assumed that the net effects of nutrition (i.e., the effects after physiological processes such as maintenance, growth and lactation are met) are the same in heifers as in cows. Since it has been shown (e.g. Dunn et al., 1969; Totusek, 1974; Wiltbank et al., 1962; Wiltbank et al., 1964) that low planes of nutrition cause a delay in the onset of estrous cycling in cows, if low planes of nutrition cause a decrease in physiological maturing rate, the above assumption implies that low planes of nutrition affect the time of first estrus in heifers in two different ways. That is, heifers on a low plane of nutrition may be expected to reach a degree of maturity necessary for estrous cycling at a later age than more liberally fed heifers, but even after this degree of maturity is reached the heifers on the low plane of nutrition may not exhibit estrus because of their poor nutritional state. Since nutritional levels both before and during the breeding season have been shown to affect fertility, body weight, in relation to growth or size potential, was used in the model to represent the effects or level of

past nutrition, while rate of weight gain was used to represent the present nutritional effects.

The factors for weight, weight gain, condition, lactational status (wet or dry), time since calving, and degree of maturity used in the model were derived from or suggested by research data reported in the literature (Amir et al., 1968; Bond et al., 1958; Bonnier and Hansson, 1945; Brody, 1945; Crichton et al., 1959; Deutscher and Whiteman, 1971; Dunn et al., 1969; Eckles, 1915; Eckles, 1918; Ellison, 1974; Hansson et al., 1953; Henning et al., 1972; Joubert, 1954; Kropp et al., 1972; Laster, 1972; Reed et al., 1924; Reid et al., 1964; Reynolds, 1963; Short and Bellows, 1971; Short et al., 1972; Smithson et al., 1966; Sorensen et al., 1954; Sorensen, et al., 1959; Turman et al., 1963; Turman et al., 1968; Wiltbank et al., 1962; Wiltbank et al., 1966; Wiltbank et al., 1969). More details concerning the model, derivation of the functions, etc. are given by Sanders (1974).

The validity of the model was tested against research data on reproductive performance reported in the literature by Dunn et al. (1969), Wiltbank et al. (1962) and Wiltbank et al. (1964) and against data on Angus-Jersey crossbred and Hereford cows collected at the Texas A&M University Agricultural Research Center at McGregor from 1968 to 1971 (Ellison, 1974). In general, the simulated results were consistent with the actual data as seen in tables 1 and 2. For example, note table 1 which gives the observed and simulated percentages of 2-year-old heifers that came into estrus by 40, 60, 80, 100 and 120 days after calving. Five groups were involved: 2 precalving nutritional levels with the higher group split into 3 postpartum groups

and the low precalving group split into 2 postpartum groups. For this set of data, the simulated and observed values converge to a quite close fit by 100 and especially by 120 days postpartum. On closer inspection it seems likely that the differences between simulated and observed values shortly after calving are more apparent than real. For both of the precalving levels of nutrition, more of the cows on the lower planes of postpartum nutrition came into heat by 40 days postpartum than those on the higher postpartum levels. By 80 days postpartum this trend was completely reversed. If the unexpected results at 40 days postpartum can be attributed to sampling error, the fit of the model to this set of data is quite good. The largest discrepancy between simulated and actual results was with the Angus-Jersey crossbred data from McGregor. The actual conception percentages for three age groups (2,3 and 4 year old cows) were 0.78, 0.82 and 0.64 versus simulated percentages of 0.81, 0.42 and 0.53. Apparently, the assumption that skeletal growth is unaffected by plane of nutrition, was not correct in the case of these dairy-beef crossbreds. The necessity of developing models that adequately describe the differential effects of nutrition upon growth of different tissues is indicated.

Fertility was simulated for yearling heifers and for two, three, and seven-year-old cows of the same genotype, but with different pre-breeding season weights and different rates of weight gain within each age class. Also, within each of these age classes, genotypes were simulated with different growth or size parameters; heifers of different genotypes were also simulated by varying parameters of the equation for the correction factor for degree of maturity. In the genotype simulations, initial weights and weight gains were the same within each age group.

For all simulated ages (table 3), increasing either daily gain or initial weight improved fertility, up to a point. Above this point, increases in either weight or weight gain were not predicted to affect fertility. Obviously, this assumption would be incorrect in cattle whose fertility is adversely affected by obesity. Age at puberty is predicted to decrease when weight gain or initial weight is increased for all levels simulated in this study. However, at high planes of nutrition, the model will give a minimum age at puberty; increasing either weight or weight gain will not further decrease this age. At the lower planes of nutrition, decreasing 240 day weight by 22 lb or decreasing weight gain by .22 lb/day have large effects on average age at puberty. These large effects occur because, at the lower levels, the model predicts that nutritional level not only decreases maturing rate but also delays the onset of estrous cycling after the heifers reach an adequate degree of maturity for cycling.

Average weights at puberty for the same simulated regimes are given in table 4. An apparent minimum weight at puberty is predicted for medium levels of nutrition: either increasing or decreasing plane of nutrition from this point increases the predicted average weight at first estrus. The increases in weight at puberty associated with decreases in nutritional level (lighter weight at 240 days and/or lower weight gain after 240 days age) are because few heifers are predicted to come into heat even after they reach an adequate degree of maturity and hence continue to grow, although at a slow rate, before reaching puberty. At the higher nutritional levels the differences in age at puberty are predicted to be relatively small and consequently heifers

on the higher levels would be fatter and heavier at puberty. The simulated percentages of heifers that come into estrus for the first time before 15 months of age, given different 240-day weights and different rates of gain after 240-days are given in table 5.

Simulated conception percents during an 80 and a 180 day breeding season beginning at 370 days of age for heifers with different initial weights and rates of weight gain are given in tables 6 and 7. Again, increasing either initial weight or weight gain is predicted to increase fertility level - conception rate in this case.

Fertility was also simulated for 2, 3, and 7-year-old cows under different nutritional regimes. Table 8 gives the percentages of 2-year-olds under 15 different nutritional regimes predicted to exhibit estrus and conceive during a 90-day breeding season beginning immediately after calving. As for the heifers, increasing either initial weight or weight gain is predicted to improve fertility. Similar results were found for the older ages (tables 9 and 10).

Different genotypes have been simulated for both heifers and cows by varying parameters of the growth equation for the condition constant weight or size. Table 11 shows the simulated estrus and conception percents for 2, 3, and 7-year-old cows with mature weights of 1003, 1058, and 1114 lb, where all other components of the growth equation have been held constant. All genotypes had postpartum weights of 807, 920,,and 1003 lb and ADG's of 0, -.22 and -.44 lb for the 2, 3, and 7-year-olds, respectively. Since weight was held constant for the different genotypes, increasing the condition constant weight has the same effect on condition as decreasing weight within a genotype.

Therefore, as expected, increasing mature weight was predicted to lower fertility for all 3 ages. This should not be interpreted as necessarily predicting lower fertility for larger cattle because weight and weight gain were held constant for the different genotypes; in effect this procedure is the same as feeding larger cows a lower percentage of their nutritional requirements. It does emphasize the necessity of correctly describing the growth parameters if fertility is to be adequately simulated by this model.

The large differences in reproductive performance demonstrated by these simulations emphasize the importance of considering the nutritional needs of cows and heifers as being dependent on their individual growth and lactation requirements and the weights they have attained in relation to their age and growth potential. These differences become more important considerations for management as the prices of nutrients from harvested feeds become higher relative to those from forages.

Literature Cited

Amir, S., J. Kali, and R. Volcani. 1968. In G.A. Lodge and G.E. Lamming (Ed.) Growth and Development of Mammals. Plenum Press, N.Y.

Bond, J., J.N. Wiltbank, and A.C. Cook. 1958. J. Ani. Sci. 17:1211. (Abstr.).

Bonnier, G. and A. Hansson. 1945. Acta Agr. Suec. 1:171.

Brody, S. 1945. Reinhold Publishing Corporation. New York.

Crichton, J.A., J.N. Aitken, and A.W. Boyne. 1959. An. Prod. 1:145: 2:45.

Deutscher, G.H. and J.V. Whiteman. 1971. J. Ani. Sci. 33:337.

Dunn, T.G., J.E. Ingalls, D.R. Zimmerman, and J.N. Wiltbank. 1969. J. Ani. Sci. 29:719.

Eckles, C.H. 1915. Mo.Agri. Exp. Sta. Bull. 135.

Eckles, C.H. and W.W. Swett. 1918. Mo. Agr. Exp. Res. Bull. 31.

Ellison, D.R. 1974. M.S. Thesis, Texas A&M Univ.

Hansson, A., E. Brannang, and O. Claesson. 1953. Acta Agr. Scand. 3:61.

Henning, G.F., E.R. Hauser, and L.E. Casida. 1972. J. Ani. Sci. 35:189.

Joubert, D.M. 1954. J. Agr. Sci. 44:5.

Kropp, J.R., D.F. Stephens, J.W. Holloway, L. Knori, J.V. Whiteman, and R. Totusek. 1972. Okla. Agr. Exp. Sta. Misc. Pub. 87, pp. 26-36.

Laster, D.B., H.A. Glimp, and K.E. Gregory. 1972. J. Ani. Sci. 34:1031 34:1031.

Reed, O.E., J.B. Fitch, and H.W. Cave. 1924. Kan, Agr. Exp. Sta. Bull. 233.

Reid, J.T., J.K. Loosli, G.W. Trimberger, K.L. Turk, S.A. Asdell, and S.E. Smith. 1964. Cornell Agr. Exp. Sta. Bull. 987.

Reynolds, W.L., T.M. De Rouen, and J.W. High, Jr. 1963. J. Ani. Sci. 22:243. (Abstr.).

Sanders, J.O. 1974. M.S. Thesis, Texas A&M Univ.

Short, R.E. and R.A. Bellows. 1971. J. Ani. Sci. 32:127.

Short, R.E., R.A. Bellows, E.L. Moody, and B.E. Howland. J. Ani. Sci. 34:70.

Smithson, Larry, S.A. Ewing, L.S. Pope, and D.F. Stephens. 1966. Okla. Agr. Exp. Sta. Misc. Pub. 78, p. 56.

Sorensen, A.M., Jr., R.W. Bratton, W. Hansel and W.H. Hough. 1954. J. Ani. Sci. 13:1031.

Sorensen, A.W., Jr., W. Hansel, W.H. Hough, D.T. Armstrong, K. McEntee, and R.W. Bratton. 1959. Cornell Agr. Exp. Sta. Bull. 936.

Turman, E.J., R.H. Edward, R.L. Willham, and R.E. Renbarger. 1968. Okla. Agr. Exp. Sta. Misc. Pub. 80, pp. 25-34.

Turman, E.J., L.S. Pope, B.J. Watkins, D.O. Pinney, D.D. McNutt, and D.F. Stephens. 1963. Okla. Agr. Exp. Sta. Misc. Pub. 70. pp. 28-35.

Wiltbank, J.N., K.E. Gregory, L.A. Swiger, J.E. Ingalls, J.A. Rothlisberger, and R.M. Koch. 1966. J. Ani. Sci. 25:744.

Wiltbank, J.N., C.W. Kasson, and J.E. Ingalls. 1969. J. Ani. Sci. 29:602.

Wiltbank, J.N., W.W. Rowden, J.E. Ingalls, K.E. Gregory, and R.M. Koch. 1962. J. Ani. Sci. 21:219.

TABLE 1. SIMULATED AND OBSERVED[1] ACCUMULATED ESTRUS PERCENTAGES OF TWO-YEAR-OLD COWS FED AT HIGH (H) OR LOW (L) LEVELS PRECALVING AND H, MODERATE (M), OR L LEVELS POSTCALVING

Group	No. in group	Time since calving (days)				
		40	60	80	100	120
HH-actual	41	17	62	93	98	100
simulated		33	89	98	100	100
HM-actual	41	22	81	92	97	100
simulated		27	75	92	98	99
HL-actual	42	36	64	81	81	81
simulated		18	47	63	72	77
LH-actual	37	5	39	88	98	100
simulated		17	61	88	98	100
LM-actual	42	7	49	73	88	93
simulated		11	40	61	78	89

[1]Dunn *et al.* (1969).

TABLE 2. SIMULATED AND OBSERVED[1] ACCUMULATED ESTRUS PERCENTAGES OF MATURE COWS FED AT HIGH (H) OR LOW (L) LEVELS PRECALVING AND H OR L LEVELS POSTCALVING.

Group[2]	Time since calving, days					
	50	70	90	110	125[3]	130[3]
HH-actual	65	90	95	-	100(0)	-
simulated	63	91	98	99	-	100(0)
HL-actual	76	81	86	-	86(0)	-
simulated	48	71	81	86	-	88(5)
LH-actual	25	70	85	-	95(0)	-
simulated	33	63	81	92	-	97(1)
LL-actual	6	22	22	-	22(11)	-
simulated	9	15	17	17	-	17(7)

[1] Wiltbank et al. (1962).

[2] Approximately 20 cows in each group.

[3] Figures in parentheses are the percentages of all cows in the groups that stopped cycling without conceiving.

TABLE 3. SIMULATED DAYS AGE AT FIRST ESTRUS OF HEIFERS OF THE SAME MATURE WEIGHT POTENTIAL (1058 lb), WITH DIFFERENT WEIGHTS AT 240 DAYS AND DIFFERENT RATES OF GAIN AFTER 240 DAYS OF AGE.

Weight at 240 days of age, lb.	Daily weight gain, lb						
	.22	.44	.66	.88	1.10	1.32	1.54
331	-	1335	834	553	465	423	397
353	-	1266	727	502	436	403	383
375	-	1191	601	461	412	385	372
397	-	1066	512	425	389	370	363
419	2007[1]	819	449	394	369	361	355
441	1728[1]	548	399	372	359	353	349
463	1321	435	376	359	352	347	343
485	875	387	360	350	345	341	338
507	548	363	349	343	340	336	334
529	393	350	342	338	335	333	332

[1] Based on heifers that reached puberty by 2250 days of age.

TABLE 4. SIMULATED WEIGHTS AT FIRST ESTRUS OF HEIFERS OF THE SAME MATURE WEIGHT POTENTIAL (1058 lb.), WITH DIFFERENT WEIGHTS AT 240 DAYS AND DIFFERENT RATES OF GAIN AFTER 240 DAYS OF AGE.

Weight at 240 days of age, lb.	Daily weight gain, lb						
	.22	.44	.66	.88	1.10	1.32	1.54
331	-	369	328	275	262	260	260
353	-	365	306	265	258	258	260
375	-	360	278	258	256	257	262
397	-[1]	345	262	254	254	258	266
419	367[1]	306	253	252	255	263	270
441	349[1]	262	248	253	260	268	276
463	318	249	251	257	266	274	282
485	283	249	256	264	272	281	289
507	261	255	263	271	280	299	296
529	255	262	271	279	288	296	304

[1] Based on heifers that reached puberty by 2250 days of age.

TABLE 5. SIMULATED PERCENTAGES OF HEIFERS OF THE SAME MATURE WEIGHT POTENTIAL (1058 lb.) THAT COME INTO ESTRUS FOR THE FIRST TIME BEFORE 15 MONTHS OF AGE, GIVEN DIFFERENT 240-DAY WEIGHTS AND DIFFERENT RATES OF GAIN AFTER 240 DAYS.

Weight at 240 days of age, lb.	Daily weight gain, lb						
	.22	.44	.66	.88	1.10	1.32	1.54
331	0	0	0	9	38	74	95
353	0	0	2	24	59	89	97
375	0	0	13	44	78	97	98
397	0	6	31	66	92	98	99
419	3	21	53	84	98	99	99
441	15	43	74	94	99	99	99
463	34	64	88	98	99	99	99
485	55	81	96	99	99	99	100
507	73	91	99	99	99	100	100
529	86	97	99	99	100	100	100

TABLE 6. SIMULATED CONCEPTION PERCENTAGES DURING AN 80 DAY BREEDING SEASON, BEGINNING AT 370 DAYS OF AGE, WHERE ALL GROUPS OF HEIFERS ARE OF THE SAME GENOTYPE (MATURE WEIGHT POTENTIAL OF 1058 lb).

Daily weight gain, lb.	Weight at 360 days of age, lb					
	485	507	529	551	573	595
.0	11	26	45	65	78	87
.22	15	32	52	71	83	90
.44	20	39	59	77	87	92
.66	27	47	67	83	91	94
.88	35	56	74	88	93	95
1.10	45	65	81	91	94	95
1.32	55	74	87	92	94	95
1.54	65	80	89	92	94	95

TABLE 7. SIMULATED CONCEPTION PERCENTAGES DURING A 180 DAY BREEDING SEASON, BEGINNING AT 370 DAYS OF AGE, WHERE ALL GROUPS OF HEIFERS ARE OF THE SAME GENOTYPE (MATURE WEIGHT POTENTIAL OF 1058 lb).

Daily weight gain, lb	Weight at 360 days of age, lb					
	485	507	529	551	573	595
.0	11	28	52	75	89	96
.22	17	42	68	87	96	99
.44	36	64	85	96	99	100
.66	62	84	95	99	100	100
.88	85	95	99	100	100	100
1.10	96	99	100	100	100	100
1.32	99	100	100	100	100	100
1.54	100	100	100	100	100	100

TABLE 8. SIMULATED FERTILITY OF TWO-YEAR-OLD COWS DURING A 180 DAY BREEDING SEASON, BEGINNING IMMEDIATELY AFTER CALVING, WHERE ALL COWS ARE OF THE SAME GENOTYPE BUT HAVE DIFFERENT POSTPARTUM WEIGHTS AND RATES OF WEIGHT GAIN.

Postpartum weight, lb	Daily gain, lb	Estrus during first 90 days, %	Conceived during first 90 days, %	Estrus during breeding season, %	Conceived during breeding season, %
739	-.88	20	11	20	11
	-.44	38	23	44	31
	0	56	38	83	71
	.44	73	53	98	93
	.88	86	67	100	99
794	-.88	52	35	58	44
	-.44	68	49	85	75
	0	82	63	98	94
	.44	92	75	100	99
	.88	97	84	100	100
849	-.88	73	52	88	79
	-.44	88	71	98	95
	0	96	81	100	99
	.44	99	89	100	100
	.88	99	89	100	100
902	-.88	93	78	99	96
	-.44	98	85	100	99
	0	99	88	100	100
	.44	99	89	100	100
	.88	99	89	100	100
959	-.88	98	85	100	99
	-.44	99	88	100	100
	0	99	89	100	100
	.44	99	89	100	100
	.88	99	89	100	100

TABLE 9. SIMULATED FERTILITY OF THREE-YEAR-OLD COWS DURING A 180 DAY BREEDING SEASON, BEGINNING IMMEDIATELY AFTER CALVING, WHERE ALL GROUPS ARE OF THE SAME GENOTYPE (MATURE WEIGHT POTENTIAL OF 1058 lb), BUT HAVE DIFFERENT POSTPARTUM WEIGHTS AND RATES OF WEIGHT GAIN.

Postpartum weight, lb	Daily gain, lb	Estrus during first 90 days, %	Conceived during first 90 days, %	Estrus during breeding season, %	Conceived during breeding season, %
860	-.88	42	27	47	34
	-.44	58	40	79	67
	0	72	53	96	90
	.44	84	65	100	98
	.88	93	76	100	100
915	-.88	68	50	83	72
	-.44	81	62	97	91
	0	90	73	100	98
	.44	96	82	100	100
	.88	99	87	100	100
970	-.88	87	69	97	93
	-.44	94	79	100	99
	0	98	86	100	100
	.44	99	89	100	100
	.88	99	89	100	100
1025	-.88	96	83	100	99
	-.44	99	87	100	100
	0	99	89	100	100
	.44	99	89	100	100
	.88	99	89	100	100
1080	-.88	99	87	100	100
	-.44	99	89	100	100
	0	99	89	100	100
	.44	99	89	100	100
	.88	99	89	100	100

TABLE 10. SIMULATED FERTILITY OF SEVEN-YEAR-OLD COWS DURING A 180 DAY BREEDING SEASON, BEGINNING IMMEDIATELY AFTER CALVING, WHERE ALL COWS ARE OF THE SAME GENOTYPE (MATURE WEIGHT POTENTIAL OF 1058 lb), BUT HAVE DIFFERENT POSTPARTUM WEIGHTS AND RATES OF WEIGHT GAIN.

Postpartum weight, lb	Daily gain, lb	Estrus during first 90 days, %	Conceived during first 90 days, %	Estrus during breeding season, %	Conceived during breeding season, %
	-.88	56	38	70	57
	-.44	69	50	92	84
946	0	81	62	99	96
	.44	90	72	100	99
	.88	96	80	100	100
	-.88	77	58	93	86
	-.44	87	69	99	96
1001	0	94	78	100	99
	.44	98	85	100	100
	.88	99	88	100	100
	-.88	91	75	99	97
	-.44	97	83	100	99
1056	0	99	89	100	100
	.44	99	89	100	100
	.88	99	89	100	100
	-.88	98	86	100	99
	-.44	99	88	100	100
1111	0	99	89	100	100
	.44	99	89	100	100
	.88	99	89	100	100
	-.88	99	88	100	100
	-.44	99	89	100	100
1166	0	99	89	100	100
	.44	99	89	100	100
	.88	99	89	100	100

TABLE 11. SIMULATED FERTILITY OF TWO, THREE, AND SEVEN YEAR OLD COWS OF DIFFERENT GENOTYPES, BUT WITH THE SAME WEIGHTS AND WEIGHT GAINS FOR EACH AGE[1] DURING A 180 DAY BREEDING SEASON BEGINNING IMMEDIATELY AFTER CALVING, WHERE DIFFERENT GENOTYPES WERE SIMULATED BY VARYING PARAMETERS OF THE GROWTH EQUATION.

Mature weight potential, lb	Age years	Estrus during first 90 days, %	Conceived during first 90 days, %	Estrus during breeding season, %	Conceived during breeding season, %
948	2	99	87	100	100
	3	99	88	100	100
	7	99	88	100	100
1003	2	94	79	100	99
	3	96	82	100	99
	7	97	83	100	99
1058	2	86	68	99	96
	3	87	70	99	97
	7	87	70	99	97
1114	2	74	55	95	89
	3	74	55	95	89
	7	73	55	94	87
1169	2	60	42	86	75
	3	57	39	84	72
	7	54	36	80	67

[1] Postpartum weights for the 2, 3, and 7-year olds were 807, 922, and 1003 lb; daily weight changes for the respective groups were 0, -.22 and -.44 lb.