# A SYSTEM ANALYSIS OF INFORMATION AND COMMUNICATION IN BEEF MARKETING

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# A SYSTEM ANALYSIS OF INFORMATION AND COMMUNICATION IN BEEF MARKETING

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# PREFACE

This study is concerned with the quality of abstract microeconomic decisions made at four levels of the beef production and marketing system. These decisions, as modeled can be made independently by subsystem with varying levels and precision of price and attribute information. Alternatively, the decisions can be made as a coordinated vertical system. The objective is identify important barriers to communication, to coordinated vertical system performance and to evaluate the feasibility and value of reducing such barriers.

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# CHAPTER I

# INTRODUCTION

## The Current Situation

The production of beef is the most important agricultural enterprise in the United States. Sales of cattle and calves in 1973 accounted for 25.7 percent of all farm cash marketings in the United States and totaled $22.739 billion (151, p. 4). The $22.739 billion was 2.6 times the value of soybeans, the product which ranked second. Sale of cattle and calves was also the number one source of revenue for Oklahoma farmers with receipts in 1973 totaling over $1.3 billion, an amount which ranked Oklahoma seventh in the nation.

The processing and distribution of beef is an important agribusiness enterprise. In 1972 total sales of the Meat Packing Industry equalled $25.8 billion (3, p. i). Activities of marketing agencies, distributors, other processors, retailers, hotels, restaurants and institutions would add materially to total income generated in and by the beef industry.

Beef is an important food to consumers. It is an important source of protein and is high in energy, vitamins and minerals. Table I displays consumption and prices for beef from 1950 to 1973. Increasing consumption at increasing prices demonstrate the popularity of beef with consumers. The fact that beef is such an important commodity makes it even more imperative that the industry operate efficiently.

## TABLE I

## RETAIL PRICE PER POUND AND PER CAPITA CONSUMPTION OF BEEF IN THE U. S. 1950-1973

| Year | Retail Price (Choice Grade) | Per Capita Consumption |
|---|---|---|
| | ¢/lb. | Lbs. (carcass basis) |
| 1950 | 74.6 | 63.4 |
| 1951 | 85.7 | 56.1 |
| 1952 | 85.7 | 62.2 |
| 1953 | 68.4 | 77.6 |
| 1954 | 67.8 | 80.1 |
| 1955 | 66.8 | 82.0 |
| 1956 | 65.4 | 85.4 |
| 1957 | 69.9 | 84.6 |
| 1958 | 80.2 | 80.5 |
| 1959 | 82.0 | 81.4 |
| 1960 | 80.2 | 85.1 |
| 1961 | 78.4 | 87.8 |
| 1962 | 81.7 | 88.9 |
| 1963 | 78.5 | 94.5 |
| 1964 | 76.5 | 99.9 |
| 1965 | 80.1 | 99.5 |
| 1966 | 82.4 | 104.2 |
| 1967 | 82.6 | 106.5 |
| 1968 | 86.6 | 109.7 |
| 1969 | 96.2 | 110.8 |
| 1970 | 98.6 | 113.7 |
| 1971 | 104.3 | 113.0 |
| 1972 | 113.8 | 116.1 |
| 1973 | 135.5 | 109.6 |

Source: U. S. Department of Agriculture, Livestock and Meat Statistics Statistical Bulletins 522, 333, 280.

## Recent Efficiency Gains

Important gains in efficiency have been achieved in production at the farm level. Total man hours used in the production of meat animals dropped from 1.307 billion hours in 1950 to .912 billion hours in 1972 (149, Table XIX). Since total production has increased, an increase in output per manhour has been realized. This is primarily the result of fewer, larger operations gaining economies of size in labor.

Feed consumption per 100 pounds of cattle and calves produced has increased slightly from 1,004 feed units in 1960-61 to 1,085 units in 1971-72 (149, Table XV). This increase reflects the trend toward high-concentrate feeding of a larger percentage of cattle. In 1962, 14.560 million head of cattle were marketed from 230,804 feedlots. In 1972, 26.835 million head were marketed from 154,536 feedlots (149, Table L). Fed cattle marketed in 1962 were 14.5 percent of cattle and calves on farms January 1, 1962. Fed cattle marketed in 1972 were 22.8 percent of cattle and calves on farms on January 1, 1972 (149, Tables III and L). Therefore, a significant increase in the proportion of cattle defined as "fed marketings" has been realized with only a small increase in feed units per head.

Sources of reduced per unit costs of production begin at the cow-calf level. Some of the cost-reducing practices that have been adopted at the cow-calf level include pasture fertilization and irrigation, improved stocking and grazing practices, mechanization, semi-confinement, cross breeding, performance testing, ertruse control, multiple calving, and artificial insemination.

Advances at the feedlot level include the rapid expansion of large sized units in the Southwest which typically have per unit costs of production below smaller operations. Improved knowledge in nutrition, the application of linear programming to ration formulation, widespread use of growth promotants such as diethylstilbestrol, synovex and ralgro, and mechanized feeding practices are other developments at the feedlot level which have increased efficiency and reduced costs of production.

At the processing and distribution levels technological advances in recent years have included moving to larger and more efficient packing facilities. Establishing new plants closer to the concentrated cattle feeding areas has reduced the costs of transportation and shrinkage. Although technology in slaughter has not changed a great deal in recent years, the proportion of cattle killed in powered on-the-rail plants has increased as older and less efficient gravity and bed plants are replaced.

An increasing percentage of all carcasses are broken and fabricated in central processing systems. This is known as "boxed beef" since packaged fabricated cuts are shipped to retailers in boxes or containers rather than as quarters or "hanging beef". Labor efficiencies are achieved by this method since work is done on large numbers of carcasses at mechanized conveyor tables in the central processing system rather than on a few carcasses at fixed stations in the retail store. Transportation costs are reduced because boxed beef can be handled on pallets by lift trucks. In addition, bone and fat cut away at the breaking plant need not be transported to the retail store and transported again to a by-product processor.

## The Problem

Even though the gains in efficiency and growth patterns in the beef industry have been impressive many problems persist. Beef boycotts, a price freeze, the banning and subsequent reinstating of stilbestrol and truck strikes have been disruptive and visible problems in recent years. But there are other less visible problems which may have greater impact and be of a more lasting or permanent nature.

In contrast to rapid strides in production and distribution efficiencies within each level of the system, progress in interlevel communication and related interlevel coordination has been slow. Anthony and Motes made this statement in 1966 and it is largely true today:

> In spite of the many changes and the impressive areas of progress in the livestock-meat industry, there has been little change since Biblical days in the way most livestock are bought and sold. Buyers and sellers of slaughter livestock argue about quality and the yield of lean meat in ways not very different from those used in ancient times (4, p. 292).

The implications of this simple quote are far reaching.

The delivery of retail beef to the consumer is the result of a series of technically interrelated actions by individuals acting in their own interest and guided by self-serving motives. A decision is made by a rancher concerning the breeds of cow and bull to combine to produce a calf. A decision is made by a cattle feeder concerning whether to buy that calf and, if bought, a decision must be made on what and how long to feed it. Then a packer must choose to buy the fed steer and produce a dressed carcass. A fabricator must decide to buy the carcass, decide how to cut it into parts and how much fat to trim away. All of these decisions are clearly technically interrelated and are, theoretically, made within the context of a goal of profit maximization for each decision maker given the knowledge available to him.

Included in this knowledge are the costs of doing business, properties (or attributes) of products (objects), the outputs and attributes associated with actions (relationships), and the costs and prices of inputs and outputs. The decisions made affect the desirability of the final product to the consumer and have direct influence on the total cost of production.

An economic problem is something that is not as it should be. Some economic goal or principle is being violated. There are three important goals or functions of an agricultural marketing system. First, there is the goal of determining accurately in quantitative and qualitative terms just what consumer demands are in time, place, form, and changes in these demands through time. A second goal is to determine the accuracy with which market prices reflect consumer demands. A third goal involves insuring that a sector is organized so that goods move from producer to consumer at the lowest possible cost permitted by existing technology (137).

In practice, marketing researchers have traditionally concentrated on examining operational efficiency and pricing efficiency. Operational efficiency assumes the essential nature of goods and services to remain unchanged. Research efforts typically focus on reducing the costs of doing a job. Analyses designed to increase pricing efficiency are concerned with improving the buying, selling, and pricing aspects of a marketing process so as to be responsive to consumer direction (79, p. 11).

There are a number of indicators the achievements in the area of pricing efficiency leave something to be desired. A variety of sources (5, 161, 164) report that the retail value differences among beef carcasses of equal weight and quality grade can range up to 20 percent of their market value due to differences in cutability. Yet, price premiums and discounts of this magnitude are rare or nonexistent in the meat trade.

A Missouri study of trade practices with 65 groups of carcasses from three slaughter plants, a total of 1,506 carcasses, revealed that price tended to vary directly with (quality) grade and that retail yield of lean cuts or cutability varied inversely with grade. Further, "if the packers had bought exclusively on the basis of estimated retail yield they would have almost reversed their buying and paid most where they actually paid least and vice versa" (132, p. 10). The Missouri study also indicated that analysis of wholesale prices indicated no relationship between estimated retail yield and wholesale prices suggesting there is little effort on the part of retailers to buy on the basis of estimated yield.

Stout and Thomas (140, p. 143) reported pricing errors on live cattle ranging from $38.18 to -$34.10 per head. Commenting on the usual practice of buying and selling on a live basis they say

> . . . the obligation to judge carcass attributes in the live animal and to be committed to pay immediately on the basis of that judgment, is in itself so impossible a task that buyers in volume fall back upon a system of buying on averages with the consequence that perhaps not one of a thousand cattle was properly priced to the producer, but the average price of a thousand quite accurately reflects aggregate value to the packer. It is interesting to note that while buyers typically defend

> their ability as cattle judges, they defend with equal ardor their need to buy on averages as an expedient in large volume operations (140, p. 131).

Purcell, a pioneer in the evaluation of communication effectiveness in beef marketing, has criticized the apparent inability of the open-market exchange system to achieve more effective vertical coordination in the beef marketing system (120). He suggests this has been a primary causal factor underlying developing tendencies toward vertical integration. Purcell outlines deficiencies and barriers to communication in the beef marketing system. A major deficiency is limited perspectives on the part of system participants who are often either unaware they are part of a system or choose to operate as if they were independent of the system. Examples of this independence are given as (1) the cattle feeder who ignores supply variability problems of packers, (2) the packer who opposed dual grading because of short run operational problems, (3) the commission agency who did not seek a new role in the emerging process of direct marketing, and (4) the researcher who severs the threads of interrelation in isolating a "function" for purposes of analysis and then forgets to knot those threads when drawing his conclusions.

A second barrier, and one closely related to pricing inaccuracy, is inadequacies in descriptive terminology--especially when value related attributes are never identified. If a system of price signals, premiums and discounts, is to be effective as a coordinating mechanism, then the product attributes which affect product value must be identified, categorized, and brought into the process of exchange.

A third communication obstacle Purcell calls variable conditions of exchange, referring to non-standardized practices for pencil shrink, weighing, etc., which add noise to the pricing process. New P & S (Packer and Stockyards Administration) regulations in 1968 have served to correct some of these problems.

Little is known of the nature and implications of the interrelations among the various levels of concentrated activity in the livestock beef marketing system. Past research has tended to deal with the operations at some single marketing level, not the entire system. Quite often, the isolated efforts are not amenable to aggregation into an effort of larger scope. Such abstractions are defended as being necessary to keep the scope of research projects within operational limits.

Whatever the reasons, marketing research in the beef industry has been concentrated at specific levels such as production, assembly, meat packing and processing activities. Much of the work is impressive in its rigor. Yet it has long been recognized that increasing the efficiency with which a particular function is performed--when considering the function in isolation--in no way guarantees efficiency of the system as a whole. Too often, the isolated function is treated as if it were independent of other functions. But the marketing system is charged with the task of coordinating what is produced with what is needed or desired by consumers. Such a task requires an interrelated sequence of functions, a system, which bridges the gap between producer and consumer. While the real-world system must and does perform in this manner, analyses of the relative effectiveness of system performance seldom go beyond consideration of activity at one particular level.

Consequently, there is a void in the available body of knowledge. Neither descriptive treatments of the nature of the interrelations between various levels of activity nor more analytical treatments to estimate probably impact of identified interrelations on system performance are adequate.

There is a history of literature in marketing calling for a systems approach to marketing problems. R. L. Kohls wrote in 1956:

> If the problem is one of firm or intrafirm efficiency, the formulation of the ends in measurable terms may be relatively simple. If the problem is one concerning efficiencies of the whole marketing system, the framework of the ends must be worked through giving explicit consideration to all of the value judgments involved (80, p. 71).

In a 1958 discussion of decision-making processes in integrated production and marketing systems, Kohls commented as follows:

> In a series of independent firms, the manager of each unit adjusts his activities to the market expectations as he sees them. He leaves the problem of coordination among the units of the series to the market process and its resultant process. . .it (therefore) becomes important to utilize the best analysis and experience available to consider both the external market and the internal relationships (78, p. 1802).

In 1962 Eldon Smith made note of the lack of research efforts in agricultural marketing ". . . which takes into account the totality of relevant relationships and interrelationships" (139, p. 1536). In 1963 the Southern Marketing Research Committee stated that

> . . . increased emphasis should be placed on adjustment problems faced by marketing firms and industry groups. Marketing research should specify alternative courses of action and evaluate the effects of each on the group concerned (143, p. v).

Boykin and Uvacek, in analyzing the research needs of the Texas livestock and meat industry, commented as follows:

> The Agricultural Economist has traditionally examined only segments of this complex industry and has thus viewed each level or firm within their livestock, meat, and fiber business as having the same goal--profit maximization. Although this predetermined goal is generally applicable to most firms within the industry, it is not entirely sufficient when explaining decisions at all levels (11, p. 14).

Shaffer in a widely read paper which appeared in 1968 summarized his recommendations as follows:

> I have argued for coordinated research which would provide an understanding of the complex system of the food and fiber sector of the economy. I have argued that the major payoff is in understanding the interfirm and intermarket relationships (133, p. 42).

Further developing his ideas later Shaffer said:

> . . . I would argue for a systems orientation. By this I do not mean formal mathematical systems modeling and formal simulation. Such modeling may be a useful tool and should be used along with other tools where appropriate. By a systems orientation I simply mean the analysis of problems in the context of the broader system, an analysis which takes into account feedback, sequences, and externalities (134, p. 1443).

Recently Purcell concluded:

> A change in research orientation by the agricultural marketing economist is badly needed. Analysis of selected systems in the Oklahoma beef marketing system reveals conflicts and inconsistencies in the most basic interstage or interlevel relationships. Such conflicts and inconsistencies undermine operation of the exchange system and prevent price from functioning effectively as an allocative and corrective device. Attention on these barriers to interlevel coordination, not on the observable behavior of the system, is what appears to be needed.

> Meeting these needs means "systems research" or at a minimum, an orientation that acknowledges the existence and importance of interlevel behavioral relationships as the primary determinant of the realized degree of coordination along the vertical dimension of any marketing system (114, p. 68).

Several works relating to the beef industry have been published which seem to have a systems orientation. Work by Halter and Dean [53], Crom and Maki [26], Duewer and Maki [36], and Bullock and Logan [19] are of special note.

The Halter-Dean and Bullock-Logan works are decision theoretic models. They both make use of stochastic predictors to aid in firm level management decisions. The Halter-Dean study focuses some interlevel attention at the stocker-feeding level. The Bullock-Logan study analyzes the feeder-packer level. Crom and Maki used an econometric model to simulate price and output in the meats industries under various experimental conditions. Duewer and Maki attempted to simulate the decisions of many firms in the livestock meat industry.

None of these analyses, however, address the problems identified by Purcell and others of the actual communication deficiencies in the marketing system. The void along this particular dimension persists.

There are, however, several traditional marketing studies within agricultural economics which have provided basic knowledge of pricing problems. The importance of communication-related problems in beef marketing have been recognized for many years. Different terminology may have been used, however, and investigation usually centered at one level in the system.

Most early works were concerned with pricing accuracy and the ability of observers to estimate carcass traits in live animals. Phillips and Pearson [110] in 1954 investigated the accuracy of slaughter cow pricing and found problems in grading accuracy, estimation dressing percentage, shrink, and hide value.

North Central Regional Publication 611, also in 1954, reported on the ability of buyers to estimate grades in live animals. The authors reported the average error in estimation was one-third of a grade for cows. They concluded that ". . . the producers of better grades and higher yielding livestock are sometimes penalized, whereas, the producers of the lower dressing animals are often paid more than their animals are worth" (106, p. 5). Similar studies and results were reported by Jebe and Clifton [67] in 1956 and McPherson and Dixon [97] in 1966.

A somewhat larger view was taken by Williams [170] in 1962 in a theoretic economic evaluation of grading. His work examined the theoretical role of grades in operational efficiency, pricing accuracy, merchandising, resource allocation, market power and general welfare.

Purcell originally conceptualized the beef marketing system as a communications system and subjectively evaluated its performance. Purcell pointed out that effective communication refers to the ability to stimulate a desired response from selected receivers within the possible array of responses. These might include (1) promotion of coordinated procedure when a series of technically interrelated actions are involved, and (2) motivation of change and adjustment when informational needs and/or the operating environment changes. Requisites of effective communication identified in the Purcell study were listed as follows:

> 1. The source must understand the needs of his receiver(s). And since needs change, this understanding must be updated constantly.
>
> 2. Feedback loops must be present and functioning. In particular, the receiver must have an adequate means of returning his reactions to a message to the source. Needed changes and adjustments on the part of the source will lag unnecessarily if response channels aren't clearly defined.
>
> 3. Each participant in the communication system must recognize the importance of the operating environment as a determinant of role conception and role performance. The successful source makes an effort to understand the receiver's operating environment to avoid conflicts with extablished norms and to enhance the likelihood of a desired response.
>
> 4. Habitual action must be avoided. Neither habitual message construction nor habitual response to a message is conducive to effective communication. The byword of a system of action such as a communication system is adjustment to change.
>
> 5. Each party to the communication process must recognize that symbols, not meaning, are transferred. The symbols comprise messages, but meanings stem from the points of origin, not in the message per se. Thus, interpretation is important and the effective source will carefully ensure the desired interpretation. One of the most commonly used techniques is that of redundancy (repetition, reiteration, or expanded message construction) (113, p. 5).

Earlier work at Oklahoma State has studied problems of interlevel coordination between two levels in the beef marketing system. Analysis of several sub-systems has been completed.

Purcell and Tapp [118] reported problems through excessive pencil shrinks and variable conditions in grade and weight sales in Oklahoma. Purcell and Dunn [115] studied the decision processes of Oklahoma cattle feeders. They found that large feeders generally attempt to maximize net returns to each lot of cattle they handle. They also found that many feeders chose a more variable pattern of returns over a less variable pattern of returns even when average returns were constant. In a related analysis, Purcell and Dunn [119] examined economic implications of conflict and inconsistency in the beef marketing system for the feeder-packer and Purcell and Rathwell [116] completed a similar analysis for the producer-feeder subsector. Large deviations were discovered in the perceptions market participants have of their roles and the roles of others in the chain. An example is the marked differences in the "type" of feeder calf that feeders wished to buy and the type that producers wished to sell. A further example is the desire of feeders to withhold facts about grade, dressing percentage and carcass cutability on previously fed cattle during price negotiations. The buying packers noted they need this type of information and without it, would tend to discount their price offers.

A budgeting study by Johnson [70] evaluated the costs associated with eight different methods of exchange channels for transferring ownership of cattle from feedlots to packers. These included terminal, auction, direct country commission, consignment, telephone auction, telephone direct and teletype auction. Total costs ranged from a high of $4.56 per head for the terminal market to $.65 per head for teletype auction. The costs associated with direct marketing (the most common method) were $1.00 per head. Johnson also estimated, for given sets of current operating conditions, that the total benefits to the industry by switching to a teletype auction method would be between $1.0 and $1.6 billion.

## Working Hypothesis

Identification and measurement of barriers to effective communication will provide information to improve effectiveness of existing systems and guide development of alternative systems or organizational structures over time.

## Objectives

The objectives are:

Major: Isolate, and measure implications of, barriers to more effective communication and more effective interlevel coordination for selected organizational structures in the beef marketing system.

Sub:
(1) Model pricing and decision processes for selected information structures;
(2) Measure the effect of communication inefficiencies, imprecise product valuation, inadequate range in and lack of price signals;
(3) Compare communication effectiveness of alternative organizational structures; and
(4) Establish an information base to facilitate inferences with regard to changes in structure which will be precipitated by communications problems.

## Procedure

The objectives will be met through the development and application of a two part model. The first part is a recursive nonlinear system of production relations which simulates necessary inputs, outputs and attributes of outputs for the growth of several size-types of beef animals.

The second part of the model uses inputs from the first in a team theoretic model cast in a linear programming framework. The model thus comprises a four-level analytical system or micro model of beef production which can be examined under changing conditions of information structures and decision functions.

The general structure of the simulator will be generated from literature in animal science and economics. Coefficients will be estimated from primary and secondary data. The predominant source of published data is the Meat Animal Research Center at Clay Center, Nebraska.

Experimentation with the systems model by varying decision functions (basis of optimization) and information structure (attributes considered in pricing, estimation of attributes, and prices associated with attributes) will yield comparative measures of decisions, the type of product produced, and total cost per unit of lean beef produced.

# CHAPTER II

# SYSTEMS ANALYSIS AND MARKETING

## System Analysis

System analysis is a broad term that emerged from World War II technology. Since the early developments "systems analysis" has found application in many disciplines other than engineering including biology, psychology, sociology, and economics. A precise definition of systems would be difficult because it is used differently in various applications. Perhaps a useful approach would be to examine the definitions of several authors.

Hall and Hagen define system as follows: "A system is a set of objects together with relationships between the objects and between their attributes " (52, p. 31). They then define the terms used in the definition of system. Objects are the parts or components of a system and these parts are unlimited in variety. Examples of objects are stars, switches, springs, mathematical variables, equations, processes, etc. Attributes are the properties of objects. Stars have temperature, distance from other stars, etc. Relationships referred to are those that tie the system together. It is these relationships that make the notion of system useful. The authors take the attitude that the relationships to be considered in the context of a given set of objects depend on the problem at hand with important or interesting relationships being included and trivial or unessential relationships excluded.

Another important definition is that for environment. For a given system, the environment is the set of all objects a change in whose attributes affect the system and also those objects whose attributes are changed by the behavior of the system. It is sometimes difficult to say whether an object belongs to the system or its environment.

Another approach to a definition of "systems" is presented by Ackoff. A system is "any entity, conceptual or physical, which consists of interdependent parts" (1, p. 121). We are interested only in those systems which can display activity, i.e., behavioral systems. Ackoff expands on this idea as follows:

> The behavior displayed by a system consists of a set of interdependent acts which constitute an operation.... Loosely put, a set of acts can be said to constitute an operation if each act is necessary for the occurence of a desired outcome and if these acts are interdependent. The nature of this interdependence can be precisely defined. Both the relevant outcome and acts involved in an operation may be defined by a set of properties which can be treated as variables....an outcome is the product of a set of interdependent acts if it is more than the sum of (or difference between) these acts (1, p. 121).

Still another attempt at a definition of systems is provided by Miller under a heading labeled general behavior systems theory. Miller defines a system as follows:

> Systems are bounded regions in space-time, involving energy inter-change among their parts, which are associated in functional relationships, and with their environments.... Those specific functions of systems which we can stipulate and whose magnitude we can measure in a relative scale, we will call 'variables' if they are within the system and 'parameters' if they are in its environment (100, p.4).

Again, following Miller, the boundary of a system is a region where energy or information exchange is significantly less than inside or outside the system. The boundary may be in flux as communication links between subsystems are established or broken.

Rabow introduces his book on systems in the following quote:

> A system is an assembly of components that perform together in an organized manner. A component of a system may itself be a smaller system, sometimes called a sub-system. The systems approach is a method of dealing with complicated systems. It consists essentially of breaking up a systems problem into a number of component or subsystem problems, which when solved together will solve the systems problem. The component or sub-system problems are usually of narrower scope than the overall systems problem and can be tackled by personnel of more specialized ability. It is thus possible to bring all relevant areas of knowledge to bear upon a problem. In the systems approach, the basic requirements imposed on the system are determined in advance, and each component must operate in such a way as to best meet the systems requirements (122, p. 2).

In all the definitions and discussions of systems thus far there are two pervasive ideas that seem important to systems. One is wholeness or the enveloping of all of the parts of an entity and the other is communication which is the link with which separate parts are joined to become a system. The study of communication and information is then important to the study of systems. Indeed, some authors have claimed them to be synonomous. However, Miller makes this distinction:

> General behavior systems theory incorporates most aspects of modern information theory, but it is more encompassing, for it deals with the transmission of both information and energy transfer" (100, p. 46).

Ackoff (1, p. 121) defines organization as a partially self-controlled system which has four essential characteristics:

(1) Some of its components are animals;

(2) Responsibility for choices from the sets of possible acts in any specific situation is divided among two or more individuals or sub-groups of individuals. The classes of action of a subgroup may be individualized by function, geography, time, etc.;

(3) The functionally distinct sub-groups are aware of each other's behavior either through communication or observation; and

(4) The system has some freedom of choice of both means (courses of action) and ends (desired outcomes).

The four essential characteristics can be briefly identified as content, structure, communication, and decision-making (choice) procedures. It follows then that there are four basic types of approaches to study or improve the effectiveness of a system that is an organization. First, one may change the content or the men and machines of the organization. This type of work is known as industrial psychology. The second approach is through structure, i.e., the way that the necessary physical and mental labor is divided. The third approach to an effective organization is communication, having the right information at the right place. The fourth and last approach to organizational problems involves decision-making procedures. The study of the effective utilization of resources is a well-established domain of micro-economics, econometrics, and operations research.

Churchman, et al., (23, p. 274) discuss a system orientation, dubbed a Communications Model. They begin with Weiner's (Cybernetics) statement that "Communication (or information transfer) and control were essential processes in the functioning of an organization." This conceptual model need not be mathematical but often takes the form of a diagram. It is often used by system researchers early in a project to sort out relevant information from trivial, to bring together knowledge from various disciplines, to suggest analogies and similarities among various kinds of organization, and to suggest points of attack on organizational problems. "A communication model can be thought of as a glorified kind of fish net, spiderweb, or network of nerves through which 'information' passes or flows" (23, p. 276).

A communication model requires three kinds of knowledge about the system being modeled. First, knowledge of a communication network which exists at a given time is required. Second, the modeler must have knowledge of existing control or decision processes in the network and how control processes change over time.

There are in general three levels of control processes observed in systems. The first is the simple transformation unit. It has its direction given from an external source and has no goal of its own. It has a single input and a single output. The second is the simple sorting system. It makes a decision and sorts a single input into two outputs. It must also be fed continuously by an external operator. The third level is a simple goal maintaining unit. In general, if an organization compares what it is doing with its goal and detects any error then the organization controls its activities.

This monitored portion of the output is referred to as feedback. If feedback tends to reduce error it is called negative feedback. The communication link containing feedback is often referred to as a feedback loop. The lack of a feedback loop makes it impossible for a system to compare its actual output with its desired output.

## A Brief Review of Information and Communication Theory

Churchman, et al., provided a non-mathematical and qualitative conceptualization of a communications model. However, a good deal of work has been done towards quantifying the concepts of information and communication and relating them to systems analysis as well as conventional scientific inquiries through statistics.

The pioneering work in this area is Shannon and Weaver's The Statistical Theory of Communication (135). References for the following brief review include Shannon (135), Hartman (58), Berlo (9), and Thiel (142).

Simple Communication Models. There are five basic units in any communication system or subsystem. The information source is the first basic unit and is the origin of the communication process. Its output is the signal or message. Second is a transmitter which operates on the message making it suitable for transmission over the channel. Third is the channel or medium used to transmit the signal from transmitter to receiver. The fourth unit is the receiver which ordinarily performs the inverse operation of that performed by the transmitter. The fifth unit is the destination, the person or thing for whom the message is intended. Figure 1 displays a simple communications diagram.

The purpose of the communication is usually to produce a response from the destination. The feedback loop, which reverses the roles of the source and destination, permits a flow of information regarding the response back to the original source and allows for adjustment in subsequent messages.

Another concept that needs introduction is the code. The code is the set of symbols into which the transmitter "codes" the message. The code most familiar to most readers is the English language.

Many authors have made refinements and additions to the basic Shannon-Weaver model to move it away from problems of engineered communications systems, such as the telephone or radio, to problems of human communication. These authors include Rothstein (127), Ogden and Richards (107), Minnick (101), and Berlo (9). A more detailed explanation of the works of these authors is provided by Purcell (113).

Quantification of Information. It should be understood that the word information, as used by Shannon and Weaver, is not to be confused with its common usage which can be described as meaning or knowledge. Information relates to what could be said, not what is said. It is a measure of the freedom of choice available in sending a message. As the symbols for a message are chosen, they are seen as being governed by a ergodic Markov Process (113, p. 70).

Information, like knowledge, is measured in terms of uncertainty. But unlike knowledge, which is a function of the background or

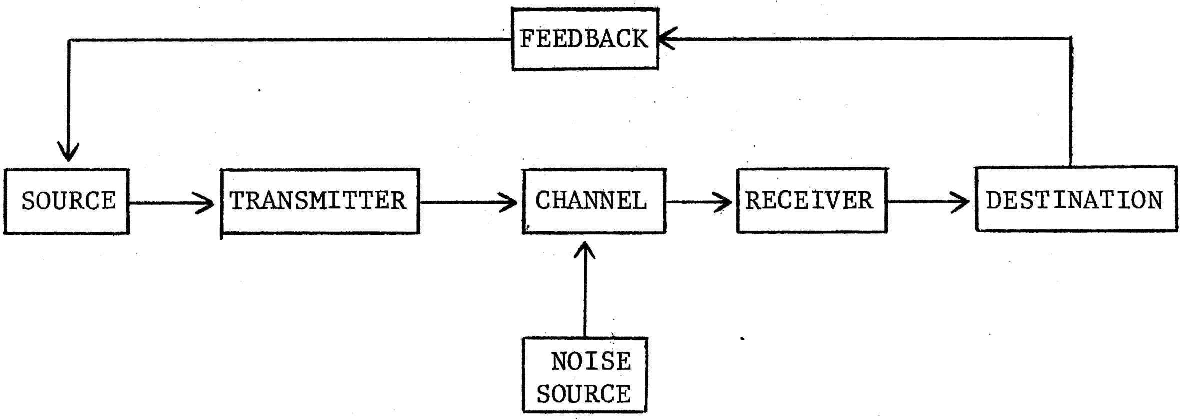

Figure 1. A Simplified Communication Model

environment of the destination, information is defined independently of the background of the destination. Meaning is in the source and in the destination, not in the message. With this definition of information discussion is limited to the carriers of knowledge, or symbols.

An intuitive "feel" for the measurement of information is given in an example by Thiel (142, p. 1). Imagine that your dog ran away and you know that he is in a rectangular field which is divided into 64 squares like a chessboard. The problem is: In which square is the dog?

An observer knows that the dog is in square 53, but you do not know which square he is in. You may ask the observer questions, each of which can be answered by yes or no. Each question costs you one dollar, so you wish to minimize the number of questions asked and still be assured of knowing which square the dog is in.

If you started with square no. 1 and asked if the dog was there, then square no. 2, etc., 53 questions would be required to find the dog. Consider the following proceudre:

Question 1: Is the dog in one of the first four columns?

Answer: No.

Question 2: Is the dog in the fifth or sixth column?

Answer: No.

Question 3: Is the dog in the seventh column?

Answer: Yes.

Question 4: Is the dog in one of the squares 49-52?

Answer: No.

Question 5: Is the dog in one of the squares 53-54?

Answer: Yes.

Question 6: Is the dog in the 53rd square?

Answer: Yes.

The dog is found. It will always be possible to locate the dog in 6 questions when there are $2^6 = 64$ possibilities.

The Information Content of a Definite Message. Suppose it is known that some event E will occur with probability X where $0 \leq X \leq 1$. Later a definite and reliable message is received stating that E occurred. When X = .99 you will not be surprised, the message had very little "information content." When X = .01, surprise is great. The message had large information content.

It is intuitive that the information content, h(x), is a decreasing function of X. The lower the probability of an event, the greater the information in a message that it has occurred. The choice of the form of this decreasing function is free but according to Thiel it is generally agreed the appropriate procedure is to take the logarithm of the reciprocal of the probability X (142, p. 4):

$$h(X) = \log \frac{1}{X} = -\log X$$

One of the reasons for this choice of functional form is to gain the convenient additive properties of the function. If $E_1$ and $E_2$ are two stochastically independent events such that $X_1X_2$ is the probability that both occurred, then the information content of the message that $E_1$ and $E_2$ did occur is: $h(X_1X_2) = \log \frac{1}{X_1X_2} = \log \frac{1}{X_1} + \log \frac{1}{X_2}$

$$= h(X_1) + h(X_2).$$

Referring back to the example of the lost dog, the information content that the dog is in a particular square if all squares are equally likely is

$$h(2^{-6}) = \log \frac{1}{2^{-6}} = \log 2^{6} = 6 \text{ bits}$$

if 2 is chosen as the base of the logarithm. In general, when 2 is the base and there are $2^{N}$ possible events, $h(X)$ is measured in bits (short for binary digit) and is given by

$$h(2^{-N}) = \log \frac{1}{2^{-N}} = N.$$

<u>Communication and Behavior.</u> Weaver (135) outlines three levels to the subject of communication:

Level A. How accurately can the symbols of communication be transmitted? (The technical problem.)

Level B. How precisely do the transmitted symbols convey the desired meaning? (The semantic problem.)

Level C. How effectively does the meaning affect conduct in the desired way? (The effectiveness problem.)

The mathematical theory of communication applies directly only to the first level. However, Weaver argues that "levels B and C can make use only of those signal accuracies which turn out to be possible when analyzed at level A....Thus the theory of Level A is, at least to a significant degree, also a theory of Levels B and C" (135,p. 79).

Ackoff (2) carries forward with Shannon and Weaver's writing to relate communication to the behavior of decision makers in what he calls a "purposeful state." He is mainly concerned with communication Level C, the effectiveness problem.

Ackoff's efforts can be characterized in three objectives: (1) to identify ways in which a sender or source can affect the behavior of a receiver (destination); (2) to construct measures of these effects; and (3) to define and construct measure of effectiveness for these relative to the receiver's objectives as well as those of the sender. He quantifies communication in three behavioral categories. A communication informs if it changes the probabilities of choice of the decision maker, it instructs if it changes the efficiencies of courses of action, and it motivates if it changes the values of outcomes. Any single communication may do any or all of these three simultaneously.

## Information and Economics

The Shannon-Weaver Model is concerned with the amount of information which can be communicated in a system rather than how much is communicated or the value of the information communicated.

Applications of information theory can be found in Thiel (142). Applications illustrated by Thiel include the measurement of income inequality, price and quantity comparisons, consumer allocation, industrial concentration, and input-output analysis.

An early use of information theory was by Green (48). He identified a basic limitation of statistical information theory for economic decision making. The amount of information measured in bits could be equivalent for a message that allowed an entrepreneur no profit and one that allowed a large profit. Green also pointed out that the familiar decision theoretic technique of Bayesian analysis (for expositions of Bayesian analysis see 19, 85) provided measures of value of information.

Other authors, in addition to Green, have discussed the similarities of information theory and Bayesian analysis or, alternatively, how the two differ. Among the more prominent of these treatments are those by Garner (41) and Leuthold (85).

## Team Theory

The techniques discussed until now have been concerned with at most two individuals, a message source and a receiver, and one decision maker, usually the receiver. The problem addressed here concerns decision makers at several technically interrelated levels making decisions which may be on the basis of different information and motivations. The frontier of decision sciences in modeling the decisions of more than one decision maker in an organization is a theory developed and expanded by Marshak and Radner (91). Team theory is extremely useful to this study as an aid in organizing and defining models and in suggesting methods of analysis.

The relationships of team theory to information theory, and to Bayesian analysis, will be obvious in this exposition. Marshak and Radner define an organization as a group of persons whose actions agree with certain rules that further their common interest (91, p. 1). In an organization individuals typically differ in at least three important respects: (1) they control different action variables; (2) they base their decision on different information; and (3) they have different preferences (123, p. 189). In many cases, however, they may have nearly identical preferences and useful analyses can be conducted assuming that preferences are similar. A team is defined as an organization which has only common interests (91, p. 9).

Information Structure and Decision Functions. An act of an organization is generated by a process of observation, communication, computation, and action. In the theoretical model acts are generated by information structures and decision functions.

Let

S = the set of alternative states of the environment,

C = the set of alternative consequences, and

A = the alternative acts available to the team.

Every team member "i" can receive as information Yi. An information function for member i is therefore a function $\eta i$, from S to Yi, as shown in equation (1).

$$Yi = \eta i\ (S). \tag{1}$$

Yi is thus the signal, perhaps noisy, that i receives if state "S" occurs.

Let $D_i$ be the set of alternatives that member i can follow. A decision function for i is a function $\delta i$ from $Y_i$ to $D_i$. Equation (2) then shows the decision member i will make if he receives information signal Yi.

$$D_i = \delta_i\ (Y_i). \tag{2}$$

Therefore, if state S occurs member i will make the decision $D_i$ as shown in equation (3).

$$D_i = \delta_i\ [\eta_i\ (S)]. \tag{3}$$

Denote $\eta = (n_i,\ldots,\eta_m)$ an information structure for the team and $\delta = (\delta_i,\ldots,\delta_m)$ a team decision function. Consequences to the team are assumed to be determined jointly by the state S and the team decision $D = (D_i,\ldots,D_m)$ according to an outcome function $\rho$ as shown in equation (4).

$$C = \rho(S,D). \tag{4}$$

Given the outcome function, $\rho$, an act is determined by an information structure $\eta$ and a team decision function $\delta$ according to equation (5).

$$A\ (S) = \rho\ (S,\ \delta\ [\eta\ (S)]. \tag{5}$$

Thus, equation (5) indicates the set of acts taken is a function of both the actual set of states of the environment, S, and the team's information about the actual state, $\delta[\eta(S)]$.

A team's preferences can be represented in terms of expected utility. There is a utility function $\mu$ defined on the set of C consequences and a probability function $\phi$ defined on the set of states such that for a team "act a " is at least as preferred as "act a'" if and only if equation (6) holds.

$$\sum_{s}\phi\ (s)\ \mu[a(s)] \geq \sum_{s}\phi\ (s)\ [a'(s)]. \tag{6}$$

The payoff function, $\omega$, combines the outcome and utility functions and is illustrated by equation (7).

$$\omega(s,d) = \mu[\rho(s,d)]. \tag{7}$$

A given pair $(\eta,\delta)$ is judged by its expected payoff shown in equation (8).

$$\Omega(\eta,\delta;\omega,\phi) = \sum_{s}\phi(s)\omega(s,\delta[\eta(s)]). \tag{8}$$

A necessary condition for an optimal team decision function, for a given information structure, is that the team decision function cannot be improved by changing any single member's decision. This condition is also sufficient if the payoff function is concave and can be differentiated in the decision variables for every fixed state.

The simplest case of a polyhedral payoff function is a linear function. In this case the team problem is amenable to linear programming solutions.

An organization is information decentralized to the extent that different members have different information on which to base their decision (94, p. 208). A team is decentralized if not all information functions are identical.

The several information structures of the members of a team can usually be viewed as being generated by processes of observation, communication, and computation. There may be no communication between team members or there may be complete communication but rarely are either of these extremes encountered. Decentralization can occur by team members sending contracted and coded messages to each other or through a central organizer under either rountine or exceptional conditions when the messages are acted on according to rules.

McGuire and Radner draw parallels to team theory and the market:

> The market provides a familiar example of this process of observation, communication, and computation. Actually, to speak of 'the market' in this case is a gross oversimplification since there are many different types of market with considerable difference among the structures of information that they generate. Indeed, to date relatively little work has been done on characterizing the information structure generated by the various market structures. Of course a market is not typically a team because the various economic agents do not have the same goal, although markets have sometimes been proposed as devices for allocating resources within a single organization in which the members do have a common goal (94, p. 209).

## The Market as a Communication System

Chapter I identified three problems which the agricultural marketing system is expected to solve. The first of these is to determine accurately and in quantitative and qualitative terms just what consumer demands are in time, place, form, and the changes in these over time. The second and related problem concerns the accuracy with which market prices reflect these consumer demands. The third problem is that of moving the goods from the producer to consumer at the lowest cost permitted by existing technology.

When producers meet consumers and sell goods in a face-to-face situation, communication is easy. Consumers can simply tell consumers what they want and why. But consumers and producers who are hundred of miles apart cannot talk directly to each other. Goods pass through several hands and several changes of ownership on their way to consumers. Messages are passed up and down through the system and can become distorted. This is particularly true since intermediaries can have different perspectives and sources of information. Shepherd and Futrell note the chief medium of communication is the system of market price that reaches all the way back from the retail store to the farmer's local market (137, p. 12).

Other authors have drawn parallels between the functions of the market and a communications system. Early among these is F. A. Hayek who elaborated as follows:

> We must look at the price system as such a mechanism for communicating information if we want to understand its real function--a function which, of course, it fulfills less perfectly as prices grow more rigid. (Even when quoted prices have become quite rigid, however, the forces which would operate through changes in price still operate to a considerable extent through changes in the other terms of the contract.) The most significant fact about this system is the economy of knowledge with which it operates, or how little the individual participants need to know in order to be able to take the right action.
> In abbreviated form by a kind of symbol, only the most essential information is passed on, and passed on only to those concerned. It is more than a metaphor to describe the price system as a kind of machinery for registering change, or a system of telecommunications which enables individual producers to watch merely the movement of a few pointers, as the engineer might watch the hands of a few dials, in order to adjust their

> activities to changes of which they may never know more than is reflected in the price movement. (59, p. 526).

Havek's statement was directed primarily to a broad economic equilibrium view of prices and outputs. Collins discussed the communicative role of price in coordinating quality as well as quantity of production in a narrower vertical agricultural production and marketing system. Collins suggested the level of output that can be achieved at one stage of production may depend on the quality of a certain input which was itself determined by the way resources were used at a previous stage (24).

Collins was calling for a systems approach in marketing research rather than focusing attention on organizing the input-output mix at a single stage along the vertical continuum. He was suggesting that to minimize total resource use for any choice of products, a coordination system must be employed (which in itself is not too costly) that will encourage entrepreneurs at one stage to take into account in their production planning the effects of their actions on the revenue determinants of other members of the system.

At this point Collins moves to defining the conditions necessary for effective communication. Collins' conditions are: 1) there must be a communications network to link the performance units in the system; 2) there must be language or set of signals which accurately characterize the relevant economic variables; and 3) each party must be willing and able to translate signals into actions (24, p. 529).

In spite of theoretical arguments for the use of price determined in an open market, there has been observed tendencies for a movement toward other avenues of coordination in agricultural marketing. These coordinating devices range from simple contracting to complete integration of the vertical levels of a production and marketing system.

The contractual arrangements connecting feed companies, broiler processors, and farmers is perhaps the best known example of vertical coordination in which firms do not buy and sell from the industry at large in an open market. Rather, they have personalized dealings restricting their supplies and customers to a few firms through administrative agreements.

The important question is: why, given the theoretical advantages of the open market, is there such pressure for other types of coordination?

At least part of this tendency to move toward other means of effecting vertical coordination is due to the complex interrelationship between levels in an industry. Decisions at one level affect product attributes and decisions at another level.

If prices determined on an open market are to serve as an effective communication and directive device, each party must recognize in them a representation of the combined production possibilities and preferences of all other decision-makers. The price signal must "say something" about each of the dimensions that define and affect the value of the product. Each decision maker, before he selects his optimum production plan, must be able to judge from market prices the implications of varying each product specification. But open market prices are not consistently related to all of the product attributes which significantly influence product value. In such cases, it is not always possible to deduce from reported price relationships exactly what kind of product is desired for purposes of production planning.

Improving the pricing mechanism is not free of cost and is usually not within the capability of individuals in the system. The expansion of the reporting service to provide detailed prices for five or ten attributes would multiply the cost many times if it could in fact be done. It is also true that some factors cannot be explicitly included in market reports. Transportation shortages, price fluctuation in related commodities and general variabilities of the business world constitute examples of factors which may influence price levels but which would be difficult to report.

## Relationship to Beef Marketing

Essentially all of the pricing problems and limitations described above apply to beef production and marketing. There has been pressure for vertical integration. Monfort of Colorado which has ownership in cattle ranches, feedlots, processing plants, and retail outlets is the outstanding example.

Pricing is often on an average basis. Stout describes meat packers' buying practices as follows:

> ...buying on averages with the consequences that perhaps not one of a thousand cattle was properly to the producer. But the average price of the thousand quite accurately reflects aggregate value to the packer (140, p. 131).

In addition to the problem of bridging the gap between final carcass value and liveweight price, other communication barriers exist. Shrink must be estimated, weighing practices are often variable and errors in judging value-related attributes all contribute to inserting "...a lot of unnecessary noise in the communication system which grossly confuses the messages before it finally filters back to producers and livestock market operators" (140, p. 132). The resulting inefficiency in resource allocation, compared with that possible under conditions of perfect communication, should be considered as the cost of using a noisy coordinating mechanism.

The preferences of consumers are not an integral part of the system, but are an overwhelmingly important part of its environment. It is the decisions of consumers which begin the process of determining prices and price differentials and, consequently, start the communication process inherent to the beef marketing system. Therefore, the ability of consumers to apply consistent interpretation to the various symbols used in describing beef will be an important determinant of the communication effectiveness of the beef marketing system.

The U.S.D.A. Quality Grade has become important to consumers as a distinguishing attribute of retail beef. A nationwide consumer study published in 1969 showed that 76 percent of the respondents who knew that beef was graded recognized the Choice grade name and 68 percent recognized the Prime grade name. Only 28 percent, however, recognized the U.S.D.A. Good grade (155).

Consumers who knew beef was graded were asked what grading meant to them. Thirty percent of the respondents made references to specific product attributes. Sixteen percent referred to tenderness or juciness, nine percent to the amount of fat, five percent to taste or flavor and 12 percent to other specific attributes. Sixty-six percent made non-specific references to quality. Wholesomeness references were made by 25 percent of these respondents. The four attributes of all meats found to be most important to consumers were: (1) assurance of good quality, (2) tastiness, (3) not wasteful, and (4) healthful. The study showed that beef generally had the qualities desired and the U.S.D.A. grades were a most important method of judging these attributes in purchased beef. Because of the importance of quality grades as basic symbols of communication the factors considered in grading and the rules of grade designation will be discussed in more detail.

U.S.D.A. Grades for Beef. Currently there are two independent sets of grading standards for beef applied to slaughter animals and beef carcasses. These are the quality grade standards which attempt to group carcasses according to eating quality and yield grade standards which attempt to identify carcasses for their percentage yield of lean meat.

Present quality grading standards involve a combination of palatability indicating characteristics and conformation. There are eight quality grade names: Prime, Choice, Good, Standard, Commercial, Utility, Cutter, and Canner. The first four are the best known to consumers and most relevant to fed beef. The latter grades are filled mainly by culled breeding animals.

Conformation as a determinant of quality grade refers to the shape of a carcass and is purported to be a measure of the ratios of lean to bone and of high to low value cuts. Designations for conformation are the same as for quality grades such as "Choice Conformation".

Marbling, another determinant of quality grade, is the flecks of fat within the lean or intramuscular fat and is evaluated in the ribeye muscle. There are 10 degrees of marbling officially recognized beginning with "devoid" and ending with "abundant". Each degree is recognized in thirds such as abundant-, abundant, and abundant+. Marbling in excess of the minimum necessary for a grade can compensate for a lack of conformation but conformation can compensate for lack of marbling only in grades other than Choice and Prime.

Five maturity groups, each divided into three divisions, are recognized in the standards and are designated A- through D+. A and B are the groups relevant to fed beef and the division between them falls at approximately thirty months of age. Maturity is evaluated by observing the degree of skeletal maturation (ossification) in the beef carcass vertegral column.

Color, firmness, and texture of the meat in the ribeye are also considered but rarely affect the final quality grade. Conformation affects the grade of fed beef cattle only in a small percentage of cases. In general, marbling as affected by maturity has been by far the most important factor in quality grading. Recently changes in the grading standards have been accepted which will change these relationships slightly. Figure 2 displays the relationships among marbling, maturity and quality as they appear before and after the changes on February 23, 1976. Slightly less marbling will now by required to allow a carcass to grade Choice. In addition, new grade standards will not include conformation as a factor. Additional discussion of quality grades is included in the U.S.D.A. publication on grade standards (161).

Yield grades have been available as an official part of the standards since 1965. Yield grading is a nationally uniform method of identifying cutability differences among beef carcasses. Yield Grades are designated by a number 1 through 5. The yield grade is determined from a linear function of 4 carcass measurements: hot carcass weight; ribeye area at the twelth rib; percent of hot carcass weight in kidney, pelvic, and heart fat; and external fat thickness at the twelth rib. For official grading the number calculated from the equation is truncated to an integer. The standards indicate that a carcass typical of its yield grade will cut out about 2.3 percent more retail product from the round, loin, rib, and chuck, and about 4.6 percent more total retail product than the next lower (higher numbered)

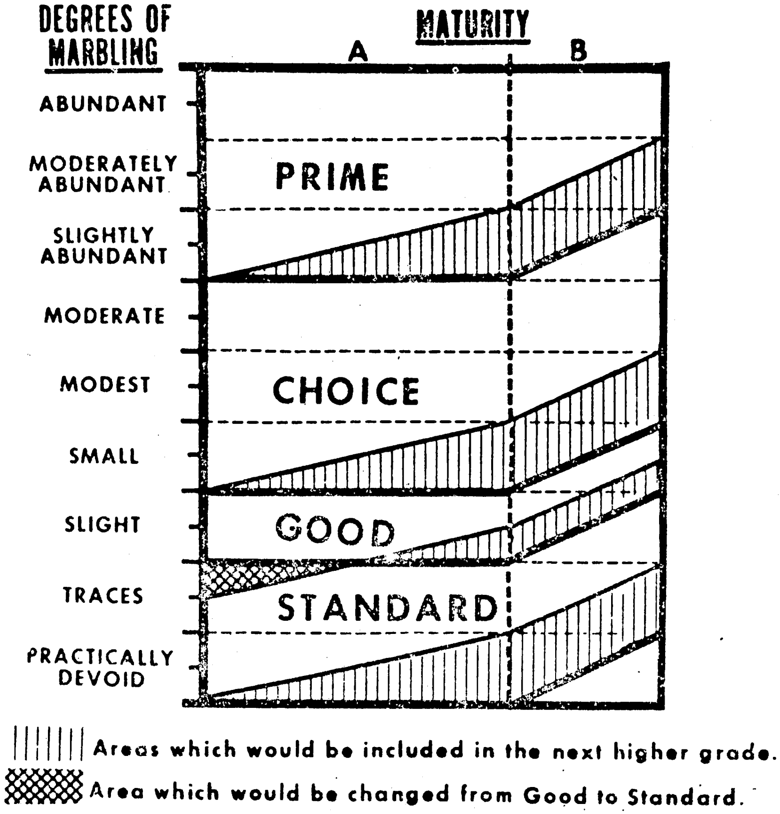

Figure 2. Changes in the Relationship Between Marbling, Maturity, and Quality Grade.

yield grade. Under the new standards which went into effect on February 23, 1976 yield grading will no longer be optional but will be tied to quality grading. If a carcass is officially graded for either quality or yield it will be graded for both.

## Subsystems in the Beef Industry

No study can take into consideration all important aspects of an industry. A systems study should attempt to isolate the objects and relationships which have greatest bearing on the problem the systems model is designed to analyze. Simplification and abstraction are necessary to confine the analysis to tractable proportions. The judgment of the researcher, limitations of available or obtainable data and supporting research are all involved in the abstractions.

This analysis centers on four basic vertical levels of the industry: (1) cattle raising, (2) cattle feeding, (3) cattle slaughter, and (4) carcass breaking and fabricating. It is primarily concerned with the specific attributes of the objects processed, the information used, and the performance of an abstracted micro model of these four levels. Only one firm will be considered at each level and alternative selling and buying conditions will be specified according to information structures available at the time of sale. It is necessary, therefore, to describe the characteristics (attributes), processes (relationships), inputs and outputs (objects) and attributes of firms (sub-systems) that represent a large portion of the output of the beef industry.

Churchman (23) outlines five basic considerations which serve as the foundation in developing a system:

1. The total system objectives and the performance measures of the system;
2. The systems environment, the fixed constraints;
3. Resources of the system;
4. The components of the system, their activities, goals; and
5. The management of the system.

The system of interest is an abstracted model of breeding, feeding, slaughtering and fabricating activities of four decision makers connected by communication links in the marketing system.

The real world system is so complex, composed of so many firms, of so many different types and connected by so many forms of links and interchanges that it would be impossible to model the "real world." Instead a small number of the more important aspects of four firms are condensed into a mathematical representation with the assumption that behavior and performance of this greatly simplified abstraction operating under simplifying assumption yields "information" about activities in the real world. This procedure allows experimentation that would be impossible in the "real world." The following is a brief description of the abstracted system.

The Cow-Calf Subsystem. The initial subsystem or component is the cow-calf firm. The output unit or object of this subsystem is a unit calf which can possibly be the sum of several different types of calves, a "composite calf". The attributes of the calf which affect decisions of the cow-calf subsystem are its weaning weight and a price schedule relating weight categories to a price per pound. The resources used have a fixed investment value and the goal of the firm is to maximize the rate of return to the fixed investment.

The decision of the cow-calf subsystem is to choose a breeding program which results in different weaning weights and calving percentages. The cow herd is considered to be of typical Hereford and Angus genetic size. The larger breeds, when used for crossbreeding, incur a cost in reduced calving percentage and increased labor at calving time. Such costs are represented as a direct subtraction from net revenues in order that the unit calf is maintained in the model. Information structures (prices and attributes) at the marketing level can be based simply on weight differentials or at an increased information level on price signals based on information of the feedlot potential (marginal value product) of the composite calf. The cow-calf operator is allowed to sell only to the feedlot level.

The Feeding Subsystem. The feeding subsystem purchases a composite weaned calf from the cow-calf subsystem. Each breed portion (if more than one) of the composite calf is fed one of twenty alternate feeding periods each ten days longer than the preceding one. The resources of the subsystem include the plant, equipment, feed, and labor necessary to provide feedlot capacity for one composite animal for one year. This capacity is assumed not to vary with the size or weight of the animal. Since it is possible for a composite animal to be several breed types, each breed types can be fed for a different length of time. As longer feeding periods are utilized for a given animal the attributes and ultimate production of carcass and meat, as affected by quality grade, yield grade, dressing percentage, and closeness of the fat tolerances on trimmed retail cuts, are determined and changed for each feeding period.

The decisions of the cattle feeding sub-system include what breed type(s) of cattle to buy and how long to feed them. The information structure at the feeder-packer interface may include (1) selling on a liveweight basis, with a price schedule defined only for liveweight, and estimated quality grade categories without reference to other attributes; (2) a liveweight basis with stochastic (noisy) estimates of quality grade, yield grade, and dressing percentage; and (3) a carcass basis with or without reference to yield grade. The goal of the feeding subsystem is to maximize the rate of return to fixed investment. This can be done on a one-time feeding turnover basis in which the feeder is in effect maximizing profit per head or on a replacement basis. The replacement basis accounts for the possibility of replacing the animal on feed with another calf and so making full use of capacity for the year. The replacement basis is represented by multiplying the single use output by 365 days and dividing by days on feed; e.g., if the feeding period is 200 days and output is 1,000 pounds liveweight, then yearly output would be 1,825 pounds. Variable costs are increased accordingly.

Packer Subsystem. Again, the single unit animal is the principal input and the unit carcass is the principal output of the system. The information structures associated with exchange between the feeder and packer subsystems were described above. The activity of the packer is to kill the live animal and produce a dressed carcass. The packer's decision involves deciding what composite live fed steer to buy for processing. In sale of the carcass, the packer can face information structures including sale of the carcass on a weight and quality grade basis or on a weight, quality grade and yield grade basis. The packer resources include the plant, equipment, and labor sufficient to slaughter, dress and cool the carcass. The goal is to maximize the rate of return to fixed investment in resources.

The Fabricator Subsystem. The fabricator subsystem purchases carcasses at the packer-breaker interface under information structures described above. The decision involves deciding what composite carcass to buy and which of two trim levels to use. The function is to break and fabricate the beef into knife-ready boxed beef cuts for sale to the environment. The resources of the subsystem include the necessary plant equipment and labor to perform its function. The goal of the system is to maximize rate of return on fixed investment.

# CHAPTER III

# BASIC OPERATIONAL AND PHYSICAL CHARACTERISTICS OF THE BEEF INDUSTRY

## The Beef Marketing System

Excellent descriptions of production and marketing activities and procedures in the beef industry are available in the literature (5, 50, 81, 150, 166). Only a brief description of certain aspects will be given here as a necessary background for development of the model to be employed in the analysis.

It will be necessary for purposes of the model to mathematically represent relationships for one firm for each of the four vertical levels of the beef system--cow-calf, cattle feeding, cattle slaughter, and beef fabricating. The characteristics of firms modeled will be affected by (1) what is typical in the Southwest beef industry; (2) what is consistent with evident technological trends; and (3) available data.

### Cow-Calf Level

The technical function of a cow-calf firm is to convert the inputs of forage, breeding stock, and other farm or ranch facilities into a weaned feeder calf. In general, cow-calf entrepreneurs have not rigorously applied economic analysis to their operation nor have they widely or rapidly employed new technology to increase production per cow. This is often because the cow-calf enterprise is supplemental to another income source (166, p. 58).

Herds are typically small. In 1969, 83.7 percent of the farms with cow herds in the Southwest had fewer than 100 cows and 46.1 percent of the cows were contained in herds of fewer than 100 head. Experts have projected that the size of cow herds will increase in the future but remain small in comparison to feedlots (166).

The model is constructed and operated with a single composite steer as the basis and the calf cost coefficients are based on a 100 head cow-calf operation in Oklahoma. Breeding relationships, production relationships, and the basis for feedlot growth and carcass characteristics are taken from data of the USDA Meat Animal Research Center. The cost, breeding and feeding relationships will be fully described in a later section.

### The Cow-Calf Feeder Interface

Feeder cattle must generally be transferred from many small farms and ranches to fewer and larger feedlots. The most common methods of exchange in the high plains areas of Texas, Oklahoma, Kansas, Colorado and New Mexico are through direct sales from farms and ranch to the feedlot operator and through auctions. Often, the feedlot operator utilizes one order buyer to buy cattle. Although USDA Market News reports classify feeders by weight range and USDA Feeder Grades (Good, Choice, etc.), the language of the market, expecially in the Southwest, often contains terms such as Okie 1, Okie 2, black baldie, etc. Attempts to associate feeder cattle characteristics or descriptive terms with price differentials have met with limited success. At different times and places, under different market conditions, characteristics that at one time bring a discount might at other times bring a premium. For example, when the cost of gain per pound is greater than the slaughter price per pound, heavy feeders are "worth more" to cattle feeders than light feeders. The opposite is true when cost of gain is less than the slaughter price. Since no consistent descriptions with accompanying prices could be associated with the types of cattle modeled in this study, and since they would likely all have the same USDA feeder grade, a constant price per pound for all breed types is used. It is also assumed that the calves move through an order buyer from the cow-calf level to the feeder level.

## The Cattle Feeding Level

The large commercial feedlot has emerged since the late 1950's as a dominant unit in the beef industry. In 1974, approximately one-half of the fed cattle marketed in the U. S. came from lots with greater than 8,000 head capacity and 37.0 percent came from lots with over 16,000 head capacity (148). The high plains area of Oklahoma, Texas and Kansas is a center of the large feeding activity.

The "typical" feedlot in this study has a capacity of 20,000 head and technical coefficients are taken from prevailing technology in the High Plains. Both calves and yearlings are fed in the lots. In 1967, high plains lots placed 43 percent of their cattle at weights below 500 pounds (50). A recent article suggests that light calves may still be the most profitable weights to feed (46).

The Clay Center data upon which the technical relationships are based used calves fed a silage and grain ration. The typical finishing rations fed in the High Plains range from 65 to 90 percent concentrates consisting mainly of grain sorghum, corn, and silages from those crops.

## The Feeder-Packer Interface

There are several marketing methods available to cattle feeders including terminals, auctions, direct sales, and order buyers. By far the most common method for large high plains lots is the direct to packer sale. In 1973, 92.8 percent of steers and heifers purchased by packers in Texas and Oklahoma were by direct sale. In the U. S., 82.4 percent were purchased by direct sale (162, Table V).

Within the direct selling method the basis for pricing and conditions of exchange can vary. Weight, USDA quality grade, and sex are the most important attributes used in pricing with live weight and estimated USDA quality grade the most common basis of exchange. Alternatives are selling on a carcass grade and weight basis, which eliminates the need to estimate dressing percentage, and on a yield grade basis which accounts for yield of lean retail cuts.

In 1973, in Texas and Oklahoma, only 10.2 percent of steers and heifers were sold on a carcass grade and weight basis (162, Table XI). Virtually none were sold on a carcass grade and yield grade basis. In this study it is assumed that steer sales are direct to the packer. The basis for price varies from estimated live grade and live weight to carcass grade and yield grade.

## The Packer Level

The packing industry has followed the trend in cattle feeding and new plants slaughtering up to 180 head of cattle per hour have been built near the sources of cattle in the West and Southwest. The synthesized plant used in this study is a powered on-the-rail plant with a slaughter capacity of 120 head per hour. Costs were estimated to be appropriate to the 120 head per hour rate which realizes most of the available economies of size. The function of the packing plant is to utilize live steers, labor and plant facilities to produce carcasses and by-products for sale.

## The Packer-Fabricator Interface

The great majority of carcass sales take place by telephone and are on a specification basis. In some instances the buyer will inspect carcasses in the cooler before purchase but more commonly they are bought on a descriptive basis and unacceptable carcasses, if delivered, are sent back (150).

Again, USDA carcass grade, weight and sex are the most important attributes for pricing. However, individual buyers can specify particular desires on attributes such as yield grade, fat thickness, maturity, color of lean, etc. In this study a steer carcass is priced on one of two bases, quality grade and weight ranges or quality grade and yield grade.

## The Fabricator Level

Although many carcasses are still delivered to the retail stores, an important and increasing segment of beef, estimated at 50 percent or more, passes through a fabricator stage. The boxed-beef method, as it is often called, allows mechanization and economies of size to be used in meat cutting. It also improves transportation efficiency since boxed beef can be moved on pallets with ordinary machinery. Some bone and fat which is removed need not be transported with the meat and is collected in amounts large enough to be economically processed and handled as by-products (81). In many cases, the fabricating plant is operated either by a packer or a retailer but for this study is considered to be an independent firm.

The function of the fabricator is to utilize carcasses, plant facilities and labor to produce fabricated, trimmed boneless cuts. Two levels of fat trim, .3 inches and .75 inches, are used and the beef is sold by USDA quality grade.

## The Retail Level

The retailing function is an important part of the beef industry but is not considered in this study. Pricing activities are considered more precise at the retail level since the consumer observes the product directly and selects products by price. Retail managers understand what is desired. Previous research has suggested the more important barriers to effective pricing and communication begin with the first transaction between the retailer and the fabricator (113). Therefore, the retailer-consumer interaction is not considered and the model is kept smaller and more manageable in scope.

## Objects, Attributes and Physical Relationships of Importance to the Beef Industry

Several of the attributes and relationships of importance in the beef industry are so important to production and pricing that they deserve special mention. Of particular importance are those attributes and relationships which affect the process of growth and composition.

### Bovine Growth and Composition

A complete understanding of the process by which beef animals grow and develop is presently beyond the grasp of science. Indeed, many questions which are ostensibly easily determined by experiment are under strong debate within the Animal Science discipline. This section will review some of the research and provide references for other research to provide a base of biological information for the production related part of this research. It is important to establish a useful description of the growth and development of beef animals which is amenable to mathematical representation and which yields results that approximate reality so that the model will be useful in decision making. Matters of concern are those which deal with the attributes of beef animals which are commercially important. These include feed and time required for growth, the composition of the growth in terms of meat, fat, and bone, and the descriptive terms applied to live animals and carcasses such as quality grade, yield grade, dressing percentage and cutability. In short, these are the attributes thought to have an important bearing on costs and value in all levels of the marketing system which are being considered.

The complexity of the problem and divergence of views is met even at the definition of growth. Many definitions have been advanced including (1) growth is a correlated increase in the mass of the body in definite intervals of time in a way characteristic of the species (129); (2) the production of new biochemical units brought about by cell division, cell enlargement, or incorporation of materials from the environment (17); and (3) an increase in weight until a mature size is reached (54).

There is no complete explanation as to why growth starts, how it is regulated, or why it stops at the point which characterizes adult development (62, p. 6). During growth cellular constituents are involved in a continuous breaking down and building up (catabolism and anabolism). Some investigators define growth to include development, others define development to include growth and no distinction is made with respect to the components of the increase in mass. Maynard and Loosli (93) maintained that true growth involves an increase in the structural tissue and excludes fat. Pomeroy (111), however, argues that there is no logical reason for regarding the deposition of fat in the fat depots as not being part of the growth process.

In the production of beef for meat, muscle with "some" fat is the desired end product. However the other components, especially excess fat, contribute materially to the cost of production and marketing. Further, offal is a saleable product so all the major components must be considered.

Although they are not unrelated, two approaches to the study of growth and development can be identified. The first and more complex might be called the metabolic control approach. This approach views all the inputs and outputs of a growing biological unit as being controlled by homeostatic mechanisms. A classic example is Klieber's hydraulic model of the control of food intake of a cow as presented by Brobeck (16). Other physical representations such as an electronic network model have been proposed in a mathematical system of dynamic differential equations (138, 173). However, a lack of both data and a sure theoretical understanding of the underlying controls, be they chemostatic, thermostatic, calorostatic, nitrogenostatic, or a combination of these persists.

A simpler approach and one that meets the needs of this analysis might be referred to as a growth-curve approach. Numerous studies have revealed the existence of a characteristic sigmoid or S-shaped functional relationship in individual components and in the total weight of an animal. Brody (17) divides growth into two principal segments and defines the initial phase as the self-accelerating phase and the second as the self-inhibiting phase. The first phase is explained biologically as a period when each cell reproduction unit in the body is generating new reproduction units. Therefore, the percentage growth rate is constant. The downward inflection of the second phase indicates the inhibiting effects of the environment as the process becomes limited by the resources available. As the body grows more and more, energy is consumed in maintaining the body and less is available for new growth. Eventually a maximum or mature limit is reached.

A fundamental law of growth, according to Brody (17) and McMeekan (96), is that the shape of the growth curve is similar in all species.

Hammond (55) reports that the order in which the various parts and tissues develop is much the same in all species since it is based on the relative importance of the functions of the parts or tissues for survival of the animal.

The order of tissue growth and development follows an outward trend from the central nervous system to bone, tendon, muscle, intramuscular fat and subcutaneous fat (96, 108). If these relationships are at least approximately general then a picture of the growth curves of the components of the body in relation to live weight can be envisioned. And, according to McMeekan, at any given weight the composition of the animal's body is related to the shape of its growth curve (95).

Many studies can be cited in which sequential slaughter of similar cattle at increasing weights confirms a general pattern of a slowly decreasing percentage of bone, a more rapidly decreasing percentage of muscle or protein, a slowly increasing ratio of carcass weight to live weight and, especially at higher weights, a quite rapid increase in the percent of fat. Two early extensive studies of growth of the bovine were by Moulton (102) at Missouri, and Haecker (51) at Minnesota. Figure 3 displays graphical relationships taken from Haecker. More recent data displayed the same general relationships. Tables II through VIII display data from several sources exhibiting such general relationships. The idea that bone is earliest maturing, muscle later and fat latest is well established.

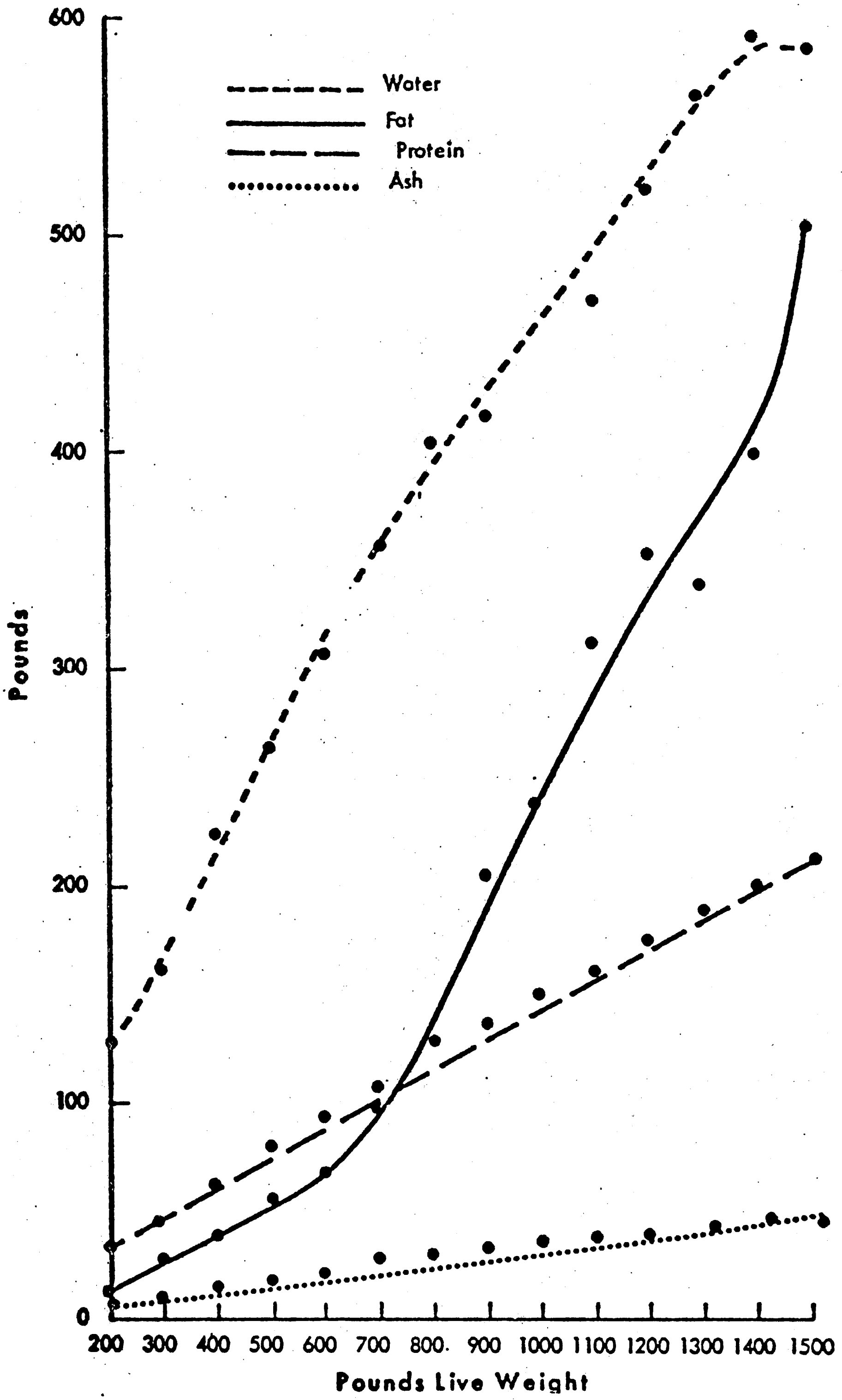

Figure 3. Typical Relationships for Weight of Beef Body Components Versus Liveweight.

## TABLE II

## COMPOSITION OF STEERS AT GIVEN WEIGHTS

| Normal Weight | Number of Steers | Empty Body Weight | Carcass Weight[a] (cold) | Percent of Cold Carcass Weight[b] | | Percent of Empty Body of Weight | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | Protein | Fat | Water | Protein | Fat | Ash |
| 100 | 5 | 84.8 | 58.0 | 20.0 | 4.6 | 71.8 | 19.9 | 4.0 | 4.3 |
| 200 | 4 | 157.9 | 105.6 | 19.9 | 7.2 | 70.4 | 19.1 | 6.0 | 4.4 |
| 300 | 4 | 244.9 | 165.0 | 19.4 | 12.3 | 65.7 | 18.8 | 11.2 | 4.3 |
| 400 | 5 | 326.6 | 226.0 | 19.9 | 11.5 | 65.7 | 19.3 | 10.6 | 4.3 |
| 500 | 5 | 414.6 | 293.9 | 19.7 | 14.9 | 62.9 | 19.2 | 13.7 | 4.2 |
| 600 | 3 | 487.0 | 342.5 | 19.8 | 15.8 | 61.2 | 19.4 | 15.0 | 4.3 |
| 700 | 4 | 580.9 | 415.0 | 18.5 | 17.7 | 60.3 | 18.6 | 16.6 | 4.5 |
| 800 | 3 | 679.1 | 486.4 | 18.8 | 19.7 | 58.4 | 18.8 | 18.5 | 4.2 |
| 900 | 3 | 769.6 | 561.4 | 17.6 | 25.9 | 54.1 | 17.6 | 24.1 | 4.2 |
| 1000 | 4 | 873.6 | 632.6 | 17.2 | 28.7 | 52.0 | 17.1 | 26.9 | 3.9 |
| 1100 | 3 | 968.7 | 703.2 | 16.6 | 34.2 | 47.8 | 16.4 | 32.0 | 3.8 |
| 1200 | 3 | 1085.8 | 794.3 | 16.2 | 33.4 | 48.0 | 16.0 | 32.3 | 3.7 |
| 1300 | 2 | 1148.6 | 834.2 | 16.3 | 33.6 | 47.9 | 15.8 | 32.5 | 3.8 |
| 1400 | 1 | 1224.0 | 918.5 | 16.6 | 34.1 | 47.7 | 16.2 | 32.5 | 3.5 |
| 1500 | 1 | 1344.9 | 977.0 | 16.1 | 38.6 | 43.4 | 15.7 | 37.6 | 3.2 |

Source: Haecker, T. L. Investigations in Beef Production. Minnesota Agricultural Experiment Station, Bull. 193, 1920.

[a] Flesh + bone + cartilage + tendon

[b] Weight of chemical components in flesh, bone, cartilage and tendon divided by weight of those components.

## TABLE III

## CARCASS, RETAIL PRODUCT MEANS FOR CATTLE SLAUGHTERED AT TEN-DAY INTERVALS

| | Slaughter Group by Days on Feed | | | | | |
|---|---|---|---|---|---|---|
| Measure | 105<br>20 Steers | 115<br>20 Steers | 125<br>20 Steers | 135<br>20 Steers | 145<br>20 Steers | 155<br>20 Steers |
| Shrunk Live Weight | 1119 | 1159 | 1186 | 1192 | 1235 | 1251 |
| Hot Carcass Weight | 724.0 | 750.5 | 777.3 | 780.2 | 808.6 | 809.7 |
| Cold Carcass Weight | 711.2 | 735.8 | 762.3 | 765.5 | 795.4 | 800.6 |
| Yield Grade | 3.0 | 3.4 | 3.6 | 3.5 | 4.3 | 4.5 |
| Quality Grade[a] | 10.4 | 9.9 | 10.3 | 10.3 | 11.0 | 10.8 |
| Marbling[b] | 12.7 | 11.3 | 12.9 | 1.3 | 14.3 | 14.7 |
| | Percent of Carcass Weight | | | | | |
| Retail Product Including Trim | 76.1 | 76.2 | 76.0 | 75.3 | 74.7 | 74.1 |
| Retail Product Excluding Trim | 44.7 | 43.6 | 43.7 | 43.1 | 42.3 | 41.8 |
| Retail Product, Four Major Primals, Including Trim | 61.8 | 61.4 | 61.1 | 60.5 | 59.6 | 58.8 |
| Retail Product, Four Major Primals, Excluding Trim | 42.7 | 39.6 | 39.4 | 39.0 | 38.5 | 37.7 |
| Retail Product, Three Major Primals, Including Trim | 41.3 | 14.8 | 14.9 | 14.7 | 15.2 | 15.4 |
| Removed Fat | 7.8 | 8.3 | 11.4 | 10.8 | 12.9 | 12.2 |
| Bone | 14.8 | 14.6 | 14.8 | 14.8 | 14.3 | 14.5 |

Source: Original data

[a] 10 = choice -, 11 = choice, etc.

[b] 10 = small -, 11 = small, etc.

## TABLE IV

## MEANS OF COMPOSITION AND CARCASS TRAITS OF THE LEFT SIDE OF GROUPS OF HEIFERS

| Component or Trait (unit) | 6 Heifers 9 mo. | 6 Heifers 9 mo. | 6 Heifers 9 mo. | 6 Heifers 9 mo. | 6 Heifers 9 mo. | 6 Heifers 9 mo. |
|---|---|---|---|---|---|---|
| Slaughter Wt. (lb.) | 451.8 | 519.7 | 712.2 | 844.3 | 1083.3 | 1183.6 |
| Cold Carcass Wt. (lb.) | 257.2 | 305.4 | 440.9 | 549.3 | 665.6 | 778.8 |
| Dressing Percent | 56.8 | 58.7 | 61.9 | 65.1 | | |
| Carcass Grade | standard | good - | good + | good + | NA | NA |
| Marbling Score | traces | traces | small | small | modest | mod. abundant |
| Yield Grade[a] | 2.5 | 3.1 | 3.6 | 4.6 | 4.8 | 5.9 |
| | | | | | | |
| Morphological Components | | | | | | |
| Lean Meat (percent of side) | 55.7 | 53.1 | 47.3 | 45.9 | 41.0 | 42.1 |
| Fat (percent of side) | 25.0 | 38.9 | 34.0 | 37.3 | 41.4 | 43.1 |
| Bone (percent of side) | 19.3 | 18.0 | 18.7 | 16.9 | 17.7 | 14.8 |
| | | | | | | |
| Histological Components | | | | | | |
| Protein (percent of side) | 17.6 | 17.5 | 15.4 | 14.2 | NA | NA |
| Ether Extract (percent of side) | 23.1 | 25.6 | 32.3 | 36.8 | NA | NA |
| Moisture (percent of side) | 57.8 | 56.2 | 52.2 | 48.6 | NA | NA |
| Ash (percent of side) | .9 | .8 | .7 | .6 | NA | NA |

Source: Henrickson, R. L., et. al., The Study of the Influence of Bovine Age Upon the Characteristics of Meat and Carcass Grade. Unpublished research under Contract 12-25-010-576 USDA. Oklahoma State University, 1964.

[a] Yield grade was not given in the publication but was estimated from date given in the study and a knowledge of the yield grade functional relationships.

# TABLE V

## MEANS OF COMPOSITION AND CARCASS TRAITS OF STEERS AND HEIFERS FED 3 SUCCESSIVE 98 DAY PERIODS

| Component or Trait (units) | Period 1 | | Period 2 | | Period 3 | |
|---|---|---|---|---|---|---|
| | 8 Steers | 8 Heifers | 8 Steers | 8 Heifers | 8 Steers | 8 Heifers |
| Shrunk Slaughter Wt. (lbs.) | 741 | 718 | 1010 | 923 | 1191 | 1014 |
| Empty Body Gain (lb./day) | 2.4 | 2.48 | 2.68 | 2.23 | 1.9 | 1.25 |
| Dressing (percent) Hot Basis | 59 | 60.1 | 62.6 | 64.4 | 66.4 | 64.3 |
| Chemical Fat as Percent of Carcass | 24.5 | 29.4 | 32.4 | 36.8 | 37.9 | 41.4 |
| Marbling Score[a] | 3.8 | 4.6 | 5.3 | 6.0 | 5.8 | 8.2 |
| Quality Grade[b] | 11.5 | 12.4 | 13.3 | 14.4 | 13.4 | 16.3 |
| Yield Grade[c] | 2.1 | 2.6 | 3.2 | 3.4 | 4.2 | 4.5 |
| | Chemical Composition of the Empty Body Weight Gain | | | | | |
| Water (percent) | 46.9 | 37.9 | 36.9 | 31.5 | 28.2 | 20.8 |
| Fat (percent) | 35.3 | 47.1 | 48.5 | 55.6 | 60.0 | 69.7 |
| Protein (percent) | 14.5 | 12.2 | 11.9 | 10.5 | 0.6 | 7.7 |

Source: Garrett, W. N. "Comparative Performance and Carcass Characteristics of Heifers and Steers Under Identical Management Practices". Proceedings of the University of California Feeders Day, 1970.

[a] 5.8 = modest, 8.2 = slightly abundant

[b] 13.4 = low choice, 16.3 = prime

[c] Yield grade was not published but was estimated from carcass data given.

# TABLE VI

# MEANS FOR COMPOSITION AND CARCASS TRAITS FOR FIVE GROUPS OF HEREFORD AND ANGUS STEERS[a]

| Component or Trait (units) | Days on Feed and No. of Animals | | | | |
|---|---|---|---|---|---|
| | 139 days 40 Steers | 167 days teers | 195 days 40 Steers | 223 days 40 Steers | 251 days 40 Steers |
| Slaughter Wt. (lbs.) | 918 | 947 | 971 | 1046 | 1074 |
| Dressing (Percent) (Hot Basis) | 58.9 | 57.9 | 60.2 | 61.7 | 61.3 |
| Trimmed Retail Cuts as Percent of Right Side[a] | 71.0 | 67.6 | 66.5 | 65.6 | 64.0 |
| Trimmed Fat as Percent of Right Side | 15.8 | 19.2 | 20.6 | 22.2 | 23.6 |
| Percent Bone | 13.0 | 13.0 | 12.7 | 12.1 | 12.3 |
| USDA Quality Grade[b] | 17.1 | 18.5 | 19.2 | 19.3 | 19.0 |
| USDA Yield Grade | 2.8 | 3.4 | 3.5 | 3.7 | 3.8 |

Source: Stringer, W. C., et. al., "Effect of Full Feeding for Various Periods and Sire Influence on Quantitative and Qualitative Beef Carcass Characteristics". Journal of Animal Science, Vol. 27, No. 6, November, 1968.

[a] Cuts were practically boneless and trimmed to less than 1 cm. outside fat.

[b] 17 = average Good, 18 high Good, etc.

## TABLE VII

## MEANS OF COMPOSITION AND CARCASS TRAITS OF FOUR GROUPS OF HEREFORD STEERS

| Component or Trait (units) | Days on Feed and No. Animals<br>185 days<br>43 Steers | <br>207 days<br>45 Steers | <br>255 days<br>43 Steers | <br>308 days<br>46 Steers |
|---|---|---|---|---|
| Slaughter Wt. (lbs.) | 776 | 900 | 974 | 1076 |
| Dressing Percent | 59.4 | 59.0 | 61.4 | 61.5 |
| Trimmed Retail Cuts as a Percent of Carcass Wt.[a] | 64.2 | 63.6 | 59.2 | 59.2 |
| Trimmed Fat as a Percent of Carcass Wt.[a] | 21.5 | 22.0 | 27.3 | 28.0 |
| Marbling[b] | 3.9 | 4.8 | 5.6 | 6.4 |
| Yield Grade[c] | 3.0 | 3.1 | 3.8 | 3.8 |

Source: Dinkel, C. A., et. al., "Changes in Composition of Beef Carcasses with Increasing Animal Weight". Journal of Animal Science, Vol. 28, No. 3, March, 1969.

[a] Cuts were practically boneless and trimmed to less than 7.5 mm. outside fat.

[b] 4 = slight amount, 5 = small amount, 6 = modest, etc.

[c] Yield grade was not published but was estimated from carcass data given.

## TABLE VIII

## MEANS OF COMPOSITION AND CARCASS TRAITS OF FOUR GROUPS OF ANGUS STEERS

| Component of Trait (units) | Days on Feed and No. Animals<br>118 days 6 Steers | 109 days 7 Steers | 202 days 7 Steers | 242 days 5 Steers |
|---|---|---|---|---|
| Slaughter Wt. (lbs.) | 686 | 900 | 1069 | 1269 |
| Dressing Percent | 55.8 | 59.9 | 60.5 | 61.5 |
| Trimmed Retail Cuts as a Percent of Carcass Wt.[a] | 68.7 | 66.9 | 58.6 | 55.5 |
| Trimmed Retail Cuts as a Percent of Live Wt.[a] | 37.2 | 39.1 | 33.6 | 33.2 |
| Trimmed Fat as a Percent of Carcass Wt.[a] | 8.8 | 12.4 | 16.9 | 20.0 |
| Marbling[b] | 3.8 | 6.6 | 6.7 | 7.6 |
| Yield Grade[c] | 2.0 | 3.0 | 3.7 | 4.9 |

Source: Dinkel, C. A., et. al., "Changes in Composition of Beef Carcasses with Increasing Animal Weight". Journal of Animal Science, Vol. 28, No. 3, March, 1969.

[a] Cuts were practically boneless and trimmed to less than 7.5 mm. outside fat.

[b] 4 = slight amount, 5 = small amount, 6 = modest, etc.

[c] Yield grade was not published but was estimated from carcass data given.

## Relationship of Growth and Composition to Genetic and Management Factors

Despite the early understanding of a general pattern of growth, many studies of beef animals have been undertaken in such a way as to give misleading if not technically incorrect results. Many researchers have set up projects to investigate the effect of one practice or attribute on some other attribute or attributes. Examples of these are the effect of breed on plane of nutrition, sex on feed efficiency, or average daily gain on carcass merit. These trials are usually terminated when the test animals are of equal weight or alternatively have been on feed for an equal period of time. Two animals with different growth curves and different mature weights which are included in such studies will attain different proportions of mature weight and will therefore be expected to contain different distributions of tissue types in the body.

It is known that the energy requirements of a growing animal for maintenance increase in proportion to metabolic weight and requirements for gain increase as more fat and less protein and water are included in the gain. Water requires essentially no energy and protein deposition requires about one-half that of fat. Thus, animals slaughtered at an earlier percentage of their mature size would logically tend to have a lower percentage of fat, have a lower dressing percentage, a lower yield grade, less marbling and therefore a lower quality grade than one slaughtered at a higher percentage of its mature size. Similarly, comparable animals fed at different nutritional planes for the same time periods would be at different percentages of mature size with predictable differences in results.

Hedrick (62) summarizes a great deal of research on growth and composition reporting effects quite often consistent with this general view. A summary of the conclusions drawn by Hedrick and other selected authors concerning factors affecting growth is presented to provide a background for the analysis.

Breed and Type. Hedrick summarizes 26 research reports on breed. These are difficult to evaluate because of differences in procedures and attributes measured but in general "small" breeds such as Angus or Shorthorn, when evaluated at constant time or weight, tended to have a higher proportion of fat, grade higher, contain a lower proportion of saleable meat, have higher dressing percentages and have lower feed efficiency than "larger" breeds such as Holstein or Charolais. Herefords tend to fall between the Angus and Charolais on most attributes. In the few studies where comparisons were made at similar "finish", a proxy for realized percent of mature weight, these compositional differences tended to disappear. There does, however, seem to be a significant difference in the distribution of fat deposits across breeds. For example, even at a similar percent of total fat, dairy breeds tend to deposit more fat in the body cavity and less as subcutaneous fat. Similarly, there appears to be a difference across breeds in the degree of marbling compared with the other fat deposits.

Much recent work has been directed at the relationship between size or type and efficiency. Today, even though over 90 percent of the value of the live animal is in the meat, most cattle are sold on a liveweight basis. Consequently, efficiency is often measured on a feed per pound of live gain basis.

Klosterman reports that there is a high correlation between rate of gain and efficiency of gain but that rate of gain is also positively related to mature size. Thus, when selective breeding emphasizes rate of gain the result is a trend toward larger cattle. A large proportion of feed use is for animal maintenance and the larger the animal the greater the maintenance requirements (75, p. 875).

Cartwright (22) has pointed out that the industry carries two animals in the breeding herd for each animal going to slaughter. Cartwright outlined a system using small, early maturing and fertile cows with large, efficient bulls selected for production and carcass traits. This procedure would also utilize the advantages of heterosis, or hybred vigor, which tends to increase calving rates and performance of calves (29).

Hultz (66) reported very little difference in economy of production between low-set and very rangy Hereford calves. Knox and Koger (77) reported little difference in efficiency among rangy and compact Hereford steers. Garrett (44) found that Hereford steers stored more fat than Holstein steers but were fully as efficient in converting feed energy to tissue calories. Klosterman, et al., (76) found no significant differences in efficiency of feed utilization among Hereford, Charolais, and crossbred steers when fed to similar grades.

An extensive experiment is reported by Brungardt (18) in which steers of three breeds, Angus, Hereford, and Charolais, and seven size types within each breed were fed under similar conditions with the aim of feeding all animals to the Choice grade. Profit per head was directly related to type category, which ranged from 1 through 7 with 1 being the smallest. Type and profit per head were respectively: type 1 = $.60, type 2 = $8.19, type 3 = $15.38, type 4 = $19.27, type 5 = $22.65, type 6 = $24.65, and type 7 = $30.79. The advantage is apparently with larger types. However, further examination reveals the profit differences are due not to differences in physical efficiency, but to the prices which were paid for feeders and received for carcasses. Some of the general conclusions reached by Brungardt are as follows:

1. At the same weights, faster gaining cattle are more efficient than slower gaining cattle of smaller mature weights.

2. At the same quality grade, faster gaining cattle are almost as efficient as the smaller and slower gaining cattle.

3. Faster gaining cattle are approximately as efficient at their heavier weights as smaller cattle at their lighter weights when both groups are at a comparable percent of mature weight.

4. The ideal situation for a feeder would be to purchase cattle bred for growth but not fed sufficiently to express this capability.

5. Cattle selected for fast growth give no feed conversion advantage when feeding to the Choice grade if the cattle are purchased at heavier weights commensurate with their growth potential.

6. While feed conversion in the feedlot may not be superior for cattle selected for gain which produce larger animals, numerous other economic reasons exist for selection for growth. Faster gaining cattle may not necessarily be more efficient in the feedlot but due to fixed costs, etc. are expected to be more profitable.

7. Cattle of varying growth potentials within a breed and cattle of all breeds marble and grade when they reach compositional maturity commensurate with the fat deposition required to marble.

8. Larger breeds require longer feeding periods to reach Choice carcass grades and achieve heavier slaughter weights. Appraising cattle of various breeds at constant or equal weight-end points results in comparing cattle at different stages of their growth curve. This fails to recognize differences in composition, quality grade, and economic market value.

Sex. It is commonly accepted throughout the beef industry that there are differences in composition and value of beef carcasses due to sex-associated characteristics. Hedrick (62) reports on over 30 studies of sex related characteristics, and in another publication makes this summary:

> Bulls surpass steers and steers usually surpass heifers in feed efficiency and rate of gain. At comparable age, length of feeding period, or live weight bulls produce carcasses that are leaner than steers and steers likewise produce carcasses that are leaner than heifers (61, p. 872).

In assessing this statement special note should be taken of the phrase "at comparable age, length of feeding period or live weight...". Again, results are dependent upon the stage of development at which an experiment is terminated. Kennedy (1958) reported steers and heifers to be of similar grade when slaughtered at similar finish. Steers had less finish than heifers at the same time on feed but when steers were fed 50 days longer, they closely matched the heifers in terms of degree of finish.

Garrett performed an extensive experiment "...designed to investigate the various basic factors which might be responsible for the practical observation that heifers are 'less efficient' than steers under similar feeding circumstances" (43, p. 10). His conclusions:

> The results of these trials indicate that heifers and steers are not different in their ability to convert feed energy into body energy. Heifers, however, reached a carcass

> composition typical to the low Choice grade about 60 days (sooner) and 200 lbs. lighter than steers when fed the same ration. The reason for this finding was the greater quantity of fat stored in each pound of gain made by the females. The marked increase in feed per pound of gain for both sexes as the feeding period progressed was due to a combination of less feed being consumed in relation to the maintenance requirement and the increase in fat content of the gain (43, p. 12).

Evidence is strong that differences in growth and composition by sex is due predominantly, if not entirely, to differences in mature size and rates of maturing.

Management. A third broad category of factors which are known to affect growth and composition of beef animals are the environmental factors, some of which can be manipulated by the manager or decision maker. The most important of these is plane (or planes) of nutrition. A second is the use of growth promotants such as Stilbestrol, Ralgro, or Synovex.

The beneficial effects of growth stimulants are well documented (20, 62, 144). A reasonable estimate is that DES (diethylstilbestrol) improves weight gains of steers up to 15 percent and improves feed efficiency by 10 percent. Similar effects have been shown with Synovex. Ralgro is slightly less effective. More information is available on what they do than on how they do it. However, some of what is known about the effects of growth promotants is consistent with the hypothesis that it effectively increases the mature size of an animal. Baker and Arthaud (7) report on more than 30 experiments with growth promotants and report that response to treatment of bulls indicates little or no likelihood of field application of the growth promotants for bulls. Williams, et al., (168), report no advantage in daily gain for bulls fed although there was an observable decrease in masculine features of the live bulls on DES. Baker and Arthaud (7) also describe the effect of promotants on steers and heifers as producing a lower percent of fat and a higher per cent of protein in the carcass at a given weight. This would explain better feed efficiency. They also report a similarity between the response of castrates to diethylstilbestrol and a difference in the growing and finishing patterns between young bulls and their castrated counterparts. Another report by Lofgreen (89, p.9) reported that implanted cattle consumed more feed, gained more weight, exhibited reduced fat content, and had increased protein content in the body. For purposes of this analysis, therefore, the administration of growth promotants is considered to be similar to increasing the mature size of an animal and can be effective only with heifers and steers and not with bulls. This approach is consistent with increased average daily gain, feed efficiency, and protein deposition at a given weight.

Nutrition and Management. Even though a great amount of research has been done to relate nutrition to beef animal growth and composition, there are still basic principles upon which animal scientists disagree. Hedrick acknowledges the complexities and limitations of research in this area by stating, "It is almost impossible to separate the effects of growth, age, and nutrition because, under normal conditions of adequate nutrition, these factors may be closely related" (62, p. 167).

Some authors report compositional effects related to the order of different planes of nutrition or different management practices. Hammond (56) reported in the 1930's that growth occurs in overlapping phases. This led many to believe that high levels of nutrition during the early period of growth leads to a leaner product. Conversely, many feedlot operators have claimed that feeding a high energy ration too soon will cause cattle to "top out" too soon and become fatter at comparable weights. The NRC (104) tables suggest that calves fed directly after weaning will reach the Choice grade at a lighter weight than will yearling steers. The debate continues.

The pioneering work by Moulton (102) constributed to the common belief that higher planes of nutrition will produce a faster growing and fatter animal at a given slaughter weight. Commenting on Moulton's work, Hedrick (62, p. 19) reported that the main effect of age and plane of nutrition on the composition of parts and total animal was through a change in fat content which increased in most cases with age and plane of nutrition.

More recent work by various reseachers, as reported by Hedrick (62), compared animals on hay, corn silage, and corn concentrate rations. Considerable differences in pounds of fat and percent edible portions were observed.

An experiment by Lofgreen showed a difference in carcass fat for nutritional planes but the results are for equal time on feed and not for equal weights. Lofgreen concluded that "if the consumer is willing to accept a product with less fat, more protein, and less marbling, this product can be produced at the same weight as our present slaughter animals by feeding different energy levels" (112, p. 22).

Guenther, et. al., (49) reported on the growth and development of major carcass tissues in beef calves from weaning to slaughter weight with reference to plane of nutrition. Thirty-six Hereford steer calves were alloted to one of the six following treatment groups; Lot W, slaughtered at weaning; Lot $H_1$, calves were fed on a high plane of nutrition to 125 Kg. postweaning gain, then slaughtered; Lot $M_1$, calves were fed on a moderate plane of nutrition and slaughtered at the same time as the $H_1$ calves and termed age constant calves; Lot $H_2$, calves were fed on a high plane of nutrition to 205 Kg. postweaning gain, then slaughtered; Lot $M_2$ calves were fed on a moderate plane of nutrition and slaughtered at the same time as the $H_2$'s; Lot $M_3$ calves were fed on a moderate plane of 205 Kg. postweaning gain and slaughtered on a weight-constant basis with the $H_2$ calves. Significant differences were found with, and only with, the $H_2$ to $M_2$ comparison. The $H_2$'s were fatter with about 25 Kg. more fat in the carcass.

Berg and Butterfield, in a review of growth and composition report "A high plane of nutrition has often been shown to increase the proportion of fat in a carcass" (8, p. 613). Although other sources were cited they stated that this point was illustrated most dramatically by the Guenther data. In contrast, papers from Winchester and others (171, 172) present data obtained using identical twins where one member of the pair was restricted in plane of nutrition for periods of three to six months while the other twin was given a high plane of nutrition. Estimation of carcass composition from separable components of the 9-10-11th rib indicated that the compositon of the carcass was not appreciable altered by a restricted period of growth. Although the restricted energy calves took longer to attain the same weight after coming back on feed, they used approximately the same total energy.

Preston (112) examined the research on nutrition and composition and concluded that the differences reported by Guenther were not significantly different. He reanalyzed Lofgreen's data and found that 92 percent of the variation of final body fat was associated with variation in carcass weight leaving eight percent to be explained by yearling vs. calves, plane of nutrition and random error. Preston noted that those treatments which result in faster gain resulted in heavier carcasses which in turn resulted in a higher final body fat percentage. Preston also concluded that energy plane failed to predict whether a carcass tended to be fatter or leaner than the least squares mean for its weight or whether it has a higher or lower marbling score than the least squares mean for its weight.

Topel, et al., (146) utilized twenty crossbred steers with Hereford-Angus dams, 10 having Charolain sires and 10 having Angus sires. The steers were all weaned at 400 pounds and fed a growing ration to 500 pounds. The steers were then paired by sire and randomly assigned to a high energy feeding treatment or to a restricted energy treatment to achieve a rate of gain approximately two-thirds that of the high energy steers. Four steers were slaughtered at 500 pounds, eight at 800 pounds, and eight at 1100 pounds. All cattle were compared for carcass traits. Their conclusion was that level of energy consumption, when regulated by level of feed intake, has no major influence on dressing percentage, carcass quality, or the muscle, fat, and bone percentage of the carcass when the cattle are compared at an equal slaughter weight. The full fed cattle were more efficient in live weight gain.

Garrett did a similar experiment feeding different roughage concentrate rations to heifers and concluded "...the cattle feeder who is fattening heifers to a given weight or grade cannot expect the energy concentration of the ration to have a very profound influence on carcass composition" (44, p. 26). Garrett also reported that his results on heifers matched those of an earlier experiment by Lofgreen for steers "...in which the final carcass composition of beef steers fed different energy levels was nearly the same when comparisons were made after each group had gained an equivalent amoung of weight" (44, p. 25).

Compensatory Gain. When cattle are put on reduced feed at young ages and later put on full feed the increased rate of gain and efficiency is often referred to as compensatory gain. Several studies have attempted to evaluate this phenomenon (40, 65, 71, 87, 99, 145). These studies show that animals in the early stages of compensatory gain eat more, gain faster, convert feed more efficiently, deposit more protein and less fat than similar genetic animals of similar weight that have been fed on full feed. However, toward the end of this compensatory period more than the normal amount of fat is deposited leaving the final composition at slaughter weights approximately the same. Differing results in total feed efficiency were reported but total feed intake for compensatory steers or heifers was usually quite similar to the full-fed groups. Riley (126) and Hedrick (61) found also that a lack of protein in a ration slowed growth but did not alter the pattern of protein and fat deposition.

This summary by Preston (112) seems to adequately describe the state of knowledge on growth, nutrition and compositon :

1. Within the practical realm of rations fed to cattle and sheep, plane of nutrition will not affect the gross chemical composition of their carcasses. This is not to say that there are no histological changes or changes in the distribution or fat, or in the distribution of the proteins that constitute lean meat. There may be a plane of nutrition, perhaps one that results in a negative energy balance, where the carcass composition may be permanently affected.

2. Reduced planes of nutrition, expecially those that result in compensatory growth when cattle are placed on full feed, yield cattle with altered body composition, at least for a period of time; however, they appear to approximate a body composition similar to cattle that have been continuously fed by the time they reach slaughter weight. In these cases, body or carcass weight does not predict body composition during this compensatory period.

3. Long periods of weight loss in cattle and sheep (negative energy balance) may result in a loss of protein from the body. When placed on full feed, cattle and sheep may not be able to compensate for this protein loss and therefore yield carcasses with more fat and less lean meat.

4. Variation in the composition of cattle carcasses is probably more of an effect of slaughter weight, expecially if expressed as a proportion of mature body weight. Variation in cattle carcass composition may best be achieved by varying slaughter weight and mature weight and not by varying planes of nutrition.

The weight of this research makes it reasonable to assume that no large error of omission will be committed by limiting the model to a single sex (steers) and to a single energy plane. The analysis is greatly simplified by these limitations and it can be argued that the loss of accuracy is small since the same principles of growth seem to apply to all sexes and similar carcass attributes seem to develop regardless of feeding regime, if the animal is fed to a constant slaughter weight.

## Nutrient Requirements

The energy requirements for beef cattle are usually expressed in calories of energy. Energy is not the only important nutrient but is usually considered the common denominator of a ration with protein vitamins and minerals being balanced with the energy concentration and consumption to obtain optimum performance.

There is a continuum of measurements for energy in a ration beginning with gross energy (GE) which is the total combustible energy contained in animal feed. Fecal energy (FE) is the gross energy of the feces. Gaseous products of digestion (GPD) includes the combustible gases (mainly methane) produced in the digestive tract during fermentation of the ration. Urinary energy (UE) is the gross energy of the urine. Metabolizable energy (ME) is the food intake gross energy minus fecal energy, minus energy in the gaseous products of digestion, minus urinary energy. Heat increment (HI) is the increase in heat production following consumption of food when the animal is in a thermoneutral environment.

Net energy (NE) is the difference between metabolizable energy and heat increment used either for maintenance only or for maintenance plus production. Net energy can also be expressed as the gross energy of the gain in tissue or of the products synthesized plus the energy required for maintenance. Net energy for maintenance (NEm) is the fraction of net energy expended to keep the animal in energy equilibrium with neither a net gain nor loss of energy in the body tissues. Net energy for production (NEp) is the fraction of net energy that is used for work or for tissue gain or for the synthesis of a fetus, milk, eggs, wool, etc.

Basal metabolism (BM) is the chemical change that occurs in the cells of an animal in the fasting and resting state. Energy of voluntary activity (VA) is the amount of energy needed by an animal to get up, move around, eat, drink, etc. Total heat production of an animal consuming food in a thermoneutral environment is composed of the heat increment plus heat used for maintenance in metabolism and activity (103).

The most commonly used energy measurements in beef nutrition are net energy, metabolizable energy and total digestible nutrients (TDN). The older TDN and ME systems have been criticized because the requirements for a given animal vary with the roughage concentrate ratio of the ration (104, p. 3). Early NE systems were criticized for their failure to evaluate roughages accurately for their use in maintanence levels of feeding (104, p. 3). As an example, low quality alfalfa hay has 42/87 the value of barley for maintenance, but only 8/58 the value of barley for producing gain (47, p. 1).

Drs. Lofgreen and Garrett developed a useful multiple net energy system which separates animal requirements and feed contributions for maintenance and for production. They empirically determined beef maintenance requirements to be equal to:

$$NE_m = 0.77W^{0.75}, \tag{1}$$

where $NE_m$ is net energy requirements per day in Mcal. per day, W is animal weight in kg., and $W^{.75}$ is commonly referred to as metabolic weight. The maintenance requirements are not different for steers and heifers. The NEg requirements are given respectively for steers and heifers as:

$$NEg = (p.05272g + 0.00684g^2)\ (W^{.75}), \tag{2}$$

and

$$NEg = (0.05603g + 0.01265g^2\ (W^{.75}), \tag{3}$$

where NEg is in Mcal. per day and g is gain per day in kg. (88, p.795).

One limitation of this system is that the relationships "work" for "typical cattle" and adjustments are necessary for early maturing or late maturing cattle. Just as a different equation is necessary for steers and heifers, a different equation would be appropriate for cattle of different genetic size. As of yet such equations or a priori methods of adjustment have not been published.

Since this study is concerned with different genetic sizes of beef animals the Lofgreen and Garrett gain equations were not considered best. Instead, the composition of empty body gain in the two major chemical components of fat and protein for each day is computed by a growth simulator and the amount of feed required to provide necessary Mcals. of net energy to synthesize the fat and protein necessary are "used" by the animal in the model. It is assumed that the necessary water, vitamins, and minerals are present in the ration and that stilbestrol is fed orally.

# CHAPTER IV

# THE MODEL AND DATA

A model to analyze the communication system was constructed to meet the general objective of quantifying the inefficiencies in resource allocation due to communication barriers in the production and marketing system for beef. It is a micro model since only one firm is represented at each of the four subsystem levels. An attempt is made to isolate the important objects, attributes, and relationships at each of the four levels. No attempt is made to simulate bargaining or the actual physical functions of marketing firms in interfacing the various stages of economic activity. The model is static in that the results from one set of operating conditions or constraints are compared with the results of some other set of operating conditions and no time path is generated. Time is considered, however, in the sense that one of the decisions made by the feeding subsystem is the length of the feeding period for a particular breed type.

There are two separate components to the model. The first is a mathematical simulation of growth and composition which computes the inputs (feed and feedlot facility) required to feed a steer of each of 14 breed types. It also computes the attributes (live weight, carcass weight, dressing percentage, yield grade, quality grade, and trimmed lean for two fat trim thicknesses) of each breed type as the feeding period increases in length.

The second component is a mathematical programming (LP) model. Mathematical programming in its many forms has probably been the most widely used tool in economic systems analysis. A more complete discussion of linear or mathematical programming is available in many references (31, 60, 86).

In this model each of the four levels of the production-marketing continuum forms a subsystem with its own inputs and outputs. Output of one level becomes an input for succeeding stages.

As in any LP problem, the objects, attributes, relationships, and the environment must be posed as activities, constraints, a right hand side, and an objective function. The activities typically represent actions of decision makers in the system. The coefficients typically represent an accounting of flows of inputs and outputs through the system. Various marketing conditions or information structures[1] can be simulated by manipulating the particular set of activities eligible to enter the basis and by changing the objective function.

## Subsystem Decision Processes

The decisions made at each subsystem level are integral parts of the model. A brief description of the basic decisions at each level will facilitate understanding of the operational aspects of the model.

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[1] The terms "information structure" refer to a combination of product attributes and associated prices of importance to decision makers in exchange processes. More detailed explanation is offered later in the chapter.

## The Cow-Calf Subsystem

The available fixed resource of the cow-calf subsystem is a cow herd. The choice of a sire and dam combination from fourteen genetic possibilities to produce a single composite calf is the major decision of the cow-calf subsystem. Each breed combination incurs a unique cost in that reproductive performance, which varies across breeds, will dictate the amount of resources necessary to produce a weaned unit calf. The particular information system faced by the cow-calf subsystem determines the exact remuneration from the feeder subsystem.

## The Feeding Subsystem

The output (unit calf) produced by the cow-calf subsystem is passed to the feeding subsystem through the marketing interface activities. The feeder makes two important decisions given an information structure: First, what breed type(s) to purchase and second, how long to feed the type(s) purchased. The feed (energy) requirements and the attributes of a produced steer are provided by the feedlot simulator and the pricing information structure is provided by the price and attribute combinations considered in selling from the feeder to the packer subsystems. For example, the simplest information structure would provide a price schedule for live weight ranges only. The most complex structure would include a price schedule for carcass quality grade and yield grade. Other structures fall along the continuum between the simple and the most complex structures.

An additional variation in the decision structure of the cattle feeder allows two different goals. The feeder can maximize returns for a given animal, as would be the case for a cornbelt feeder having only one turnover per year, or he can maximize returns per unit of time. Maximizing over time would be the most appropriate goal of a continuous feeding operation which replaces an animal on feed and has multiple turnovers per year.

### The Packer Subsystem

The packer subsystem must decide within an information structure what animal(s) to buy, kill, and dress. Since costs for the packer tend to be incurred on a carcass basis rather than a weight basis (14, p. 5), the packer would prefer a heavy carcass to a light one if cattle are purchased for the same price per pound.

### The Fabricator Subsystem

The function of the fabricator is to break the carcass into retail cuts. The fabricator's most important decision is what carcasses to buy in order to maximize returns to his investment. The fabricator's profit is directly affected by the retail cutout which is in turn affected by the two levels of retail trim allowed in the model.

## The Growth Simulator in General

Following the development in Chapter III, the growth simulator is based upon the proposition that given sufficient energy intake the increase in liveweight will follow a sigmoid curve over time. In addition, a concept of compositional maturity can be defined by which the chemical composition of the empty body[2] in the three major components of fat, protein and water can be estimated for any liveweight for a given animal if the composition at any other weight is known. A combination of the growth curve, which relates liveweight to time, and a composition curve, which relates composition to weight, are sufficient to determine the weight and composition of the empty body at any given time. The energy composition for the increase in mass of chemical components is known (42, 173) and the energy requirements for maintenance of the body have been estimated (88). Therefore, in addition to the liveweight and chemical components, the energy (feed) requirements for gain and maintenance within a given time period can be estimated. Quality grade, yield grade, and dressing percentage are all closely related to chemical composition and the genetic capacities of a given animal to deposit fat in the various depots such as marbling, backfat, and internal fat. Therefore, it is reasonable to relate attributes such as quality grade, yield grade and dressing percentage to chemical composition with allowance for genetic deposition patterns. With this conceptual construct it is possible to simulate the important economic variables given appropriate quantification of necessary equations and parameters.

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[2] The terms "empty body" refer to the body of the animal after all fill--feed, water--has been removed.

## Estimation of Growth Relationships

### The Gompertz Curve

Both empirical and biological evidence have been given for the appropriateness of a form of the Gompertz function to depict the sigmoid-shaped path for increases in weight through time (69, 82, 83). It is assumed that a time path of weight for fed beef animals less than 2 years of age can be described by a Gompertz function of the form

$$W_t = W_0 e^{\frac{A_0}{\alpha}(1-e)^{-\alpha t}}$$ where:

$W_t$ = liveweight at time t;

$W_0$ = a parameter, weight at time t = 0 or birth;

$A_0$ = a parameter, the initial specific rate of growth;

$\alpha$ = a parameter, the rate of exponential decay of the specific growth rate; and

t = a variable, time in days after birth.

Non-linear iterative methods were used to estimate the function.

Data for the Gompertz Curves. Many sources provide data for computing weight through time. However, the availability of published material covering a large number of animals of several genetic types under controlled feeding conditions and providing carcass composition and grade data under serial slaughtering conditions is very limited. The most complete data of this kind currently available is from the U. S. Meat Animal Research Center (M.A.R.C.) at Clay Center, Nebraska (152, 153, 154). The published data from the Center's Germ Plasm Evaluation program was used extensively in this study since it provides data for fourteen breed groups of steers, both purebreds and crossbreds, and provides sequential slaughter data for three different feeding periods for a relatively large number of cattle.

All cattle were fed the same ration which was of a sufficient energy concentration to assume that differences in actual rate were due to genetic growth potential of the cattle and not the ration. Support for this assumption is given by another experiment at the center in which similar steers, fed rations of higher energy concentration, did not gain significantly faster (27, p. 68).

Data in the Germ Plasm Evaluation Project was recorded in three successive years with the data from the first two years (1970, 1971) reported for each year. The third year data for all three years (1972) was reported as aggregated least squares means. An attempt was made to obtain individual data for the third year from the Research Center but these data were not provided. Data from the first two years were therefore used for most estimating purposes. The estimation of the Gompertz parameters themselves was an exception. The means reported in 1972 were also used to provide the additional observations needed in order to use the non-linear estimation procedure.

The fourteen breed groups were from the same Hereford and Angus cow herds with seven bull breeds in straight bred and reciprocal cross combinations making 14 total breed groups. The breed groups and the symbolism used to represent them with sire and dam respectively are: Hereford-Herford, HEHE; Angus-Angus, ANAN; Angus-Hereford, ANHE; Hereford-Angus, HEAN; Jersey-Hereford, JEHE; Jersey-Angus, JEAN; South Devon-Hereford, SOHE; South Devon-Angus, SOAN; Limousin-Hereford, LIHE; Limousin-Angus, LIAN; Simmental-Hereford, SIHE; Simmetal-Angus, SOAN; Charolais-Hereford, CHHE; and Charolais-Angus, CHAN.

These breed groups do not represent all possible size-types of cattle raised and fed but do include the common ones as well as a wide range from small (Jersey-Angus) to fairly large (Charolais-Hereford). Much larger cattle exist but the range covered here would include most sizes that could reasonably be expected to be available in large numbers in the next few years.

Non-linear Estimation of the Gompertz Curve. An iterative non-linear least squares computer algorithm from the Biomedical Computer Programs (BMD) X series labelled BMDX85 was used. A complete discussion of this procedure is provided in several references (34, 57). In general, the program provides a weighted least squares fit $Y = f (X_1, \ldots, X_t; \theta_1, \ldots\theta_p) + e$ of a specified function f to data $X_1, \ldots X_t)$ through Gauss Newton iterations on the parameters $\theta_1, \ldots\theta_p$. The parameter selected at a given step is the one which, differentially, makes the greatest reduction in the error sum of squares. Weight gain is given for each of the breed groups at birth, either weaning or 200 days of age, and three sequential slaughter points each of which contain approximately one third of the animals in each breed group. In 1970 the slaughter dates were at 215, 243, and 271 days on feed. In 1971 the slaughter dates were at 200, 242, and 284 days on feed. The 1972 data, which were averages of 1970, 1971, and 1972, were 212, 247, and 279 days.

In the estimation process all three data sets were used and weighted by the number of animals represented at each time period. Table IX displays results from the non-linear regression procedure.

The relatively small number of times at which slaughter occurred and their concentration in a small interval of the time domain made it

## TABLE IX

## PARAMETER ESTIMATES, ASYMPTOTIC STANDARD DEVIATIONS OF PARAMETERS, AND ERROR MEAN SQUARES FOR NON-LINEAR REGRESSION OF GOMPERTZ CURVES

| Breed Group | $W_0$ (Asymptotic standard deviation of $W_0$) | $A_0$ (Asymptotic standard deviation of $A_0$) | (Asymptotic standard deviation of $\alpha$) | Error Mean Square |
|---|---|---|---|---|
| HEHE | 80.7<br>(12.1) | .012818<br>(.00037) | .00427<br>(.000136) | 17,945 |
| ANAN | 73.8<br>(13.9) | .01473<br>(.00050124) | .0048445<br>(.00019411) | 29,395 |
| ANHE | 80.064<br>(12.82) | .013059<br>(.00037602) | .004284<br>(.00014583) | 27,763 |
| HEAN | 78.99<br>(12.95) | .014078<br>(.00044025) | .0047752<br>(.00016065) | 30,566 |
| JEHE | 72.7<br>(.012451) | .013906<br>(.00042616) | .0045973<br>(.0016547) | 15,707 |
| JEAN[a] | 71.498<br>(10,986) | .013934<br>(.00038526) | .0046152<br>(.00014916) | 18,032 |
| SOHE | 85.856<br>(12.207) | .012363<br>(.0003345) | .004991<br>(.00012453) | 11,006 |
| SOAN | 80.843<br>(10.418) | .013830<br>(.00033353) | .004643<br>(.00012498) | 97,706 |
| LIHE[a] | 75.563<br>(14.246) | .014577<br>(.00048163) | .0038067<br>(.0001904) | 28,068 |
| LIAN[a] | 79.357<br>(10.673) | .014495<br>(.00036518) | .0048955<br>(.0001364) | 16,910 |
| SIHE[a] | 77.862<br>(16.905 | .014306<br>(.000518) | .0046244<br>(.00021345) | 40,389 |
| SIAN[a] | 80.298<br>(12.943) | .014293<br>(.00040514) | .0047093<br>(.00015943) | 27,618 |
| CHHE | 84.111<br>(14.65) | .014267<br>(.00046887) | .0048229<br>(.00017432) | 34,489 |

TABLE IX (Continued)

| Breed Group | $W_0$ (Asymptotic standard deviation of $W_0$) | $A_0$ (Asymptotic standard deviation of $A_0$) | (Asymptotic standard de- (viation of $\alpha$) | Error Mean Square |
|---|---|---|---|---|
| CHAN | 87.77<br>(8.4301) | .013467<br>(.00025293) | .0045778<br>(.000091755) | 17,373 |

[a] The estimation process did not converge to an absolute minimum for these breeds.

desirable to use the theoretically superior Gompertz function rather than some other regression specification. A third degree polynomial would in most cases "fit" the data better than the curves used. However, peculiarities in the sample data may produce cubic curves which are theoretically unacceptable. Such would occur if gain should increase at an increasing rate throughout the feeding period.

### Energy Disposition

Given the general liveweight growth patterns for 14 breeds as represented by the Gompertz equations, several other attributes and relationships logically follow. Support was given in Chapter III for a picture of growth in which fat and protein disposition in the bovine body can be usefully represented as largely a function of a ratio of attained weight to a physiological mature weight. Also, it was noted that the values for net energy requirements can be represented as a function of energy disposition and that maintenance energy is a direct function of the growth curve. Genetic differences in marbling (quality grade) and cutability can be represented as deviations from a standard relationship expressing fat as a percentage of empty body weight. Dressing percentage was also demonstrated to be closely related to fatness with some breed differences which could be represented as deviations from an arbitrary standard.

Thus, the important value-related attributes are determined by relationships based on the growth curve and composition. These relationships were specified and estimated using data from 1970 and 1971 from the M.A.R.C. Germ Plasm Evaluation Program as well as several secondary sources.

The first step was to convert to equational form the graphical relationship between percent of mature weight and percent fat given by Preston (112, p. 38). Table X displays the equations estimated from Preston's publication.

The M.A.R.C. publications do publish values for percent fat in the empty body. However, an article by Crouse and Glimp (27) who are researchers at the M.A.R.C. provides an equation for predicting carcass fat composition using carcass data which is provided in the M.A.R.C. publications. In addition Garrett and Hiniman (42) provide an equation for converting percent fat in the carcass to percent fat in the empty body. They also provide a conversion to estimate empty body weight from known carcass weight. These relationships are given in Table XI.

## Estimates of Mature Weight by Breed Type

The relationships given above applied to carcass data from the M.A.R.C. allow the estimation of mature weights[3] for each of the fourteen breed types. This was done by specifying a dummy variable regression in which the dependent variable is defined as observed live weight divided by calculated percent mature weight/100 or calculated mature weight. For each breed there are three mean observations in each of two years yielding six observations for each breed type. The regression equation then is comprised of the dependent variable as a function

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[3] Mature weight, as used in this study, is a mathematical relationship which relates liveweight to body composition. According to Preston (112), fat composition as a percent of carcass weight approaches an operational maximum between 40 and 45 percent. There is general agreement that 30-35 percent fat composition meets the conditions required for the carcass to grade choice.

## TABLE X

## ESTIMATED EQUATIONS FOR PRESTON'S BODY COMPOSITION CURVES

| Equation[a,b] | $R^2$ | F-value for Regression |
|---|---|---|
| $\text{PCTFAT} = 1.05224 + \underset{(.04506)}{.59531}\ \text{PCMTQT} - \underset{(.00077)}{.00908}\ \text{PCMTWT}^2 + \underset{(.00000)}{.00007}\ \text{PCMTWT}^3$ | .99973 | 16095.35037 |
| $\text{PCTPRO} = 18.17657 + \underset{(.01232)}{.09965}\ \text{PCMTWT} - \underset{(.00010)}{.00133}\ \text{PCMTWT}^2$ | .98841 | 597.15300 |
| $\text{PCMTWT} = -46.24047 + \underset{(.42383)}{7.78357}\ \text{PCTFAT} - \underset{(.01723)}{.14239}\ \text{PCTFAT}^2 + \underset{(.0021)}{.00095}\ \text{PCTFAT}^3$ | .99954 | 8390.9400 |

[a] Standard errors of the estimated coefficients are shown in parentheses.

[b] Symbols used in the equations are defined as follows:
PCTFAT = Fat as a percentage of empty body weight;
PCTPRO = Protein as a percentage of empty body weight; and
PCMTWT = Percentage of mature weight.

## TABLE XI

## EQUATIONS FOR PREDICTING PERCENT EMPTY BODY FAT AND EMPTY BODY WEIGHT

| Equation[a] | $R^2$ | F-value for Regression[b] |
|---|---|---|
| EMBOWT = 30.26 + 1.36 CRWT | .99 | |
| CARCFAT = 88.68 - 1.08 REPROD + .07 MARB + 1.59 YG + .14 REA | .94 | |
| EMBOFAT = -.65 + .92 CARCFAT | .99 | |

Source: Crouse, John D. and Michael E. Dikeman. "Methods of Estimating Beef Carcass Chemical Composition." _Journal of Animal Science_, Vol. 38 (July, 1974), pp. 1190-1195, and Garrett, W. N. and N. Hinman. "Re-evaluation of the Relathipship Between Carcass Density and Body Composition of Beef Steers." _Journal of Animal Science_, Vol. 28 (January, 1969), pp. 1-5.

[a] Symbols used in the equations are defined as follows:

EMBOWT = Empty body weight;
CRCT = Carcass weight in kilograms;
CARCFAT = Percent fat in the carcass;
REPROD = Percent trimmed retail cuts in carcass;
MARB = USDA marbling score;
YG = Yield grade;
REA = Ribeye area in $CM^2$; and
EMBOFAT = Percent fat in the empty body.

[b] The F-value for regression statistics were not presented in the original sources.

of thirteen dummy variables, one for each breed other than HEHE which serves as the standard and is contained in the intercept. Nonsignificant variables were removed and the regressions respecified. Table XII displays the coefficients for the statistically significant breeds.

The value affecting carcass attributes of yield grade, quality grade and dressing percentage,have been shown to be related to general fatness of the animal and to genetic factors generally referred to as muscling propensity and fat distribution patterns. The M.A.R.C. data for 1970 and 1971 were utilized again to obtain estimates of these attributes as a function of body fatness and breed type. The dependent variable is, in turn, yield grade (YG), quality grade (QG), and dressing percentage (DP) and the independent variables are percent fat (PCTFAT) in the empty body and thirteen dummy variables for breed type. The observations were means and each was weighted by the square root of the numbers of single observations used to compute the mean. Nonsignificant variables were dropped and the equations were reestimated. The resulting equations are presented in Tables XIII, XIV, and XV.

## Energy Requirements

Feed requirements on a given day are a function of the metabolic size of the animal, the weight of tissue gain and the composition of the tissue when factors such as stress, illness, unpalatable feed, wide variation in energy concentration of the ration are ignored. The growth curve and Preston composition curves provide a mechanism for estimating metabolic weight and tissue gain. Needed is the conversion

## TABLE XII

## MATURE WEIGHTS FOR BREED TYPES AS ESTIMATED FROM DUMMY VARIABLE REGRESSIONS

| Breed | Coefficient | Standard Error of Coefficient | Estimated Mature Wt. (lb.) |
|---|---|---|---|
| HEHE[a] | 1244.9 | - | 1244.9 |
| ANAN | -51.9 | 20.21 | 1193.0 |
| ANHE[b] | | | 1244.9 |
| HEAN | -38.49 | 19.34 | 1206.4 |
| JEHE | -63.44 | 21.52 | 1181.5 |
| JEAN | -106.20 | 20.22 | 1138.7 |
| SOHE[b] | | | 1244.9 |
| SOAN[b] | | | 1244.9 |
| LIHE | 127.78 | 21.43 | 1371.8 |
| LIAN | 112.42 | 20.82 | 1357.3 |
| SIHE | 212.15 | 20.71 | 1457.0 |
| SIAN | 112.30 | 20.09 | 1357.2 |
| CHHE | 249.48 | 20.64 | 1494.4 |
| CHAN | 132.74 | 20.52 | 1377.6 |

$R^2 = .65$ F for Regression = 45.96

[a] The standard or intercept.

[b] Not significantly different from the intercept.

## TABLE XIII

## REGRESSION ESTIMATES FOR YIELD GRADE AS DEPENDENT VARIABLE ON BODY FAT AND BREED TYPE

| Explanatory Variable | Coefficient | Standard Error of Coefficient | t-statistic |
|---|---|---|---|
| BODFAT[a] (%) | .09519 | .00545 | 17.47 |
| HEHE (intercept) | .27859 | | |
| ANAN | .2209 | .04736 | 4.7 |
| HEAN | .15319 | .04585 | 3.3 |
| JEHE[b] | - | - | - |
| JEAN[b] | - | - | - |
| SOHE[b] | - | - | - |
| SOAN[b] | - | - | - |
| LIHE | -.50859 | .05466 | 9.3 |
| LIAN | -.36313 | .5200 | 6.9 |
| SIHE | -.431 | .05138 | 8.4 |
| SIAN | -.23893 | .04689 | 5.1 |
| CHHE | -.40517 | .05356 | 7.6 |
| CHAN | -.32067 | .04961 | 2.2 |

$R^2$ = .8784 F for Regression = 174.82

---

[a] Percent fat of empty body weight.

[b] Net significantly different from zero at .05 level.

# TABLE XIV

## REGRESSION ESTIMATES FOR QUALITY GRADE AS DEPENDENT VARIABLE ON BODY FAT AND BREED TYPE[a]

| Explanatory Variable | Coefficient | Standard Error of Coefficient | t-statistic |
|---|---|---|---|
| BODFAT[b] (%) | .17646 | .01285 | 9.4 |
| HEHE (intercept) | 4.1932 | | |
| ANAN | .88107 | .17719 | 6.9 |
| ANHE | .33394 | .12586 | |
| HEAN[c] | | | |
| JEHE | -.31547 | .12828 | 6.0 |
| JEAN | .29558 | .12512 | 5.6 |
| SOHE[c] | | | |
| SOAN | .64820 | .13361 | 48.3 |
| LIHE[c] | | | |
| LIAN[c] | | | |
| SIHE[c] | | | |
| SIAN | .29737 | .11625 | 2.5 |
| CHHE | .48188 | .11789 | 4.1 |
| CHAN | .87389 | .11610 | 7.5 |

$R^2$ = .692 F for Regression = 49.12

[a] Quality grade is converted to a numerical scale where 10 - Choice-, 11= Choice, 12 = Choice +, etc.

[b] Percent fat of empty body weight

[c] Not significantly different from zero at .05 level.

## TABLE XV

## REGRESSION ESTIMATES FOR DRESSING PERCENT AS DEPENDENT VARIABLE ON BODY FAT AND BREED TYPE

| Explanatory Variable | Coefficient | Standard Error of Coefficient | t-statistic |
|---|---|---|---|
| BODFAT[a] (%) | .13710 | .02038 | 6.6 |
| HEHE (intercept) | 57.054 | - | - |
| ANAN[b] | - | - | - |
| ANHE[b] | - | - | - |
| HEAN[b] | - | - | - |
| JEHE | -1.58388 | .19531 | 8.1 |
| JEAN | -1.26882 | .18234 | 7.0 |
| SOHE[b] | - | - | - |
| SOAN | .64088 | .20373 | 3.1 |
| LIHE | 1.275 | .2162 | 5.8 |
| LIAN | 1.4536 | .20549 | 7.1 |
| SIHE | -.50669 | .20297 | 2.5 |
| SIAN[b] | - | - | - |
| CHHE | .51274 | .21171 | 2.5 |
| CHAN | .8594 | .19565 | 4.4 |

$R^2 = .52$ F for Regression = 29.32

[a] Percent fat of empty body weight.

[b] Not significantly different from zero at .05 level.

in ration energy for gain into tissue gain. The net energy system as described in Chapter III was developed for this purpose. Estimates of the energy composition of fat and protein vary slightly. The values used in the simulator are 5.65 Mc/Kg of energy for protein and 9.45 Mc/Kg for fat as given by Witz (173, p. 105). Similar values have been reported by other researchers such as Garrett and Hiniman (42, p. 3). The net energy system gives estimates of the tissue producing calories net of the inefficiencies of energetic conversion.

The energetic efficiency of fat and protein are assumed equal in this study following evidence in Martin (92, p. 177). There has been discussion and debate of this point as exemplified by Rattray, et al.,(125) who find evidence that animals more efficiently utilize metabolizable energy in the synthesis of fat than in protein. This is but one of many unresolved questions in the growth and composition of beef cattle.

### The Ration

The energy values assumed for the ration in the simulator are the same as those calculated for the finishing ration at Clay Center as presented in Table XVI. The energy concentration of this ration is lower than that of the typical large feedlot but is sufficiently "hot" that it is reasonable to assume that no highly significant changes in gain or composition would result from a hotter ration. The assumption is supported by Crouse and Glimp who reported differences between ADG (average daily gain) of the steers on the medium and high energy rations would be considered of no practical importance (27, p. 68). Some small differences were found in subcataneous fat deposits.

## TABLE XVI

## FINISHING RATION COMPOSITION AND COST PER UNIT OF ENERGY

| Ingredient | Pounds in 100 lbs. of Ration | Megacal $\text{NE}_m$[a] | Megacal $\text{NE}_p$[b] | Cost | Cost per Megacal $\text{NE}_m$ | Cost per Megacal $\text{NE}_p$ |
|---|---|---|---|---|---|---|
| | | | | (¢ per lb.) | (¢ per megacal) | (¢ per megacal) |
| Corn Silage | 60 | 22 | 13 | .51 | NA | NA |
| Concentrates | 34 | 92 | 60 | 2.27 | NA | NA |
| Protein Supplement | 6 | 75 | 50 | 3.89 | NA | NA |
| Total Ration | 100 | 50 | 31.2 | 1.31 | 2.62 | 4.20 |

[a] Net energy for maintenance.

[b] Net energy for production.

However, it is not clear if adjustments for weight were made.

The ration recipe and prices for ingredients as well as the NEp and NEm concentration of the ration are given in Table XVI. It is assumed that the finishing ration is used for the entire finishing period even though it is customary in practice to feed one or two roughage rations for the early weeks of a feeding regime. The simulator ration yields 50 megacals per 100 pounds of NEm and 31.2 megacals per 100 pounds of NEq and for the 1968 to 1972 period cost $1.31 per 100 pounds.

## The Simulator (BEEFSIM)

The next step is to incorporate the relationships developed thus far into a computer simulation which yields predicted values for the physical objects (inputs and outputs) and their attributes for fourteen breed-type steers. It is also desirable that the simulator output these values in forms suitable for direct use by the linear programming model.

The actual fortran source program for BEEFSIM consists of 549 statements plus 200 documentation statements. Its general form and logic can be shown in an example on one steer for one day as simplified and displayed in flow chart form in Figure 4.

Appendix A displays a tabulated output for 10-day feeding intervals for selected objects and attributes. Appendix B displays computer plots for all fourteen breed groups of liveweight, carcass weight, yield grade, quality grade, dressing percentage, and percent of retail product with .3 inches of trim. For purposes of comparison, the original M.A.R.C. data are also presented. Inspection of these plots

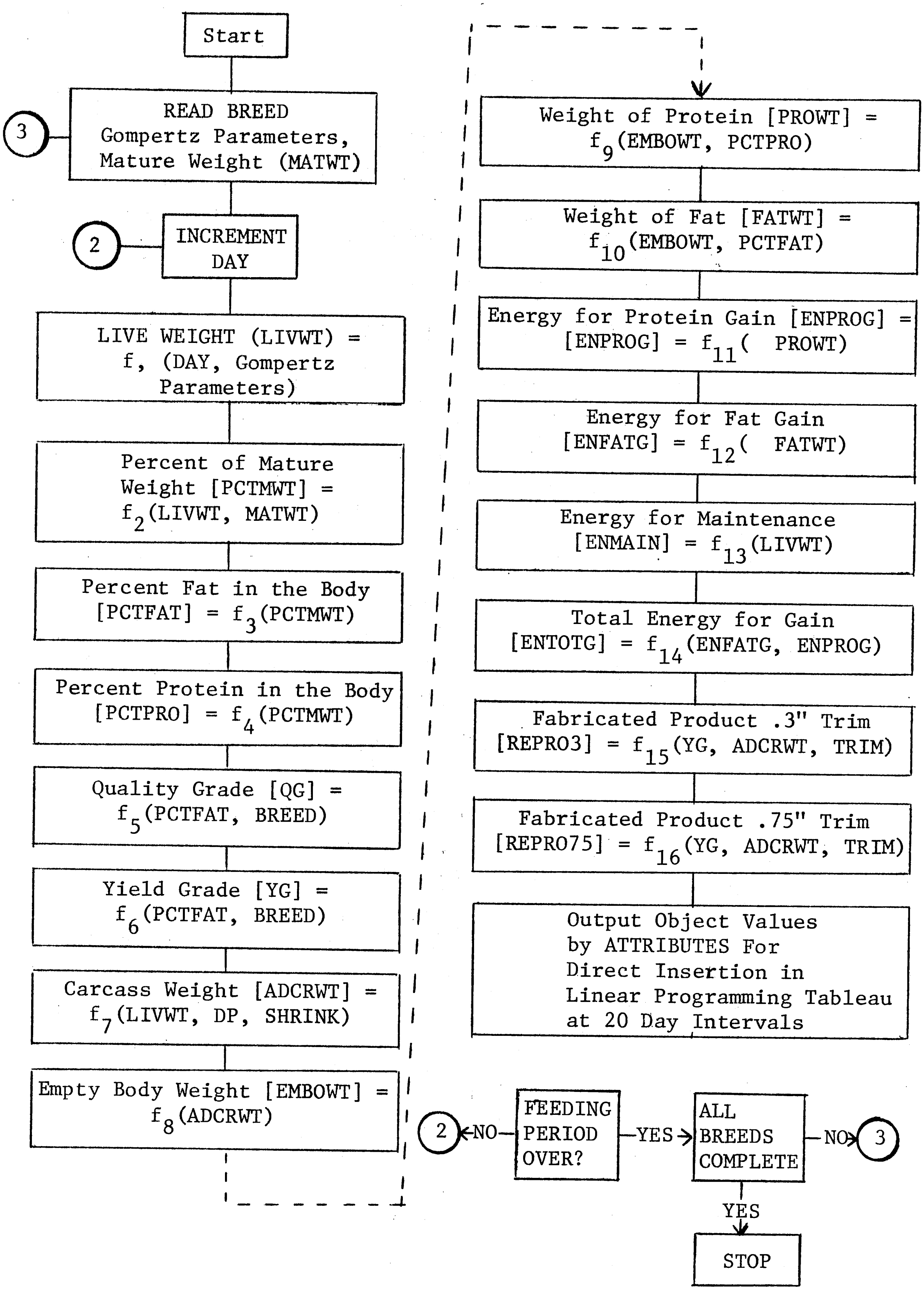

Figure 4. Simplified Flow Chart of BEEFSIM.

reveals that the simulated plotted lines fit the data quite well.

## The System Model

The growth simulation provides only the physical relationships and attributes for a fed beef steer to be used in a decision model. The objective is to model a series of decisions including what breed type to produce and how long to feed that breed type under experimental conditions of market communication and optimization.

Chapters II and III reviewed the considerations made in conceptualizing a model. Only a subset of those ideas can be incorporated into an applied model.

### The Subsystems

It is impossible to recreate all the information flows and interactive decision processes of four stages of the beef production and marketing system. An attempt will be made to consider a range of production and market factors at each level which most affect decisions and profitability.

Cow-Calf Level. Among the factors of importance at the cow-calf level are the following:

(1) Cow reproductive performance as measured by calving percentage and calving difficulty are important attributes in making decisions.

(2) Weight of the calf at weaning is a second important attribute as sales are made on a liveweight basis. Price premiums and discounts are usually based on weight range and often do not

discriminate between calves of similar weight but differing potential.

Cattle Feeding Level. The factors of importance include:

(1) As the feeding period lengthens and a steer gets fatter feed costs per unit of output increase.

(2) A feeder may feed only one set of cattle per year (or have available feedlot capacity) such that a desirable decision rule is to maximize returns per head. With a full lot and a desire to keep it full, a desirable decision rule is to maximize returns per unit of time (equivalent to per unit of capacity per year).

(3) A feeder may face price information structures giving a "price signal" based on: live weight categories, with estimated values for quality grade; live weight categories based on actual quality grade; estimated quality grade and yield grade; and carcass grade and weight categories. Within a sales method different premiums and discounts can be associated with the same set of attributes. Increasing feed costs can change optimal conditions.

(4) The feeder's behavior can be described by the type of cattle fed and the length of the feeding period.

Packer Level. At the packer level, factors of importance include:

(1) The packer's cost are on a carcass basis. It costs as much to slaughter an animal yielding a 650-lb. carcass as an animal yielding a 500-lb. carcass.

(2) The packer must procure a steer on the same basis and at the same prices at which the feeder sells it.

(3) The packer can sell on the basis of weight range and quality grade or on the basis of quality grade and yield grade.

<u>Fabricator</u>. The fabricator is concerned with such factors as:

(1) The fabricator's costs are on a carcass basis.

(2) The fabricator's product must meet either a .3 inches or a .75 inches fat trim requirement and the sale and can be for Good, Choice, or Prime grades of beef.

Conditions that apply to the system as a whole are:

(1) All calculations and transactions are on the basis of a composite steer. It is possible that the composite steer is of more than one breed. Implications of this are that a calving percentage of .8 requires that 1.25 units of cow-calf inputs are required to produce one calf. If the feeder replaces cattle and feeds one calf plus a portion of another in one year, all feedlot inputs and outputs except feedlot capacity are increased by the portion of the feeding period which is completed.

(2) The calf produced and the live steer fed are the same throughout the system. There is no opportunity to buy and sell from the environment.

(3) The objective of the team is to maximize rate of return to the fixed investment of the four-stage system.

(4) No macro considerations are made. All costs and prices are considered static and are average for the 1968-72 period.

A conceptual diagram of the system with object flows by attribute scheme is depicted in Figure 5.

## Operating Costs and Investment Requirements

The costs and investments associated with each subsystem are indexed to be representative of the 1968-1972 period. Cow calf costs and investment are based on published budgets and are on a per cow basis (196). In the model a reduced calving percentage is represented by an increased cow unit cost. Table XVII itemizes these costs and investments and Table XVIII summarizes them.

Feedlot costs were estimated from two major sources to obtain investment per unit of capacity and nonfeed cost per head per day (13, 32). Feed costs are calculated within the LP model from energy requirements by feeding period.

Table XIX displays nonfeed variable costs per head per day for a 20,000 head capacity lot. Table XX displays fixed costs per head per day and Table XXI displays investment requirements.

Costs and investments for a 120 head per hour beef slaughtering plant are presented in Tablex XXII and XXIII. These are based on Logan (90) and are used on a per carcass basis, consistent with the assumption that carcass costs occur on a carcass basis.

Variable costs for the fabricating subsystem were taken from Ericksen and Lichty (38) and are on a carcass basis. Table XXIV displays fabricator subsystem costs.

Investment for the fabricator was most difficult to obtain. In fact, no published figures for investment in an independently operating beef fabricator were found. Values were synthesized from Schnake,et al.,

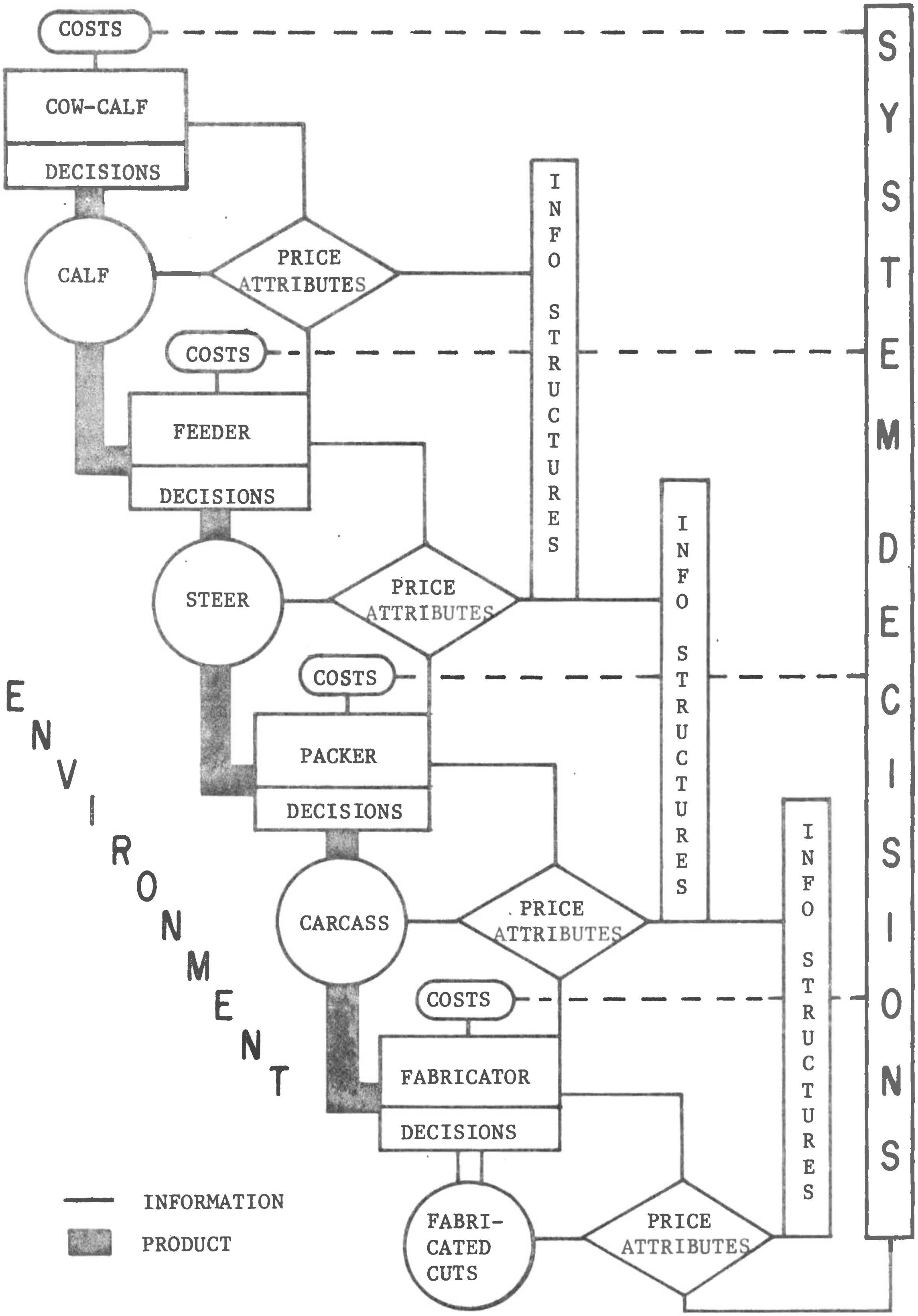

Figure 5. Diagram of System Model

## TABLE XVII

## COW-CALF INVESTMENT AND OPERATING COSTS PER COW UNIT, AVERAGE 1968-1972

| Livestock Investment | Units | Price | Value |
|---|---|---|---|
| Beef Cow | 1.0 | $222.25 | $222.25 |
| Beef Bull | .03 | 475.00 | 14.28 |
| Beef Heifer | .09 | 175.00 | 15.71 |
| Horse | .01 | 200.00 | 2.00 |
| Total | | | $254.24 |
| | | | |
| Land Investment | NA | NA | $1000.00 |
| | | | |
| Operating Inputs | | | Value |
| 41% Protein Supplement | 403.2 lbs. | $.04/lb. | $ 16.22 |
| Grass Hay | 815.36 lbs. | .01/lb. | 8.15 |
| Pasture | 6.72 AUM | 0.0 | 0.00 |
| Salt & Minerals | 26.88 lb.s | .03/lb. | .73 |
| Vet. and Medicine | 1.0 | --- | 2.33 |
| Hauling & Marketing | 1.0 | --- | 5.00 |
| Personal Taxes | 1.03 | 2.00 | 2.06 |
| Livestock Supplies | 1.0 | --- | 2.91 |
| Bulls | .01 Hd | 476.25/hd. | 4.77 |
| Native Pasture | 4.14 AUM | 0.0 | 0.00 |
| Machinery Fuel & Lube. | | | 2.00 |
| Mach. & Equip. Repair | | | 3.98 |
| Total | | | $ 48.15 |
| | | | |
| Labor Costs | | | |
| Machinery Labor | 4.38 hrs. | 1.64/hr. | $ 7.20 |
| | 3.61 hrs. | 1.64/hr. | 5.92 |
| Total | | | $ 13.12 |
| | | | |
| Ownership Costs (Depreciation, Taxes, Insurance) | | | |
| Machinery | | | $ 2.91 |
| Equipment | | | 6.37 |
| Livestock | | | .32 |
| Total | | | $ 9.60 |
| | | | |
| Capital Costs | | | |
| Annual Operating Cap. | $27.76 | .076/dol. | $ 2.11 |
| Machinery Investment | 14.61 | .076/dol. | 1.11 |
| Equipment Investment | 36.27 | .076/dol. | 2.76 |
| Livestock Investment | 254.24 | .076/dol. | 19.33 |
| Land Investment | 1000.00 | .077/dol. | 77.20 |
| Total | | | $102.51 |
| | | | |
| Revenue from Sale of Cull Stock | | | $ 22.83 |

# TABLE XVIII

## SUMMARY OF COW-CALF INVESTMENT AND COSTS

| Item | Costs | Cost Less Allowance for Cull Sales |
|---|---|---|
| | ($) | ($) |
| Livestock | 254.24 | NA |
| Land Investment | 1,000.00 | NA |
| Annual Cost per Brood Cow Excluding Interest on Land and Livestock | 76.85 | 54.02 |
| Interest on Land and Livestock | 96.53 | NA |
| Annual Cost per Brood Cow Including Interest on Land and Livestock | 173.38 | 150.55 |

## TABLE XIX

## VARIABLE NONFEED COSTS FOR CATTLE FEEDING IN A 20,000 HEAD LOT, 1968-72

| Component of Nonfeed Variable Costs | Percent of Total | Adjustment Index |
|---|---|---|
| Labor | 21.6 | 1.052 |
| Interest | 49.0 | 1.106 |
| Death Loss | 14.4 | 1.106 |
| Veterinary and Medicine | 7.9 | 1.030 |
| Gas, Oil, Electricity | 4.3 | 1.110 |
| Telephone, Communication | .6 | 1.110 |
| Other (Taxes, Insurance, etc.) | 1.4 | 1.106 |

Variable Nonfeed Costs per Head Per Day for 1969 = \$.097312[a]

Variable Nonfeed Costs per Head per Day for 1968-72 = \$.105000[b]

---

[a] Taken from Brant, Bill. "Economies of Scale in Beef Production." Presented at Great Plains and Western Outlook Conference, Purango, Colorado, July 29, 1969.

[b] The costs for 1968-72 were estimated from the 1969 costs using adjustment indexes in U.S. Department of Agriculture. Agricultural Statistics, 1974. Washington: U.S. Government Printing Office, 1974.

## TABLE XX

## ANNUAL FIXED COST FOR CATTLE FEEDING IN A 20,000 HEAD LOT

| Component of Fixed Costs | 1969 Costs[a] | Adjustment Index | Average Cost[b] 1968-72 |
|---|---|---|---|
| | ($) | | ($) |
| Depreciation | 68,200 | 1.042 | 71,004 |
| Repairs | 15,600 | 1.042 | 16,255 |
| Taxes | 7,100 | 1.042 | 7,358 |
| Insurance | 3,700 | 1.042 | 3,855 |
| Management | 45,000 | 1.052 | 47,340 |
| Interest | 37,900 | 1.042 | 39,492 |
| Total | 177,500 | | 185,403 |
| Fixed Cost per Head of Capacity[c] | | | 10.30 |
| Fixed Cost per Head per Day[c] | | | .02822 |
| Fixed Cost per Head of Capacity Excluding Interest[c] | | | 8.11 |
| Fixed Cost per Head per Day Excluding Interest[c] | | | .02220 |
| One Time Handling Cost per Animal | | | 7.50 |

[a] The costs for 1969 are taken from Brant, Bill. "Economies of Scale in Beef Production," (Paper presented to the Great Plains and Western Outlook Conference, Durango, Colorado, July 29, 1969.) Stillwater, Oklahoma: Oklahoma State University, Department of Agricultural Economics, 1969.

[b] The average costs for 1968-72 are generated from the 1969 costs using adjustment indexes based on U. S. Department of Agriculture, Agricultural Statistics, 1974, Washington: U. S. Government Printing Office, 1974.

[c] Based on 90 percent utilization.

## TABLE XXI

## INVESTMENT REQUIREMENTS FOR A 20,000 HEAD FEEDLOT

| Component of Investment | 1969 Investment[a] | Adjustment Index | Average Investment[b] 1968-72 |
|---|---|---|---|
| | ($) | | ($) |
| Pens and Equipment | 241,600 | 1.042 | 251,747 |
| Water System | 54,400 | 1.033 | 56,195 |
| Mill Equipment | 236,800 | 1.033 | 244,614 |
| Feed Storage | 100,000 | 1.042 | 104,200 |
| Feed Handling Equipment | 70,400 | 1.055 | 74,272 |
| Manure Handling Equipment | 19,200 | 1.055 | 20,256 |
| Transportation Equipment | 16,000 | 1.055 | 16,880 |
| Office, Office Equipment | 16,000 | 1.033 | 16,528 |
| Scales, Related Equipment | 20,000 | 1.033 | 20,660 |
| Land | 22,400 | 1.108 | 24,819 |
| Total Investment | 800,000 | | 834,400 |
| Investment per Head of Capacity[c] | 44.44 | | 46.35 |

[a] The 1969 investment is taken from Brant, Bill, "Economies of Scale in Beef Production," (Paper presented to the Great Plains and Western Outlook Conference, Durango, Colorado, July 29, 1969.) Stillwater, Oklahoma: Oklahoma State University, Department of Agricultural Economics, 1969.

[b] The average investment for 1968-72 is generated from the 1969 investment using adjustment indexes based on U. S. Department of Agriculture, Agricultural Statistics, 1974, Washington: U. S. Government Printing Office, 1974.

[c] Based on 90 percent utilization.

## TABLE XXII

## ANNUAL SLAUGHTER COSTS FOR A 120 HEAD PER HOUR PLANT

| Component of Cost | 1965 Costs[a] | Adjustment Index | Average Costs 1968-72[b] |
|---|---|---|---|
| | ($) | | ($) |
| Labor (Includes Management) | 1,208,584 | 1.142 | 1,380,203 |
| Equipment Depreciation | 31,312 | 1.136 | 35,570 |
| Building Depreciation | 48,693 | 1.384 | 67,391 |
| Annual Property Taxes | 23,223 | 1.384 | 32,141 |
| Insurance | 8,100 | 1.384 | 11,210 |
| Interest | 51,375 | 2.208 | 113,436 |
| Other Expenses | 397,736 | 1.317 | 484,308 |
| Utilities | 54,819 | 1.115 | 61,123 |
| Total Annual Cost | 1,793,842 | | 2,185,382 |
| Total Annual Cost Excluding Interest | 1,742,467 | | 2,071,946 |
| Total Cost per Carcass[c] | 7.91 | | 9.636 |
| Total Cost per Carcass Excluding Interest[c] | 7.683 | | 9.136 |
| Transport Cost[c] | | | 5.85 |

[a] The 1965 costs are taken from Logan, Samuel H, "Economies of Scale in Cattle Slaughtering Plants." Organization and Competition in the Livestock and Meat Industry, Washington: National Commission on Food Marketing, Supplemental Study No. 2 of Technical Study No. 1, 1966.

[b] The average costs for 1968-72 are generated from the 1965 costs using adjustment indexes based on U. S. Department of Agriculture, Agricultural Statistics, 1974. Washington: U. S. Government Printing Office, 1974.

[c] Based on an annual carcass output of 226,782 carcasses.

## TABLE XXIII

## ANNUAL INVESTMENT REQUIREMENTS FOR A 120 HEAD PER HOUR SLAUGHTER PLANT

| Investment Item | 1965 Investment[a] | Adjustment Index | Average Investment 1968-1972[b] |
|---|---|---|---|
| | ($) | | ($) |
| Building | 1,159,368 | 1.384 | 1,604,565 |
| Equipment | 406,017 | 1.136 | 461,235 |
| Land | 46,236 | 1.402 | 64,823 |
| Total Investment | 1,531,621 | | 2,130,623 |
| Investment per Carcass[c] | 6.754 | | 9.395 |

[a] The 1965 investment is taken from Logan, Samuel H., "Economies of Scale in Cattle Slaughtering Plants," Organization and Competition in the Livestock and Meat Industry, Washington: National Commission on Food Marketing, Supplemental Study No. 2 of Technical Study No. 1, 1966.

[b] The average investment for 1968-72 is generated from the 1965 investment using adjustment indexes based on U. S. Department of Agriculture, Agricultural Statistics, 1974, Washington: U. S. Government Printing Office, 1974.

[c] Based on an annual carcass output of 226,782 carcasses.

## TABLE XXIV

## OPERATING COSTS AND INVESTMENT REQUIREMENTS FOR CARCASS BREAKING AND FABRICATING 1968-72

| Source of Operating Costs or Investment | Operating Costs per Carcass, 1968-72 | Investment per Carcass, 1968-72 |
|---|---|---|
| | ($) | ($) |
| Operating Costs[a] | | |
| Storage (Carcasses) | 3.754 | |
| Storage (Cuts) | .836 | |
| Primal Breaking | 9.059 | |
| Fabricating | 6.089 | |
| Wrapping and Labeling | 1.332 | |
| Transportation | 5.249 | |
| Total | 26.330 | |
| Total Less Interest | 24.300 | |
| Investment[b] | | |
| Building | | 25.673 |
| Equipment | | 7.841 |
| Land | | .432 |
| Total Investment | | 33.940 |

[a] The operating costs are taken from Erickson, D. B. and Richard W. Lichty, "Cost Analysis of Systems to Distribute Fresh and Frozen Meat," Frozen Meat--Its Distribution Costs, Acceptance and Cooking and Eating Qualities, Manhattan, Kansas: Kansas Agricultural Experiment Station, Bulletin 166, 1973, pp. 35-46.

[b] The investment requirements are synthesized from Braisington, C. F. and D. R. Hammons, Beef Carcass Boning Lines--Operations, Equipment, and Layouts, Washington: U. S. Department of Agriculture, Agricultural Research Service, Marketing Research Report No. 941, 1972, and Schnake, L. D., John R. Franzmann, and Don R. Hammons, Economies of Size in Non-Slaughtering Meat Processing Plants, Stillwater, Oklahoma: Oklahoma Agricultural Experiment Station Technical Bulletin T-125, 1965.

(130) and Brasington,et al.,(12). These are presented in Table XXV.

## Information Structures

The concepts that are referred to in this study as information structures consist of the combinations of attributes and associated prices with which the decision maker is faced. One example is a live estimated grade and weight selling method for the cattle feeder. In this method live weight, estimated quality grade and the prices associated with grade and weight categories are presented to the cattle feeder. Assuming that his costs are known and that he will not replace immediately cattle which are sold (a factor affecting the decision function), there is a combination of breed to buy and choice of feeding period length that would maximize his profit (or equivalently, return on investment). If the information structure is changed and the feeder faces a price schedule based on carcass weight and yield grade, which brings his renumeration closer to that based on ultimate retail product, his profit maximizing decision may change.

Comparable variations exist for other parts of the system. For example, the packer's choice of steer to maximize profits may differ depending on the buying and selling attributes utilized as well as decisions at the cow-calf, feeder and fabricator decisions.

There are six basic information structures. Each will be described briefly.

Information Structure #1. The steer is bought and sold on the attributes of live quality grade and weight and the carcass is traded on a carcass grade and weight basis. The grade on the live animal is the same as the carcass quality grade and no estimation is involved.

## TABLE XXV

## INVESTMENT REQUIREMENTS FOR BREAKING CARCASSES AND FABRICATING CUTS

| Investment Item | 1965 Investment[a] | Adjustment Index | Average Investment 1968-1972[b] |
|---|---|---|---|
| | ($) | | ($) |
| Building | 621,471.53 | 1.384 | 860,116.60 |
| Equipment | 207,674.55 | 1.136 | 235,880.30 |
| Land | 7,369.40 | 1.402 | 10,331.89 |
| Total Investment per Carcass[c] | | | $33.94 |

[a] The 1965 investment is taken from Braisington, C.F. and F. R. Hammons, Beef Carcass Boning Lines--Operations, Equipment, and Layouts, Washington: U. S. Department of Agriculture, Agricultural Research Service, Marketing Research Report No. 941, 1972, and Schnake, L. D., John R. Franzmann, and Don R. Hammons, Economies of Size in Non-Slaughtering Meat Processing Plants, Stillwater, Oklahoma: Oklahoma Agricultural Experiment Station Technical Bulletin T-125, 1965.

[b] The average investment for 1968-72 is generated from the 1965 investment using adjustment indexes based on U. S. Department of Agriculture, Agricultural Statistics, 1974, Washington: U. S. Government Printing Office, 1974.

[c] Based on annual carcass output of 33,500 carcasses.

Information Structure #2. Steers are traded on the attributes of live quality grade and yield grade and the carcass is traded on a carcass quality grade and yield grade basis. The live grades are assumed known and no estimation is involved.

Information Structure #3. The steer is traded on the attributes of live estimated quality grade and estimated yield grade and the carcass is traded on quality grade and yield grade. Here, both the live quality and live yield grades are estimated.

Information Structure #4. The steer is traded on the basis of live estimated quality grade and estimated yield grade and the carcass is traded on the basis of carcass quality grade and yield grade.

Information Structure #5. The steer is traded on the attributes of carcass quality grade and weight and the carcass is traded on the basis of carcass quality grade and weight.

Information Structure #6. The steer is traded on the attributes of carcass quality grade and yield grade and the carcass is traded on the attributes of carcass quality grade and yield grades.

In some cases prices were changed experimentally within a given information structure. Three price combinations were used. These are referred to as (1) base prices, which are the observed average prices for the 1968-72 period; (2) carcass adjusted prices for which the premiums and discounts for yield grade are calculated as a percentage of the base carcass price; and (3) the retail adjusted prices in which the premiums and discounts for yield grades are calculated as a percent of retail product price. Tables XXVI, XXVII, and XXVIII display the base prices and adjusted prices which were used.

Other prices used in the model are hide and offal value at \$2.41 per 100 pounds live weight, tallow at 4.46¢ per pound and bone at 1.0¢ per pound (158).

The feeder-calf price used was the average price of 300-550 pound Good and Choice feeder cattle 1968-72, which was \$35.12 per 100 pounds (158, Table 166).

The price of fabricated beef was estimated since no published price series for the 1968-72 time period was located. The procedure used to arrive at fabricated cut prices for Good, Choice, and Prime grades was as follows: Retail equivalent price differentials for grade were calculated by finding the difference in value for a 1,000-pound live steer for each grade, then dividing the net value differences by 437 pounds which is the retail cutout assumed by USDA for computing price spreads. This procedure produced a retail differential of 1.71¢ pound for Prime over Choice and 5.99¢ per pound for Choice over Good. The 5-year average price of Choice beef at retail was \$.999 per pound (158, Table 169). Erickson and Lichty estimated the retail costs when receiving fabricated beef at 5.394¢ per retail pound. Assuming a profit allowance of 2.2¢ per pound, the estimated price to the fabricator for Choice fabricated beef is \$.923 per pound. Applying the calculated price differentials yields a price for Prime of \$.940 and for Good \$.865 per pound.

In two of the information structures trading occurs on the basis of estimated rather than actual values for quality grade and yield grade. This procedure follows simple tenets of probability and

## TABLE XXVI

## BASE LEVEL SLAUGHTER STEER PRICES BY GRADE AND WEIGHT AT OMAHA 1968-1972

| | GOOD | | | CHOICE | | | PRIME | | |
|---|---|---|---|---|---|---|---|---|---|
| Year | 7-900 | 9-1100 | 11-1300 | 9-1100 | 11-1300 | 13-1500 | 9-1100 | 11-1300 | 13-1500 |
| | | ($ per cwt.) | | | ($ per cwt.) | | | ($ per cwt.) | |
| 1968 | - | 24.79 | 24.89 | 26.87 | 27.96 | 26.44 | 27.73 | 27.99 | 27.41 |
| 1969 | - | 27.14 | 27.39 | 29.45 | 29.69 | - | 30.62 | 30.88 | - |
| 1970 | - | 27.04 | 27.16 | 29.36 | 29.20 | - | 30.22 | 30.11 | - |
| 1971 | - | 29.58 | 29.75 | 32.39 | 32.39 | - | 33.38 | 33.53 | - |
| 1972 | - | 33.43 | 33.50 | 35.78 | 35.59 | - | 36.67 | 36.58 | - |
| 5 yr. Ave. | - | 28.40 | 28.54 | 30.77 | 30.97 | - | 28.40 | 28.54 | - |

Source: U.S. Department of Agriculture. Livestock and Meat Statistics. Washington: Economic Research Service and Statistical Reporting Service, Statistical Bulletin 522, 1973.

## TABLE XXVII

## BASE LEVEL WHOLESALE DRESSED MEAT PRICES, CARLOT BASIS, MIDWEST, IOWA, AND MISSOURI RIVER MARKETS BY GRADE AND WEIGHT 1968-72

| | GOOD | | | CHOICE | | |
|---|---|---|---|---|---|---|
| Year | 5-600 | 6-700 | 7-800 | 6-700 | 7-800 | 8-900 |
| | | ($ per cwt.) | | | ($ per cwt.) | |
| 1968 | - | 40.75 | 40.75 | 43.25 | 43.29 | 42.87 |
| 1969 | - | 44.43 | 44.40 | 47.16 | 47.18 | 46.79 |
| 1970 | - | 44.21 | 44.21 | 46.74 | 46.23 | 45.37 |
| 1971 | - | 48.06 | 48.07 | 51.93 | 51.75 | 51.09 |
| 1972 | 53.54 | 53.54 | 53.68 | 56.24 | 56.32 | 55.54 |
| 5 YR. AVE. | 56.24 | 46.24 | 46.26 | 49.06 | 48.95 | 48.33 |

Source: U.S. Department of Agriculture. Livestock and Meat Statistics. Washington: Economic Research Service and Statistical Reporting Service, Statistical Bulletin 522, 1973.

## TABLE XXVIII

## CALCULATED LIVE AND CARCASS PRICES BY QUALITY GRADE AND YIELD GRADE USED IN INFORMATION STRUCTURES #2, #3, AND #6

| Yield Grade Grade | LIVE |  |  | CARCASS |  |  |
|---|---|---|---|---|---|---|
|  | Good | Choice | Prime | Good | Choice | Prime |
|  | ($ per cwt.) |  |  | ($ per cwt.) |  |  |
| 1 | 29.40 | 31.77 | 32.73 | 48.04 | 50.95 | 51.20 |
| 2 | 28.90 | 31.27 | 32.23 | 47.14 | 49.95 | 50.10 |
| 3 | 28.40 | 30.77 | 31.73 | 46.24 | 48.95 | 50.0 |
| 4 | 27.90 | 30.27 | 31.23 | 45.34 | 47.95 | 48.90 |
| 5 | 27.40 | 29.77 | 30.73 | 44.44 | 46.95 | 47.80 |

information theory. If a steer's actual attributes are, for example, Choice, Yield Grade 3 then it is assumed that for each pound of beef of that description there is a distribution of beef of other descriptions sold with the Choice, Yield 3 carcass. The distribution of beef by quality and yield grades is based on the probability distributions around Choice and Yield 3 from typical pens or groups of cattle.

Although there are published estimates for the ability of traders to estimate values for attributes (67),none were found which combined estimates of quality grade and yield grade into bivariate estimates. It can be expected that the errors in estimating quality grade are correlated with the errors in estimating yield grade since both involve measures of fat. Cooperation of USDA's Market News Service was gained to obtain data from a procedure the Service calls grade correlations. At some infrequent intervals Market News reporters are asked to estimate and record grade attributes of live steers. Then actual carcass characteristics are recorded and the two are compared.

Data on 1374 cattle in 90 lots from eight markets were obtained and analyzed first on a quality grade basis alone and second with quality grade combined with yield grade. The relative frequencies calculated in both analysis are given in Tables XXIX and XXX. These values are used in the model to convert an actual attribute to a distribution of estimated characteristics. Note that this is exactly the procedure used in information theory to represent a noisy channel.

## Decision Functions

It is an objective of this study to evaluate system performance given various information structures and decision functions. The

# TABLE XXIX

## ESTIMATES OF QUALITY GRADE FOR LIVE CATTLE BY FREQUENCY OF ESTIMATE

| Correct Grade | Estimated Grade<br>Good | <br>Choice | <br>Prime |
|---|---|---|---|
| | | (frequency) | |
| Good | .57 | .37 | .06 |
| Choice | .23 | .64 | .13 |
| Prime | .04 | .47 | .49 |

## TABLE XXX

## ESTIMATES OF YIELD GRADE FOR LIVE CATTLE BY FREQUENCY OF ESTIMATE ACROSS QUALITY GRADES

| Correct Yield Grade by Quality Grade | | Estimated Yield Grade | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Good | | | | | Choice | | | | | Prime | | | | |
| | | 1 | 2 | 3 | 4 | 5 | 1 | 2 | 3 | 4 | 5 | 1 | 2 | 3 | 4 | 5 |
| Good | 1 | .189 | .583 | .098 | | | .008 | .076 | .038 | | | | | .008 | | |
| | 2 | .029 | .329 | .152 | .004 | | | .202 | .224 | .011 | | | .004 | .043 | .004 | |
| | 3 | | .216 | .190 | | | | .069 | .414 | .017 | | | .017 | .043 | .034 | |
| | 4 | | .133 | .067 | .033 | | | .067 | .300 | .100 | | | .133 | .133 | .033 | |
| | 5 | | .500 | | .250 | | | | | | | | | | | .250 |
| Choice | 1 | | .571 | .143 | | | | .238 | .048 | | | | | | | |
| | 2 | .015 | .176 | .095 | | | .007 | .370 | .271 | .004 | | | .011 | .040 | .011 | |
| | 3 | | .086 | .075 | .004 | | | .154 | .450 | .046 | .004 | | .025 | .114 | .039 | .004 |
| | 4 | | .051 | .034 | | | | .085 | .424 | .169 | | | | .169 | .051 | .017 |
| | 5 | | | | | | | | .333 | | | | .167 | .500 | | |
| Prime | 1 | | | | | | | | | | | | | | | |
| | 2 | | .053 | | | | | .289 | .342 | | | | .079 | .237 | | |
| | 3 | | .022 | .022 | .011 | | | .191 | .258 | .011 | | | .022 | .281 | .169 | .011 |
| | 4 | | | | .200 | .200 | | .026 | .308 | | | | .154 | .308 | .179 | .026 |
| | 5 | | | | | | | | | .200 | .200 | | .100 | .400 | .100 | |

decision (or objective) functions are formulated under a number of alternatives. The first is termed sub-system optimization. In this mode, each sub-system is independently allowed to maximize net revenue under a given information structure. This results in five decision functions, one for each sub-system except the feeder which has two. The feeder has one decision function with replacement and one without replacement.

The second mode of decision functions are termed team decision functions. In this mode the decision making point assumes that all information is known and that the rate of return to the system is maximized. Information structure has no effect on the decision in this mode as all revenue comes from the sale of fabricated cuts. The distribution of profits among sub-systems is recorded, however, and is affected by the information structure. Again, two separate decision functions are used for replacement and non-replacement at the feeder level.

A third decision mode, termed an environment mode, allows the computation of the decisions resulting in the least cost per pound of fabricated cuts given a constraint that a particular quantity and quality grade of fabricated beef is to be produced.

One of the desirable properties of the model is that when a given decision function is not being optimized it is used as an accounting row and its value can be monitored.

## The LP Model

An abbreviated picture of the linear programming model is presented in Tables XXXI through XXXV. A literal explanation of some of

## TABLE XXXI

## SIMPLIFIED PICTURE OF THE COW-CALF SUBSYSTEM

| Rows | Columns | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | BHECOW | BANCOW | BRDHEHE | ... | BRDDHHE | OPULDOST | CDECDOST | UNTTOOST |
| OBCOWNR | –a | –a | a | 1 | a | –a | –a | –a |
| OBCOWNR2 | –a | –a | a | . | a | –a | –a | –a |
| OBFDNR | | | –a | . | –a | | | –a |
| OBFDNR2 | | | –a | . | –a | | | –a |
| TOTCOST2 | –a | –a | | | | –a | –a | |
| CPULL | | | –a | ... | –a | 1 | | |
| CSECT | | | –a | ... | –a | | 1 | |
| CCUNIT | | | –a | ... | –a | | | 1 |
| HECOW | -1 | | 1 | | | | | |
| ANCOW | | -1 | | | 1 | | | |
| KOUNT | | | 1 | ... | 1 | | | |
| JEAN | | | -1 | | | | | |
| . | | | | . | | | | |
| . | | | | . | | | | |
| . | | | | . | | | | |
| CHAN | | | | | -1 | | | |

## TABLE XXXII

## SIMPLIFIED PICTURE OF FEEDER-PACKER INTERFACING ACTIVITIES

| Row | Columns | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | FD.... | ESLGY.. | ESLGW.. | ESXLGW.. | ESXLY.. | #2 BLGY.. | #1 BLGW.. | #3 BELGY.. | #4 BELW.. | #2 XBLY.. | #1 XBLW.. | #2 XBELY.. | #4 XBELW.. | #6 BCGY.. | #5 BCGW.. | #6 XBCY.. | #5 XBCW.. |
| OBFDNR | | | | | | A | A | A | A | | | | | A | A | | |
| OBFDNR2 | | | | | | A | A | A | A | | | | | A | A | | |
| XOBFDNR | | | | | | | | | | A | A | | A | | | A | A |
| XPBFDMR2 | | | | | | | | | | A | A | | A | | | A | A |
| OBPACNR | | | | | | -A | -A | -A | -A | | | | | -A | -A | | |
| OBPACNR2 | | | | | | -A | -A | -A | -A | | | | | -A | -A | | |
| LGY.. | -A | 1 | | | | 1 | | | | | | | | | | | |
| LGW.. | -A | | 1 | | | | 1 | | | | | | | | | | |
| ELGY.. | | -P | | | | | | 1 | | | | | | | | | |
| ELGW.. | | | -P | | | | | | 1 | | | | | | | | |
| XLGY.. | -A | | | 1 | | | | | | 1 | | | | | | | |
| XLGW.. | -A | | | | 1 | | | | | | 1 | | | | | | |
| XELGY.. | | | | -P | | | | | | | | 1 | | | | | |
| XELGW.. | | | | | -P | | | | | | | | 1 | | | | |
| CGY.. | -A | | | | | | | | | | | | | 1 | | | |
| CGW.. | -A | | | | | | | | | | | | | | 1 | | |
| XCGY.. | -A | | | | | | | | | | | | | | | 1 | |
| XCGW.. | -A | | | | | | | | | | | | | | | | 1 |

# TABLE XXXIII

## SIMPLIFIED PICTURE OF THE CATTLE FEEDING SUBSYSTEM

| Rows | BRDHEHE | BRDCHAN | BYXHEHE | BYXCHAN | FDHEHE1 | FDHEHE10 | ... | FDCHAN1 | FDCHAN10 | BYNEM | BYNEG | BYXNEM | BYXNEG | BYFEDAY | BYXFEDAY | MKTCOST | XMKTCOST |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| OPFDNR | -a... | -a | | | | | | | | -a | -a | | | -a | | -a | |
| OBFDNR2 | -a... | -a | | | | | | | | -a | -a | | | -a | | -a | |
| XOBFDNR | | | -a... | -a | | | | | | | | -a | -a | | -a | | -a |
| XOBFDNR2 | | | -a... | -a | | | | | | | | -a | -a | | -a | | -a |
| TOTCOST | | | | | | | | | | -a | -a | | | -a | | -a | |
| TOTCOST2 | | | | | | | | | | -a | -a | | | -a | | -a | |
| HEHE | 1 | | | | | | | | | | | | | | | | |
| CHAN | | 1 | | | | | | | | | | | | | | | |
| XHEHE | | | a | | | | | | | | | | | | | | |
| XCHAN | | | | a | | | | | | | | | | | | | |
| ENMAINT | | | | | A.. | | | A | | -1 | | | | | | | |
| ENGAIN | | | | | A.. | | | A | | | -1 | | | | | | |
| XENMAINT | | | | | A.. | | | A | | | | -1 | | | | | |
| XENGAIN | | | | | A.. | | | A | | | | | -1 | | | | |
| DAYSFED | | | | | A.. | | | A | | | | | | -a | | | |
| PERIODS | | | | | A.. | | | A | | | | | | | | | -1 |

## TABLE XXXIV

## SIMPLIFIED PICTURE OF THE PACKER AND FABRICATOR SUBSYSTEMS AND INTERFACE

| Rows | Columns | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | FD.... | PACCOST | #1, 4,5 BFCW.. | #2, 3,6 BFCGY.. | FABCOST | SLGLFAN7 | SLCLEAN7 | SLPLEAN7 | SLFAT75 | SLBON75 | SLGLEAN3 | SLCLEAN3 | SLPLEAN3 | SLFAT3 | SLBON3 |
| OBPACNR | | -a | A | A | | | | | | | | | | | |
| OBPACNR2 | | -a | A | A | | | | | | | | | | | |
| OBFABNR | | | -A | -A | -a | a | a | a | a | a | a | a | a | a | a |
| OBFABNR2 | | | -A | -A | -a | a | a | a | a | a | a | a | a | a | a |
| TOTNR | | -a | | | -a | a | a | a | a | a | a | a | a | a | a |
| TOTCOST2 | | -a | | | -a | | | | | | | | | | |
| FGWG.. | -a | | | | | | | | | | | | | | |
| FCGY.. | -a | | | | | | | | | | | | | | |
| GLEAN3 | -a | | | | | 1 | | | | | | | | | |
| CLEAN3 | -a | | | | | | 1 | | | | | | | | |
| PLEAN3 | -a | | | | | | | 1 | | | | | | | |
| FAT3 | -a | | | | | | | | 1 | | | | | | |
| BONE3 | -a | | | | | | | | | 1 | | | | | |
| GLEAN75 | -a | | | | | | | | | | 1 | | | | |
| CLEAN75 | -a | | | | | | | | | | | 1 | | | |
| PLEAN75 | -a | | | | | | | | | | | | 1 | | |
| FAT75 | -a | | | | | | | | | | | | | 1 | |
| BONE75 | -a | | | | | | | | | | | | | | 1 |
| LEAN3 | -a | | | | | | | | | | | | | | |
| LEAN75 | -a | | | | | | | | | | | | | | |

## TABLE XXXV

## SIMPLIFIED PICTURE OF DECISION FUNCTIONS

| Rows | Columns | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | TRANCOW | TRANFED | TRANPAC | TRANFAB | XTRANFED | DCCOWRR | DCFEDRR | DCPACRR | DCFABRR | DCXFDRR | TEAMRR | XTEAMRR | |
| OBCOWNR2 | | | | | | | | | | | | | N |
| OBFDNR2 | | | | | | | | | | | | | N |
| XOBFDNR2 | | | | | | | | | | | | | N |
| OBPACNR2 | | | | | | | | | | | | | N |
| OBFADNR2 | | | | | | | | | | | | | N |
| OBDCRR | | | | | | 1 | 1 | 1 | 1 | | | | N |
| XOBDCRR | | | | | | 1 | | 1 | 1 | 1 | | | N |
| OBTEAM | | | | | | | | | | | 1 | | N |
| XOBTEAM | | | | | | | | | | | | 1 | N |
| OBCOWNR | -1 | | | | | | | | | | | | E |
| OBFDNR | | -1 | | | | | | | | | | | E |
| OBPACNR | | | -1 | | | | | | | | | | E |
| OBFABNR | | | | -1 | | | | | | | | | E |
| XOBFDNR | | | | | -1 | | | | | | | | E |
| OBCOWNR3 | -1 | | | | | -a | | | | | | | E |
| OBFDNR3 | | -1 | | | | | -a | | | | | | E |
| OBPACNR3 | | | -1 | | | | | -a | | | | | E |
| OBFABNR3 | | | | -1 | | | | | -a | | | | E |
| XOBFDNR3 | | | | | -1 | | | | | -a | | | E |
| COLECTNR | 1 | 1 | 1 | 1 | | | | | | | -a | | E |
| XCLECTNR | 1 | | 1 | 1 | 1 | | | | | | | -a | E |

the column and row names is given in Table XXXVI. Note that dots in a nmemonic indicate more than one class of variable names represented by one name.

## TABLE XXXVI

## LITERAL DESCRIPTION OF TERMS USED IN THE LINEAR PROGRAMMING TABLEAU

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### Columns

BHECOW, BANCOW: Two activities that provides the basic inputs of one Hereford Cow and one Angus cow and all accompanying costs and investments.

BRDHEHE, ..., BRDCHAN: Fourteen breeding activities that combine a bull and cow to produce a calf and account for the revenue to the cow-calf subsystem generated from the sale of calf or well as the cost to the feeding subsystem and the additional physical inputs required due to calving rate and calving difficulty for a given breed.

CPULLCOST: Activity that adds required costs to the cow-calf subsystem for less serious calving problems such as frequency of calf pulling requirements.

UNITCOST: Activity that adds required costs to the cow-calf subsystem to represent calving percentage. For example, if the breeding activities is the basis have a calving percentage of .8 then costs must increase by 20 percent per calf.

BYXHEHE, ..., BYXCHAN: Fourteen activities that procure calves for replacement by the feeder. Note that all activities and rows that contain an X relate to the replacement of feeders in the feeder subsystems. These replacement calves are obtained from the environment.

FDHEHE1, ..., FDHEHE10 to FDCHAN1, ..., FDCHAN10: One hundred and forty feeding activities which are inserted into the LP model from the simulation program. Each breed can be fed any one of ten feeding periods in increments of twenty days. The shortest period is thus 135 days and the longest 335 days. All physical inputs and outputs by attribute are introduced in these activities and maintained in accounting rows.

BYNEM: An activity that adds costs to the feeding subsystem according to the megacals of net energy for maintenance used in the feeding activities for one time feeding.

BYNEG: An activity that adds costs to the feeding subsystem according to the megacals of net energy for gain required by the feeding activities for one time feeding.

BYXNEM: An activity similar to BYNEM, but for replacement feeding.

TABLE XXXVI (Continued)

BYXNEG: An activity similar to BYNEG, but for replacement feeding.

BYFEDAY: An activity that adds costs to the feeding subsystem for each day an animal is fed and represents non-feed variable costs for one time feeding.

BYXFEDAY: An activity that adds costs to the feeding subsystem for one years feeding under replacement.

MKTCOST: An activity for one time feeding that adds a fixed charge for each feeder introduced into the feedlot for one time feeding.

XMKTCOST: An activity that adds a fixed charge for each feeder introduced to the feeding subsystem in one year under replacement. For example, if the composite calf is fed 200 days then 365/200 or 1.825 calves could be fed in one year.

ESLGY..: Fifteen activities for one time feeding that represent the estimation of quality grade and yield grade attributes simultaneously. ESLGYG1 reads: Estimate quality grade Good and yield grade 1.

SEXLY...: Fifteen activities that are identical to ESLGY.. but are used with replacement.

ESLGW..: Three activities that represent estimation of quality grade attributes alone under one time feeding.

ESXLGW..: Three activities identical to ESLGW but used under replacement.

BLGY..: Fifteen activities that represent the sale of the live steer on an actual quality grade and yield grade basis. This set of activities is used with information structure #2 for one time feeding. These add revenues to the feeding subsystem and costs to the packer subsystem.

BLGW..: Nine activities that represent the sale of live steer on a quality grade and weight range basis. The weight ranges are less than 700 pounds, 700 to 900 pounds, 900 to 1100 pounds and greater than 1100 pounds. This set of activities is used with information structure #1 and add revenue to the feeding subsystem and costs to the packers subsystem.

BELGY..: Fifteen activities representing trading on an actual live quality grade and yield grade basis, used with information structure #2 for replacement feeding.

## TABLE XXXVI (Continued)

BELW..: Nine activities representing trading on an estimated quality grade and actual weight range basis, used with information structure #4 for one time feeding.

XBLY..: Fifteen activities representing trading on an actual live quality grade and yield grade basis, used with information structure #2 for replacement feeding.

XBLW..: Nine activities representing trading on an estimated quality grade and weight range basis, used with information structure #1 for replacement feeding.

XBELY..: Fifteen activities representing trading on an estimated quality grade and yield grade basis, used with information structure #3 for replacement feeding.

XBELW..: Nine activities that represent trading on a live estimated quality grade weight range basis. Used with information structure #3 for replacement feeding.

BCGY..: Fifteen activities that represent trading on a carcass quality grade and yield grade basis. Used with information structure #6 for one time feeding.

BCGW..: Fifteen activities that represent trading on a carcass quality grade and weight range basis, used with information structure #5 for one time feeding.

XBCY..: Fifteen activities that represent trading on a carcass quality grade and yield grade basis, used with information structure #6 for one time feeding.

XBCW..: Fifteen activities that represent trading on a carcass quality grade and weight basis, used with information structure #5 for replacement feeding.

PACCOST: An activity that introduces costs on a carcass basis for the packing subsystems. It is forced into the basis at a level of one.

BFCW..: Fifteen activities that represent trading from the packer to the fabricator for carcasses on a carcass quality grade and weight range basis, used with information structures #1, #4, and #5. These add revenue to the packing subsystem and costs to the fabricator subsystem.

BFCY..: Fifteen activities that represent trading from the packer to the fabricator on a carcass quality grade and weight range basis, used with information structures #2, #3, and #6. These add revenue to the packer subsystem and costs to the fabricator subsystem.

TABLE XXXVI (Continued)

FABCOST: An activity which introduces operating costs on a carcass basis for the fabricator. It is forced into the basis at a level of one.

SLGLEAN7: An activity which sells boxed beef to the environment which has a quality grade of Good and a fat trim thickness of .75 inches maximum. It adds revenue to the fabricator subsystem.

SLCLEA7, SLPLEAN7: Activities like SLGLEAN7 but for Choice and Prime.

SLFAT7, SLBON75: Activities which sell fat and bone from cuts trimmed to .75 inches.

SLFAT#, SLBON#: Activities which sell fat and bone from cuts with .3 inches fat cover.

TRANCOW, TRANFED, TRANPAC, TRANFAB, XTRANED: Activities which are bounded such that they may be negative and transfer revenue or losses from subsystems to accounting rows for system decision functions.

DCCOWRR, DCFEDRR, DCPACRR, DCFABRR, DCXFDRR: Activities which "divide" the net revenue from a given subsystem by the investment in that subsystem and transfers the dividend to the decentralized decision functions.

TEAMRR, XTEAMRR: Activities which "divide" the summed net revenue for each subsystem by the total system investment and transfers the dividend to the team decision functions.

Rows

OBCOWNR2: An unconstrained row representing the cow calf subsystem decision function as the net revenue of the cow-calf subsystem. Costs include a charge forinterest on invested capital.

OBFDNR2: An unconstrained row representing the feeding subsystem decision function as the net revenue of the feeding subsystem for one time feeding. Costs include a charge for interest on investment.

XOBFDNR2: An unconstrained row representing the feeding subsystem decision function as the net revenue of the feeding subsystem for replacement feeding. Costs include a charge for interest on investment.

OBPACNR2: An unconstrained row representing the packer subsystem decision function as the net revenue of the packer subsystem. Costs include a charge for interest on investment.

TABLE XXXVI (Continued)

OBDCRR: An unconstrained row representing rate of return for the decentralized decision function under one time feeding.

XOBDCRR: An unconstrained row representing rate of return for the decentralized decision function under replacement feeding.

OBTEAM: An unconstrained row representing rate of return for the team or system decision function under one time feeding.

OBCOWNR, OBFDNR, OBPACNR, OBFABNR, XOBFDNR: Equality rows similar to .... NR2 above but containing no charge for interest on investment. These are used by the decentralized decision function activities.

TOTCOST2: An unconstrained row which moniters total cost for the system applying costs which contain a charge for interest on investment.

COLECTNR, XCOLECTNR: Equalities which "collect" net revenues from the separate subsystems for use by the team decision activities.

CPULL, CSECT, CCUNIT: Equalities which carry physical requirement for excess calving costs and calving percentages.

HECOW, ANCOW: Accounting rows which ascertain what necessary cow is available for breeding.

KOUNT: An equality that assures that one and only one composite calf is bred.

JEAN, ..., CHAN: Fourteen equalities that assure that the calf fed is the same as the calf bred used for one time feeding.

XHEHE, ..., XCHAN: Fourteen equalities that assure that a calf fed under replacement was purchased from the environment.

ENMAINT, EGAIN, XENMAINT, XENGAIN: Equalities which assure that the energy fed under both one time and replacement feeding is purchased.

DAYSFED: Equality which assures that the feeding subsystem is charged for each day a steer spends in the feedlot under one time feeding.

Periods: Equality which assures that the feeding subsystem is charged for each calf and portion of a calf that if fed under replacement feeding.

LGY.., ..., FCGY..: 156 accounting rows which account for all live and carcass product traded between the feeder and packer by categories of attributes on a pound basis. For example, there are fifteen categories for LGY... consisting of one category for each

TABLE XXXVI (Continued)

combination of the 3 live quality grade and 5 yield grades. A set of rows is an equality when the information structure appropriate to it is the being operated upon and unconstrained otherwise. These assure that only product produced can be sold by the feeder and that product will be sold only once at its appropriate price.

FGWG.., FCGY: Accounting rows as above but for carcasses traded between the packer and fabricator. These also assure that only product produced can be sold at its appropriate price.

GLEAN3, ...BONE3: Five accounting rows which assure that product sold by the fabricator to the environment was properly produced. These are equalities under a fat trim requirement of .3 inches, unconstrained otherwise.

GLEAN.75, ...BONE3: Five accounting functions as above but are equalities under a fat trim requirement of .75 inches, unconstrained otherwise.

LEAN3, LEAN75: Unconstrained rows which monitor the amount of lean beef produced of each trim thickness from the composite calf.

# CHAPTER V

# ANALYSIS AND RESULTS

There are a large number of combinations of information structures, decision functions and variations in prices and costs which could be examined. More combinations were analyzed than will be reported here. However, constraints of time and funds available for computer experiments limited the analysis to a basic set of analyses and model specifications. Tables XXXVII through XLII display the results for seven decision functions under each of the six basic information structures. These are followed by Tables XLIII through XLVIII which display results for specified decision functions under selected variations in information structures. Examples are increased cost of feed and change in the price premiums and discounts associated with yield grade. Next, tables XLIX through LII display the breeding and feeding decisions which result in the minimum total cost of producing specified quantities of boneless trimmed beef.

## Explanation of Tables

Table XXXVII displays values for selected variables in the model. The seven solution sets identified in the seven columns were all computed under information structure #1. All transactions at the feeder-packer interface were on a live grade and weight basis.

## TABLE XXXVII

## NET REVENUES, RATES OF RETURN AND PRODUCT ATTRIBUTES FOR SEVEN DECISION FUNCTIONS UNDER INFORMATION STRUCTURE #1

| | | Subsystem or System Decision Function Maximized | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | Subsystem | | | | | Total System | |
| Item | Units | Cow Calf | Feeder No Repl | Feeder With Repl | Packer | Fabricator | No Repl | With Repl |
| Cow-calf NR | $ | 11 | -1 | -7 | 11 | -10 | -1 | 8 |
| Feeder NR, No Repl | $ | NA | 63 | 53 | 21 | 60 | 63 | 50 |
| Feeder NR, With Repl | $ | NA | 70 | 102 | 32 | 68 | 70 | 73 |
| Packer NR | $ | NA | -19 | -14 | 20 | -10 | -19 | -10 |
| Fabricator NR | $ | NA | 98 | 58 | 59 | 98 | 98 | 87 |
| System RR, No Repl | % | NA | 18 | 14 | 16 | 18 | 18 | 17 |
| System RR, With Repl | % | NA | 18 | 18 | 16 | 18 | 18 | 19 |
| | | | | | | | | |
| Total Cost per Steer | $ | NA | 396 | 306 | 345 | 398 | 396 | 347 |
| Live Weight | Lbs. | NA | 1330 | 966 | 1123 | 1301 | 1330 | 1162 |
| Carcass Weight | Lbs. | NA | 802 | 599 | 691 | 793 | 802 | 709 |
| Fabricated Cuts | Lbs. | NA | 530 | 391 | 470 | 532 | 530 | 478 |
| Trimmed Fat | Lbs. | NA | 170 | 134 | 131 | 159 | 170 | 139 |
| Production Cost/Lb. | ¢/lb. | NA | 75 | 78 | 73 | 75 | 75 | 73 |
| Quality - Yield Grade | Grade | NA | C-3 | C-3 | G-2 | C-2 | C-3 | C-2 |
| Breed of Steer | - | HEAN | SIHE | ANAN | LIAN | CHHE | SIHE | CHAN |
| Feeding Period | Days | NA | 335 | 195 | 255 | 335 | 335 | 255 |

Each column displays a decision set under an identified decision function. Column 1 displays a solution set for decision function OBCOWNR2. This decision function maximizes net returns for the cow-calf stage. Only the net revenue for the cow-calf state and the breeding decision are shown in column 1.

Column 2 of Table XXXVII desplays the solution set for the decision function OBFDNR2. This decision function maximizes the net revenue to the feeding stage when only one calf per unit of feedlot capacity is fed per year (no replacement). Reading down the column, the first entry, $1, is the net revenue experienced by the cow-calf state given that OBFDNR2 is maximized. The second entry,$63, which lies on the diagonal is the maximum net revenue for OBFDNR2. The third entry in the column, $70, is the net revenue that would be experienced by the feeder stage if the breed and feeding period are the same but the lot is kept full (replacement).

The fourth entry in column 2, $-19, is the net revenue per unit of capacity experienced by the packer stage when forced to purchase and process the animal maximizing the column decision function. Similarly, the fifth or fabricator's entry, $98, is the net revenue experienced by the fabricator when purchasing and processing the carcass dictated by maximizing OBFDNR2. The sixth entry, 18, is the percent rate of return to total system investment when OBFDNR2 is maximized. The seventh and last entry in the upper part of the table, 18, is the percent rate of return on total system investment if the feedlot stage replaced using the same breed and feeding period.

The eighth entry, $396, is the total cost per carcass required to bring the beef to the point of boneless, trimmed and fabricated cuts.

The ninth and tenth entries in column 2, 1330 and 802, are the live weight and carcass weight of the animal produced. The eleventh entry, 530, is the weight of boneless, trimmed beef produced per carcass and the twelfth entry, 170, is the weight of fat trimmed away in processing.

The thirteenth entry, 75, is the total cost, in cents, per pound of boneless, trimmed beef. The fourteenth entry, C-3, gives the quality grade and yield grade of the carcass produced. The notation "C" indicates Choice and 3 indicates yield grade 3. The fifteenth entry, SIHE, denotes the breed group, Simmental-Hereford, and the last entry, 334, is the number of days the animal is fed in the feedlot.

Successive columns are read in a similar manner. In each case, the entries in a column are the solution set for optimizing the decision function named at the head of the column. Subsequent tables are constructed like table XXXVII. The tables differ from each other in that each displays solution sets optimized within different information structures.

## Results by Information Structure and Decision Function

### Information Structure #1: Live Grade and Weight with.3 Inches Fat Trim

Cow-Calf Decision Function (OBCOWNR2). Actual, not extimated, grade and weight are employed in all exchange and transfer processes. Quality grade for the live animal is assumed known based on carcass grade. All transactions are on a liveweight basis. Table XXXVII displays objective function values for the subsystem or system being optimized, concomitant returns for other stages and physical data for the steer, carcass, and fabricated meat produced. The optimum decision for the cow-calf decision function is to produce a Hereford-Angus (HEAN)cross calf yielding a long run net revenue of $11 per calf. The remaining rows in the first column are marked NA (not applicable) because the values computed from other subsystems are neither constrained nor optimized, are meaningless and therefore are not reported.

<u>Feeder Decision Function Without Replacement (OBFDNR2)</u>. The feeder stage maximized returns to a single feeding period (no replacement) feeding a Simmental-Hereford (SIHE) for 335 days. This yields a long-run net revenue of $63 per head. Under this decision and information structure the cow-calf stage loses $1 per head and the packer stage loses $19 per carcass. The fabricator net revenue is $98 and the total system rate of return on investment is 18 percent. The carcass produced under this decision is a Choice yield grade 3 and the total production costs are slightly under $.75 per pound.

<u>Feeder Decision Function With Replacement (XOBFDNR2).</u> The feeder stage with replacement, which involves selling one steer and replacing it with another to keep feedlot space full for the year, results in the feeding of an Angus-Angus (ANAN) for 195 days. This feeding program returns a net revenue of $102 to one unit of feedlot capacity. Cow-calf net revenue per head is reduced to $-7 and packer net revenue to $-14 per head. Net revenue for the fabricator stage is $58 and the system rate of return with replacement is 18 percent.

Packer Decision Functions (OBPACNR2). The packer stage maximizes net revenue per carcass under live grade and weight sales when buying a Limousin-Angus (LIAN) fed for 255 days. The packer nets $20 per head and the cow-calf stage nets slightly under $11. The feeder's returns are $21 and $32 respectively for nonreplacement and replacement and the fabricator's net revenue is reduced to $59. Total system rate of return is also reduced by two percentage points to 16 percent without and with replacement. The carcass is a Good yield grade 2. The cost per pound of lean is $.73.

Fabricator Decision Function (OBFABNR2). The fabricator maximizes net revenue per carcass with a Charolais-Hereford (CHHE) fed 335 days. The net revenue to the fabricator is $98 per carcass. The feeder is harmed little by maximizing to the fabricator but the packer and cow-calf subsystems suffer losses. The system maximum rate of return is back to 18 percent and the cost of beef is $.75 per pound.

Total System Decision Function Without Replacement (OBTEAM). The "team" optimum without replacement is to produce and process a Simmental-Hereford (SIHE) fed 335 days. This is identical to the feeder solution without replacement and thus shows agreement between feeder and system optima. The fabricator receives the same net revenue as when maximizing to the fabricator level. The solution indicates a minor loss for the cow-calf system and an important loss for the packer subsystem. The optimum rate of return to the system without replacement is 18 percent and the carcass produced is a Choice yield grade 3.

Total System Decision Function with Replacement (XOBTEAM). This decision function determines the optimum feeding and breeding decision when the feeding level is operated at capacity. The system rate of return is 19 percent, a level obtained under no other decision function with information structure #1. A Charolais-Angus (CHAN) was produced and fed 255 days before being replaced. Revenues were distributed so that the packer loses $10 per carcass. The carcass produced is a Choice yield grade 2 and the cost of producing fabricated beef trimmed to .3 inches is $.73 per pound.

### Information Structure #2: Live Grade and Yield Grade with .3 Inches Fat Trim

All solutions derived under Information Structure #2 are based on interlevel transactions involving premiums and discounts based on actual live quality grade and yield grade. Carcass trades are based on carcass quality grade and yield grade. The price schedules were developed in Chapter IV. A summary of solutions discussed below is displayed in Table XXXVIII.

Cow-Calf Decision Function (OBCOWNR2). The cow-calf optimum is not affected by the information structure. Hereford-Angus (HEAN) is optimum for all information structures.

Feeder Decision Function Without Replacement (OBFDNR2). The inclusion of yield grade in the pricing mechanism caused the feeder optimum without replacement to change to Charolais-Hereford (CHHE), fed for 335 days. Net revenue increased by $1 to $19. A Choice yield

## TABLE XXXVIII

## NET REVENUES, RATES OF RETURN, AND PRODUCT ATTRIBUTES FOR SEVEN DECISION FUNCTIONS UNDER INFORMATION STRUCTURE #2

| Item | Units | Sybsystem or System Decision Function Maximized | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | Subsystem | | | | | Total System | |
| | | Cow Calf | Feeder No Repl | Feeder With Repl | Packer | Fabricator | No Repl | With Repl |
| Cow-calf NR | $ | 11 | -10 | -7 | 11 | -1 | -1 | 8 |
| Feeder NR, No Repl | $ | NA | 64 | 53 | 17 | 60 | 60 | 53 |
| Feeder NR, With Repl | $ | NA | 72 | 102 | 22 | 67 | 67 | 79 |
| Packer NR | $ | NA | -7 | -14 | 8 | -11 | -11 | -7 |
| Fabricator NR | $ | NA | 90 | 58 | 71 | 93 | 93 | 78 |
| System RR, No Repl | % | NA | 18 | 14 | 15 | 18 | 18 | 17 |
| System RR, With Repl | % | NA | 18 | 17 | 16 | 18 | 18 | 19 |
| Total Cost per Steer | $ | NA | 398 | 305 | 369 | 396 | 396 | 347 |
| Live Weight | Lbs. | NA | 1301 | 996 | 1216 | 1330 | 1330 | 1162 |
| Carcass Weight | Lbs. | NA | 793 | 599 | 754 | 802 | 802 | 709 |
| Fabricated Cuts | Lbs. | NA | 532 | 391 | 500 | 530 | 530 | 478 |
| Trimmed Fat | Lbs. | NA | 158 | 134 | 159 | 170 | 170 | 139 |
| Production Cost/Lb. | ¢/lb. | NA | 75 | 78 | 74 | 75 | 75 | 73 |
| Quality - Yield Grade | Grade | NA | C-2 | C-3 | G-2 | C-3 | C-3 | C-2 |
| Breed of Steer | - | HEAN | CHEE | ANAN | LIAN | SIHE | SIHE | CHAN |
| Feeding Period | Days | NA | 335 | 195 | 315 | 335 | 335 | 255 |

grade 2 carcass is produced. There is no significant change in the total cost of producing fabricated beef.

Feeder Decision Function With Replacement (XOBFDNR2). Incorporating information structure #2 brought no change in either the breeding and feeding decision or in revenue to the feeding subsystem with replacement.

Packer Decision Function (OBPACNR2). The optimum breed remained Limousin-Angus (LIAN) for the packer under information structure #2. However, the feeding period increased from 255 to 315 days under information structure #2 with the grade attributes remaining Good, yield grade 2. The maximum net revenue for the packer subsystem is \$8 compared to \$20 under information structure #1. The cost of producing fabricated beef for the system under packer optimization is \$.74 per pound.

Fabricator Decision Function (OBFABNR2). The fabricator decision function under information structure #2 calls for a Simmental-Hereford (SIHE) fed 335 days and yielding a net revenue of \$93, \$5 less than the \$98 obtained under information structure #1. Effects on other subsystems include an increase in losses at the cow-calf level, small changes at other subsystem levels.

Total System Decision Function Without Replacement (OBTEAM). The optimum breeding and feeding decision for the total system are the same for each of the six basic information structures. This is predictable since the decisions are based on costs, final sales, and total investment that do not vary with information structure. Of interest, however, is the distribution of revenues among subsystems by information structure. Comparing results for #2 against #1 reveals increases in net revenue for the feeder and packer subsystems and decreases for the fabricator.

Total System Decision Function With Replacement (XOBFDNR2). Again optimum breeding and feeding decisions are predictably unchanged. But there is a revenue transfer from the fabricator to the replacing feeder and packer subsystem.

### Information Structure #3: Estimated Live Grade and Weight with .3 Inches Fat Trim

This information structure allows the live steer to be traded according to eyeball estimates of quality grade and yield grade. The carcass trade is according to actual quality grade and weight. Price schedules were given in Chapter IV. Comparisons will be made against information structure #2 in Table XXXVIII in order to examine the effects of estimation errors on decisions and returns. The summary of solutions for information structure #3 is displayed in Table XXXIX.

Feeder Decision Function Without Replacement (OBFDNR2). The introduction of estimation errors into the system caused feeder net revenue to be maximized with a Simmental-Hereford (SIHE) fed 335 days rather than a Charolais-Hereford fed 335 days. A Choice yield grade 3 carcass rather than a Choice yield grade 2 carcass is produced. Total production costs are increased less than $.01 per pound. Compared with the same decision function under information structure #1, the cow-calf subsystem and fabricator are better off while the feeder and packer are both worse off. Total system rate of return remains at 18 percent.

## TABLE XXXIX

## NET REVENUES, RATES OF RETURN, AND PRODUCT ATTRIBUTES FOR SEVEN DECISION FUNCTIONS UNDER INFORMATION STRUCTURE #3

| Item | Units | Subsystem or System Decision Function Maximized | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | Subsystem | | | | | Total System | |
| | | Cow Calf | Feeder No Repl | Feeder With Repl | Packer | Fabricator | No Repl | With Repl |
| Cow-calf NR | $ | 11 | -1 | -7 | -7 | -1 | -1 | 8 |
| Feeder NR, No Repl | $ | NA | 58 | 41 | 43 | 58 | 58 | 43 |
| Feeder NR, With Repl | $ | NA | 66 | 99 | 49 | 66 | 66 | 65 |
| Packer NR | $ | NA | -10 | -19 | 10 | -10 | -10 | 3 |
| Fabricator NR | $ | NA | 93 | 45 | 84 | 93 | 93 | 80 |
| System RR, No Repl | % | NA | 18 | 12 | 17 | 18 | 18 | 17 |
| System RR, With Repl | % | NA | 18 | 16 | 18 | 18 | 18 | 19 |
| Total Cost per Steer | $ | NA | 396 | 283 | 390 | 360 | 396 | 347 |
| Live Weight | Lbs. | NA | 1330 | 907 | 1251 | 1330 | 1330 | 1162 |
| Carcass Weight | Lbs. | NA | 802 | 541 | 776 | 801 | 802 | 709 |
| Fabricated Cuts | Lbs. | NA | 530 | 361 | 516 | 530 | 530 | 478 |
| Trimmed Fat | Lbs. | NA | 170 | 110 | 161 | 170 | 170 | 139 |
| Production Cost/Lb. | ¢/lb. | NA | 75 | 78 | 75 | 75 | 75 | 73 |
| Quality - Yield Grade | Grade | NA | C-3 | G-2 | C-2 | C-3 | C-3 | C-2 |
| Breed of Steer | - | HEAN | SIHE | ANAN | LIHE | SIHE | SIHE | CHAN |
| Feeding Period | Days | NA | 335 | 155 | 335 | 335 | 335 | 255 |

Feeder Decision Function With Replacement (XOBFDNR2). The optimum breed is still Angus-Angus (ANAN). However, the feeding period is decreased to 155 days and the actual quality grade is Good with a yield grade of 2. This solution changed the quality grade of the beef without significantly changing its total cost of production. The total net revenue to the system is reduced as rate of return drops from 16 percent to 12 percent and all stages experience reduced revenue when compared with information structure #2.

Packer Decision Functions (OBPACNR2). The packer subsystem is able to increase net revenue $2 over information structure #2 by buying a Limousin-Hereford (LIHE) fed 335 days rather than a LIAN fed 315 days. The carcass is a Choice yield grade 2 and the total cost of producing Choice fabricated beef is $.75 per pound. The rate of return on system investment changed very little.

Fabricator Decision Function (OBFABNR2). The fabricator decision and returns were predictably not different from information structure #2. The distribution of revenues was not appreciably affected.

Total System Decision Function Without Replacement (OBTEAMNR). As previously stated the "team" decisions are unaffected by information structure but the distribution of revenues is affected. This distribution is only slightly changed from information structure #2 to #3 with feeder returns decreased $2, the packer returns increased $1 and the fabricator returns are unchanged.

Total System Decision Function With Replacement (XOBTEAMNR). Feeder net revenue decreased almost $14 while the packer's increased

$10 and the fabricator's increased over $2. The system rate of return increased to 19 percent.

### Information Structure #4: Estimated Live Grade and Weight With Actual Carcass Grade and Weight

Within this information structure each decision function was optimized with trade on a live basis, quality grade estimated, and the carcass passing from the packer to the fabricator on an actual quality grade and weight basis. Comparisons are made with information structure #1 which differs from #4 in that live quality grades in #1 are imputed actual grades and not estimated. The solution summary for information structure #4 is displayed in Table XL.

Feeder Decision Function Without Replacement (OBFDNR2). The maximum net revenue for the feeder without replacement under information structure #4 calls for the same breed and feeding period as under information structure #1. Feeder net revenue decreased, however, and packer net revenue increased.

Feeder Decision Function With Replacement (XOBFDNR2). The optimum breeding and feeding decisions differed markedly from information structure #1. The optimum dictated moving to feeding of Charolais-Hereford (CHHE) for only 155 days and producing a Good yield grade 1 carcass. Under this program the feeder is paid a Choice price for a portion of a Good grade animal because of errors in estimating quality grade. The feeder's net revenue is still about $8 less than under information structure #1, however. The packer's net revenue is reduced,

## TABLE XL

## NET REVENUES, RATES OF RETURN, AND PRODUCT ATTRIBUTES FOR SEVEN DECISION FUNCTIONS UNDER INFORMATION STRUCTURE #4

| | | Subsystem or System Decision Function Maximized | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | Subsystem | | | | | Total System | |
| Item | Units | Cow Calf | Feeder No Repl | Feeder With Repl | Packer | Fabricator | No Repl | With Repl |
| Cow-calf NR | $ | 11 | -1 | -10 | 11 | -10 | -1 | 8 |
| Feeder NR, No Repl | $ | NA | 56 | 39 | 33 | 54 | 56 | 44 |
| Feeder NR, With Repl | $ | NA | 64 | 94 | 49 | 61 | 64 | 66 |
| Packer NR | $ | NA | -13 | -19 | 8 | -4 | -13 | -5 |
| Fabricator NR | $ | NA | 97 | 74 | 59 | 98 | 98 | 87 |
| System RR, No Repl | % | NA | 18 | 14 | 16 | 18 | 18 | 17 |
| System RR, With Repl | % | NA | 18 | 18 | 17 | 18 | 18 | 19 |
| Total Cost per Steer | $ | NA | 396 | 300 | 334 | 398 | 396 | 347 |
| Live Weight | Lbs. | NA | 1330 | 962 | 1123 | 1302 | 1330 | 1162 |
| Carcass Weight | Lbs. | NA | 802 | 573 | 691 | 793 | 802 | 709 |
| Fabricated Cuts | Lbs. | NA | 530 | 408 | 470 | 532 | 530 | 478 |
| Trimmed Fat | Lbs. | NA | 170 | 85 | 131 | 158 | 170 | 139 |
| Production Cost/Lb. | ¢/lb. | NA | 75 | 73 | 71 | 75 | 75 | 73 |
| Quality - Yield Grade | Grade | NA | C-3 | G-1 | G-2 | C-2 | C-3 | C-2 |
| Breed of Steer | - | HEAN | SIHE | CHHE | LIAN | CHHE | SIHE | CHAN |
| Feeding Period | Days | NA | 335 | 155 | 255 | 335 | 335 | 255 |

the fabricator's is increased $16. High turnover and low feed costs allow the system replacement rate of return to remain high at 18 percent.

The remaining decision functions under information structure #4 will not be discussed individually because all breeding and feeding decisions are unchanged and only small income redistributions occur.

### Information Structure #5: Carcass Grade and Weight with .3 Inches Fat Trim

Information structure #5 allows transactions between the feeder and packer, and between packer and fabricator, to occur on an actual carcass grade and weight basis with price schedules as given in Chapter IV, Solution summaries are given in Table XLI and are compared with information structure #1 from Table XXXVII.

Feeder Decision Function Without Replacement (OBFDNR2). The breed and feeding combination which maximizes net revenue per unit of capacity for the feeder without replacement is Charolais-Hereford (CHHE) fed for 335 days.

A change in the distribution of revenues between the packer and the feeder is apparent. The net revenue to the feeder is $45 compared with $63 in Table XXXVII. Net revenue to the packer increased from -$19 to $5. Fabricator revenue remains constant at $98. However, the cow-calf subsystem drops from $-1 to $-10. A Choice yield grade 2 carcass is produced and the cost per pound of fabricated beef is approximately $.75.

TABLE XLI

NET REVENUES, RATES OF RETURN, AND PRODUCT ATTRIBUTES FOR SEVEN DECISION FUNCTIONS UNDER INFORMATION STRUCTURE #5

| | | Subsystem or System Decision Function Maximized | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | Subsystem | | | | | Total System | |
| Item | Units | Cow Calf | Feeder No Repl | Feeder With Repl | Packer | Fabricator | No Repl | With Repl |
| Cow-calf NR | $ | 11 | -10 | -7 | 11 | -10 | -1 | 8 |
| Feeder NR, No Repl | $ | NA | 45 | 40 | 19 | 45 | 38 | 37 |
| Feeder NR, With Repl | $ | NA | 51 | 78 | 31 | 51 | 43 | 55 |
| Packer NR | $ | NA | 5 | -7 | 21 | 5 | 6 | 2 |
| Fabricator NR | $ | NA | 98 | 58 | 53 | 98 | 97 | 87 |
| System RR, No Repl | % | NA | 18 | 14 | 15 | 18 | 18 | 17 |
| System RR, With Repl | % | NA | 18 | 17 | 16 | 18 | 18 | 19 |
| | | | | | | | | |
| Total Cost per Steer | $ | NA | 398 | 306 | 333 | 398 | 385 | 347 |
| Live Weight | Lbs. | NA | 1302 | 996 | 1140 | 1302 | 1330 | 1162 |
| Carcass Weight | Lbs. | NA | 793 | 599 | 606 | 793 | 802 | 709 |
| Fabricated Cuts | Lbs. | NA | 532 | 391 | 460 | 532 | 530 | 478 |
| Trimmed Fat | Lbs. | NA | 158 | 134 | 138 | 158 | 170 | 139 |
| Production Cost/Lb. | ¢/lb. | NA | 75 | 78 | 72 | 75 | 75 | 73 |
| Quality - Yield Grade | Grade | NA | C-2 | C-3 | G-2 | C-2 | C-3 | C-2 |
| Breed of Steer | - | HEAD | CHHE | ANAN | SIAN | CHHE | SIHE | CHAN |
| Feeding Period | Days | NA | 335 | 195 | 235 | 335 | 335 | 255 |

Feeder Decision Function With Replacement (XOBFDNR2). No important change occurs relative to information structure #1. The breeding and feeding decision is the same. The feeder net revenue decreased and packer net revenue increased but remained negative. The system rate of return decreased slightly and the cost of production moved up to $.78 per pound.

Packer Decision Function (OBPACNR2). Under information structure #5, the packer subsystem can increase net revenue from $20 to $21 by purchasing a Simmental-Angus (SIAN) fed only 275 days with Good yield grade 2 attributes.

Total System Decision Functions With and Without Replacement (OBTEAM and XOBTEAM). There was no change from information structure #1 under either decision function. The revenues were distributed more evenly, however, especially with replacement.

### Information Structure #6: Carcass Grade And Yield Grade With .3 inch Fat Trim

This information structure is considered the most precise of the 6 basic structures. All transactions are based on actual carcass quality grade and yield grade. Comparisons are again made with information structure #1. Solution summaries for information structure #6 are displayed in Table XLII.

Feeder Decision Function Without Replacement (OBFDNR2). The feeder maximizes net revenue at $53 when feeding a Charolais-Hereford (CHHE) for 335 days. This is $10 less than the maximum under information structure #1 feeding a SIHE 335 days. The accompanying packer net

## TABLE XLII

## NET REVENUES, RATES OF RETURN, AND PRODUCT ATTRIBUTES FOR SEVEN DECISION FUNCTIONS UNDER INFORMATION STRUCTURE #6

| | | Subsystem or System Decision Function Maximized | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | Subsystem | | | | | Total System | |
| Item | Units | Cow Calf | Feeder No Repl | Feeder With Repl | Packer | Fabricator | No Repl | With Repl |
| Cow-calf NR | $ | 11 | -10 | -7 | -1 | -1 | -1 | 8 |
| Feeder NR, No Repl | $ | NA | 53 | 40 | 43 | 43 | 43 | 44 |
| Feeder NR, With Repl | $ | NA | 60 | 77 | 49 | 49 | 49 | 65 |
| Packer NR | $ | NA | 5 | -1 | 5 | 5 | 5 | 2 |
| Fabricator NR | $ | NA | 90 | 58 | 93 | 93 | 93 | 80 |
| System RR, No Repl | % | NA | 18 | 14 | 18 | 18 | 18 | 17 |
| System RR, With Repl | % | NA | 18 | 17 | 18 | 18 | 18 | 19 |
| | | | | | | | | |
| Total Cost per Steer | $ | NA | 398 | 306 | 296 | 396 | 396 | 347 |
| Live Weight | Lbs. | NA | 1302 | 996 | 1330 | 1330 | 1330 | 1162 |
| Carcass Weight | Lbs. | NA | 793 | 599 | 874 | 874 | 802 | 709 |
| Fabricated Cuts | Lbs. | NA | 532 | 391 | 530 | 530 | 530 | 478 |
| Trimmed Fat | Lbs. | NA | 158 | 134 | 170 | 170 | 170 | 139 |
| Production Cost/Lb. | ¢/lb. | NA | 75 | 78 | 75 | 75 | 75 | 73 |
| Quality - Yield Grade | Grade | NA | C-2 | C-3 | C-3 | C-3 | C-3 | C-2 |
| Breed of Steer | - | HEAN | CHHE | ANAN | SIHE | SIHE | SIHE | CHAN |
| Feeding Period | Days | NA | 335 | 195 | 335 | 335 | 335 | 255 |

revenue is much improved at $5 compared to $-19 and the fabricator returns are comparable at $90 versus $98. Production cost per pound of fabricated beef remains at $.75 and total system rate of return is still at 18 percent.

Feeder Decision Function With Replacement (XOBFDNR2). ANAN fed 195 days remains the optimum program for the feeder who replaces with net revenue at $77. This is down from $102 for XOBFDNR2 under information structure #1. The packer's losses are reduced and the fabricator's net revenues are substantially reduced from #1. Production costs per pound of fabricated beef increase to $.78. The total system rate of return for replacement is 17 percent, down 1 percent from information structure #1.

Packer, Fabricator, and Total System Without Replacement Decision Functions (OBPACNR2, OBFABNR2, and OBTEAM). Optimizing for each of these decision functions under information structure #6 results in the same breeding and feeding decisions. The optimum calls for SIHE fed 335 days. Function values are $5, $93 and 18 percent for the packer, fabricator and system respectively.

The cow-calf subsystem net revenue is $-1 and the feeder revenues are $43. The total production cost per pound for fabricated beef is again $.75.

Total System With Replacement Decision Functions (XOBTEAM). Good net distribution is achieved with this information structure. However, it does not appear to be better than that attained under information structure #3.

## Recap for Six Basic Information Structures

### Goal Conflict

It is apparent that given the costs, price schedules, and assumptions of the model, important goal conflict exists among the subsystems. The difference between the highest net revenue or rate available to a particular sector when its own decision function is optimized and the level realized when some other decision function is optimized is generally large. For example, the largest net revenue per calf possible for the cow-calf subsystem is $11 and the smallest occuring is $-10. This $-10 occurs under at least one information structure when each of the other 4 subsystem decision functions is optimized.

The largest net revenue generated for the feeder without replacement is $64 under information structure #2. The smallest is $17 which results when the packer subsystem decision function is maximized under the same information structure. The wide range of returns indicates the importance of coordination as to type of cattle and feeding program if transactions are on a liveweight basis.

The feeder decision function with replacement has an overall maximum at $102 also under information structure #2. With the packer decision function being maximized under the same information structure, the feeder's revenue drops to $22.

The packer decision function reaches an overall maximum at $21 with information structure #5. The lowest value occurs when the feeder decision function, with replacement, is optimized under information structure #3. Again, major conflicts appear between the feeder and packer.

The fabricator's maximum net revenue occurs under information structures #1, #4 and #5. Each is a structure in which yield grade is not considered in pricing. A low of $45 evolves under structure #3 when the feeder's decision function, with replacement, is optimized.

The total system rates of return and decisions are the same regardless of information structure when the system decision function is optimized. The non replacing system optimum decision of SIHE fed 335 days appears as the optimum on several occasions: once in information structure #1 (for the non replacing feeder); once in #2 for the fabricator; twice in #3 (non replacing feeder and fabricator); once in #4 (non replacing feeder); and twice in #6 (packer and fabricator). A total of fourteen out of a possible twenty-four subsystem optima yielded non-replacing system rates of return that rounded to equal the 18 percent maximum. The system rate of return dropped as low as 12 percent when ANAN were fed 155 days, the optimum for the replacing feeder under information structure #3.

The optimum replacement system decisions (feeding a Charolais-Hereford for 255 days) never appears as a subsystem optimum and the 19 percent rate of return obtained from this breeding and feeding combination is not equalled by any other solution although many (seventeen) miss by only 1 percent at 18 percent. It is also one of the few decisions yielding a positive net revenue to the cow-calf subsystem.

No subsystem optimum came within $.02 per pound of matching the overall minimum production cost per pound achieved with the Charolais-Angus program when the system decision function was optimized. Costs were $.73 for Choice fabricated beef trimmed to .3 inch of fat cover.

The difference between the maximum possible net revenue available to each subsystem and that resulting from a program producing in accordance with the total system optimum with replacement across all information strucutres are: cow-calf \$3; replacing feeder \$39; packer \$19; and fabricator \$18. Within information structure #6 these differences are: cow-calf \$3; replacing feeder \$22; packer \$3; and fabricator \$13.

Thus there is conflict both among subsystem and between subsystem optima and total system optima. It seems then that the pricing schemes modeled fail to promote decisions by subsystem net revenue maximizers which lead either to highest returns on investment or the lowest cost of production when the feeders replace.

There is always at least one information structure which leads each subsystem, except the cow-calf, to the Simmental-Hereford fed 335 days which is the system optimum for feeding without replacement.

## Selected Special Analyses

In an attempt to study the implications of restricting all "subsequent" subsystems to the product produced by a previous (in the chain of actions) subsystem the following analyses were performed. First, the cow-calf subsystem was optimized. The remaining subsystems and total system were analyzed to find their optima given that a Hereford-Angus, (HEAN) the cow-calf subsystem optimum breed, is the only possible breed.

In a second and related analysis, the packer, fabricator, and total system measures were limited to both the breed determined by the cow-calf subsystem and the optimum feeding period determined by analysis of the feeding subsystem. These two analyses were performed for information structure #1 (labeled #1-HEAN) and information structure #6 (labeled #6-HEAN) respectively.

An increase in the allowable fat cover on retail cuts was the important change in another analysis. Cutout tests on 158 steer carcasses gave results which suggested the fat cover is an important determinant of the yield of retail cuts as a percent of carcass weight. The fat cover was allowed to range up to .75 inches at any one point, the normal procedure for the commercial fabricating plant in which the tests were conducted, and the change was incorporated into the model and tested for possible impact on the optimal solutions.

The cost of feed (energy) was increased by increments up to a 50 percent increase to test the sensitivity of results to changes in feed costs. This additional analysis permitted an examination of the relationship between breed-types of cattle and changing energy costs.

In the base data set, the change in price per yield grade was set at $1.00 per hundred weight, carcass basis, for Choice grade beef. As an alternative, the change was modified to be consistent with the 4.6 percent change in yield of lean retail cuts per yield grade as reported by the USDA. Both carcass and retail prices were applied to the 4.6 percent differential and selected information structures analyzed to test for change in the optimal solutions.

Lastly, an analysis was conducted to provide the solution which generates the least-cost production of lean beef. Solutions for Good grade only, Choice grade only and a combination of the two grades were generated.

### Information Structure #1-HEAN: Live Grade and Weight With Breed Restricted to Hereford-Angus

Under this restriction all subsystem decision functions except the packer subsystem function result in a 275 day feeding period. The packer subsystem optimizes with a feeding period of 255 days. Comparing the diagonals of Table XXXVII and Table XLIII, it is evident that net revenues and rates of return are significantly reduced by the restriction on breed type.

Cow-calf net revenus is $11, the maximum level realized by the cow-calf subsystem across all information structures. Returns to the non-replacing feeder is $35 with the restriction on breed, well below the $63 realized by feeding the Simmental-Hereford (SIHE) under information structure #1. Therefore, the feeder could subsidize the cow-calf subsystem the $12 necessary to yield the same net revenue which the cow-calf subsystem realizes from the Hereford-Angus (HEAN) and have the Simmental-Hereford produced. With a $12 subsidy, the feeder would still net $16 more than he receives when breed is restricted. Alternatively, the non-replacing feeder could subsidize the cow-calf subsystem in the form of higher prices for the weaned calf if information on the potential profitability of the calves were known at the time exchange processes are completed.

The maximum net revenue available to the packer under information structure #1-HEAN is $13 compared to $20 under information structure #1. The fabricator net revenue drops from $98 with a Charolais-Hereford (CHHE) fed 335 days to $60 with the Hereford-Angus fed 275 days. The

## TABLE XLIII

## NET REVENUES, RATES OF RETURN, AND PRODUCT ATTRIBUTES FOR SEVEN DECISION FUNCTIONS UNDER INFORMATION STRUCTURE #1 - HEAN

| | | Subsystem or System Decision Function Maximized | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | Subsystem | | | | | Total System | |
| Item | Units | Cow Calf | Feeder No Repl | Feeder With Repl | Packer | Fabricator | No Repl | With Repl |
| Cow-calf NR | $ | 11 | 11 | 11 | 11 | 11 | 11 | 11 |
| Feeder NR, No Repl | $ | NA | 35 | 35 | 9 | 35 | 35 | 35 |
| Feeder NR, With Repl | $ | NA | 48 | 48 | 13 | 48 | 48 | 48 |
| Packer NR | $ | NA | 11 | 11 | 16 | 11 | 11 | 11 |
| Fabricator NR | $ | NA | 57 | 57 | 38 | 57 | 57 | 57 |
| System RR, No Repl | % | NA | 14 | 14 | 12 | 14 | 14 | 14 |
| System RR, With Repl | % | NA | 15 | 15 | 12 | 15 | 15 | 15 |
| | | | | | | | | |
| Total Cost per Steer | $ | NA | 345 | 345 | 333 | 345 | 345 | 345 |
| Live Weight | Lbs. | NA | 1118 | 1118 | 1086 | 1118 | 1118 | 1118 |
| Carcass Weight | Lbs. | NA | 681 | 681 | 658 | 681 | 681 | 681 |
| Fabricated Cuts | Lbs. | NA | 430 | 430 | 420 | 430 | 430 | 430 |
| Trimmed Fat | Lbs. | NA | 171 | 171 | 171 | 158 | 171 | 171 |
| Production Cost/Lb. | ¢/lb. | NA | 80 | 80 | 79 | 80 | 80 | 80 |
| Quality - Yield Grade | Grade | NA | C-3 | C-3 | C-3 | C-3 | C-3 | C-3 |
| Breed of Steer | - | HEAN | HEAN | HEAN | HEAN | HEAN | HEAN | HEAN |
| Feeding Period | Days | NA | 275 | 275 | 255 | 275 | 275 | 275 |

fabricator net revenue is also $98 with the Simmental-Hereford which was optimal for the non-replacing feeder. Thus, all other subsystems could subsidize the cow-calf subsystem and depending upon the distribution of revenues, improve their own position by guaranteeing the more profitable cattle would be available to them.

The total system solution points to the inefficiency of the restricted solution. Under #1-HEAN the highest system rate of return without replacement is 14 percent with an accompanying cost per pound of producing fabricated beef of $.80. This compares with a rate of return of 18 percent in #1 with a cost of production of $.73 per pound.

### Information Structure #6-HEAN: Carcass Grade and Yield Grade with Restrictions on Breed and Feeding Period

This solution summary is given in Table XLIV and can be compared with information structure #6 in Table XLII. The comparisions are similar to #1 versus #1-HEAN. An improvement is noted in that all subsystem net revenues are positive when the total system decision functions are maximized.

### Increase in Fat Cover to .75 Inches

As discussed in Chapter III, the amount of fat remaining on the fabricated cuts when sold affects the total amount of meat sold from a given carcass. A set of runs was made in which the maximum fat thickness remaining on cuts at any one point was changed from .3 inches to .75 inches. The information structure used was #6. This set of runs is labeled "information structure #6-.75" and

## TABLE XLIV

## NET REVENUES, RATES OR RETURN, AND PRODUCT ATTRIBUTES FOR SEVEN DECISION FUNCTIONS UNDER INFORMATION STRUCTURE #6 - HEAN

| Item | Units | Subsystem or System Decision Function Maximized | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | Subsystem | | | | | Total System | |
| | | Cow Calf | Feeder No Repl | Feeder With Repl | Packer | Fabricator | No Repl | With Repl |
| Cow-calf NR | $ | 11 | 11 | 11 | 11 | 11 | 11 | 11 |
| Feeder NR, No Repl | $ | NA | 22 | 22 | 7 | 11 | 22 | 22 |
| Feeder NR, With Repl | $ | NA | 31 | 31 | 10 | 14 | 31 | 31 |
| Packer NR | $ | NA | 1 | 1 | 3 | 3 | 1 | 1 |
| Fabricator NR | $ | NA | 57 | 57 | 58 | 60 | 57 | 57 |
| System RR, No Repl | $ | NA | 14 | 14 | 13 | 13 | 14 | 14 |
| System RR, With Repl | $ | NA | 15 | 15 | 13 | 13 | 15 | 15 |
| Attributes | | | | | | | | |
| Total Cost per Steer | $ | NA | 345 | 345 | 383 | 370 | 345 | 345 |
| Live Weight | Lbs. | NA | 1118 | 1118 | 1205 | 1178 | 1118 | 1118 |
| Carcass Weight | Lbs. | NA | 681 | 681 | 743 | 723 | 681 | 681 |
| Fabricated Cuts | Lbs. | NA | 430 | 430 | 450 | 444 | 430 | 430 |
| Trimmed Fat | Lbs. | NA | 171 | 171 | 208 | 196 | 171 | 171 |
| Production Cost/Lb. | ¢/lb. | NA | 80 | 80 | 85 | 83 | 80 | 80 |
| Quality - Yield Grade | Grade | NA | C-3 | C-3 | C-4 | C-4 | C-3 | C-3 |
| Breed of Steer | - | HEAN | HEAN | HEAN | HEAN | HEAN | HEAN | HEAN |
| Feeding Period | Days | NA | 275 | 275 | 335 | 315 | 275 | 275 |

the solution summaries are presented in Table XLV. Comparisons are made with information structure #6 in Table XLII. The only decision functions that could be affected by this change are the fabricator subsystem and the two total system decision functions since they are the only ones directly concerned with final cutout.

The decisions on breed and feeding period remain the same for the fabricator and non-replacing total system both of which dictate that a Simmental-Hereford (SIHE) be produced and fed 335 days. Net revenues increase for both subsystems. The total system decision function with replacement does change as trim thickness is increased. With a thicker fat cover, the Simmental-Hereford fed 335 days becomes the optimal system decision. Fabricator net revenue and system rates of return increase to \$158, 22 percent and 23 percent from \$93, 18 percent, and 19 percent respectively.

This experiment indicates that increasing the thickness of fat cover left on retail cuts with other things held constant does not affect the optimum breeding and feeding decisions without replacement and makes the replacement decision somewhat less critical.

## Increased Cost of Feed

In order to examine the sensitivity of the solutions to increased feed costs, a set of runs was made under information structures #1 and #6 in which the cost of feed energy was increased parametrically. These were labelled structure "#1-50" and "#6-50." Solutions proved quite stable up to increases of the order of 50 percent. Table XLVI displays solution summaries for the four decision functions which would be influenced by increased feed costs for information structure #1-50.

## TABLE XLV

## NET REVENUES, RATES OF RETURN, AND PRODUCT ATTRIBUTES FOR SEVEN DECISION FUNCTIONS UNDER INFORMATION STRUCTURE #6 - .75

| | | Subsystem or System Decision Function Maximized | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | Subsystem | | | | | Total System | |
| Item | Units | Cow Calf | Feeder No Repl | Feeder With Repl | Packer | Fabricator | No Repl | With Repl |
| Cow-calf NR | $ | 11 | 11 | -7 | -1 | -1 | -1 | -1 |
| Feeder NR, No Repl | $ | NA | 53 | 40 | 43 | 43 | 43 | 43 |
| Feeder NR, With Repl | $ | NA | 60 | 77 | 49 | 49 | 49 | 49 |
| Packer NR | $ | NA | 5 | -1 | 5 | 5 | 5 | 5 |
| Fabricator NR | $ | NA | 149 | 110 | 158 | 158 | 158 | 158 |
| System RR, No Repl | % | NA | 22 | 18 | 22 | 22 | 22 | 22 |
| System RR, With Repl | % | NA | 22 | 20 | 23 | 23 | 23 | 23 |
| Total Cost per Steer | $ | NA | 398 | 305 | 396 | 396 | 396 | 396 |
| Live Weight | Lbs. | NA | 1302 | 996 | 1330 | 1330 | 1330 | 1330 |
| Carcass Weight | Lbs. | NA | 793 | 600 | 802 | 802 | 802 | 802 |
| Fabricated Cuts | Lbs. | NA | 603 | 454 | 608 | 608 | 608 | 608 |
| Trimmed Fat | Lbs. | NA | 74 | 58 | 77 | 77 | 77 | 77 |
| Production Cost/Lb. | ¢/lb. | NA | 66 | 67 | 65 | 65 | 65 | 65 |
| Quality - Yield Grade | Grade | NA | C-2 | C-3 | C-3 | C-3 | C-3 | C-3 |
| Breed of Steer | - | HEAN | CHHE | ANAN | SIHE | SIHE | SIHE | SIHE |
| Feeding Period | Days | NA | 335 | 195 | 335 | 335 | 335 | 335 |

## TABLE XLVI

### SELECTED NET REVENUES, RATES OF RETURN, AND PRODUCT ATTRIBUTES FOR SEVEN DECISION FUNCTIONS UNDER INFORMATION STRUCTURE #1-50 AND #6-50

| | Subsystem or System Decision Function Maximized | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Information Structure #1-50 | | | | Information Structure #6-50 | | | |
| | Feeder | | Total System | | Feeder | | Total System | |
| Item | Without Replac | With Replac | Without Replac | With Replac | Without Replac | With Replac | Without Replac | With Replac |
| Cow-calf NR | -7 | -7 | 8 | 8 | -10 | -10 | 4 | 4 |
| Feeder NR, No Repl | 18 | 18 | 2 | 2 | 6 | 6 | -1 | -1 |
| Feeder NR, With Repl | 36 | 36 | 6 | 6 | 13 | 16 | 1 | 1 |
| Packer NR | -13 | -13 | -10 | -10 | 0 | -1 | 2 | 2 |
| Fabricator NR | 58 | 58 | 87 | 87 | 67 | 64 | 77 | 77 |
| System RR, No Repl | 12 | 12 | 14 | 14 | 12 | 12 | 14 | 14 |
| System RR, With Repl | 13 | 13 | 14 | 14 | 13 | 13 | 14 | 14 |
| Total Cost per Steer | 341 | 341 | 395 | 395 | 339 | 325 | 383 | 383 |
| Live Weight | 996 | 996 | 1161 | 1161 | 1009 | 962 | 1080 | 1080 |
| Carcass Weight | 599 | 599 | 709 | 709 | 603 | 573 | 690 | 690 |
| Fabricated Cuts | 391 | 391 | 539 | 539 | 427 | 408 | 523 | 523 |
| Trimmed Fat | 134 | 134 | 139 | 139 | 93 | 85 | 129 | 129 |
| Production Cost/Lb. | 87 | 87 | 83 | 83 | 79 | 80 | 82 | 82 |
| Quality - Yield Grade | C-3 | C-3 | C-2 | C-2 | G-1 | G-1 | G-1<br>C-2 | G-1<br>C-2 |
| Breed of Steer | ANAN | ANAN | CHAN | CHAN | CHHE | CHHE | CHHE<br>CHAN | CHHE<br>CHAN |
| Feeding Period | 195 | 195 | 255 | 255 | 175 | 155 | 195<br>255 | 195<br>255 |

The results can be compared with corresponding decision functions in Tables XXXVII and XLII.

Information Structure #1-50. With a 50 percent increase in the cost of feed energy the nonreplacing feeder net revenue drops from $63 to $18. An Angus-Angus (ANAN) was fed for 195 days. This is the same combination generated for the replacing feeder both before and after the increase in feed costs.

The total system optimum, after the increase in feed costs, called for Charolais-Angus(CHAN) fed 255 days both with and without replacement. The breeding and feeding combination which in the earlier case had been optimum with replacement only is generated both with and without replacement. Maximum total system rate of return for #1-50 is 14 percent.

Information Structure #6-50. The same procedure as above was performed with information structure #6, actual carcass quality grade and yield grade selling. The solution summaries are presented in the right half of Table XLVI and can be compared with information structure #6 in Table XLII.

The nonreplacing feeder optimized with Charolais-Hereford (CHHE) fed 175 days after the increase in feed cost compared to a Charolais-Hereford fed 335 days before the cost change. Net revenue is reduced from $53 to $6. The feeding subsystem with replacement feeds a Charolais-Hereford for 155 days as opposed to an Angus-Angus (ANAN) fed 195 days using base feed prices. The net revenue is $16 compared to $77 before the cost increase.

The total system rates of return with and without replacement were maximized with a composite of two breeds and feeding periods. The composite is 20 percent Charolais-Hereford fed 195 days and 80 percent Charolais-Angus(CHAN) fed 255 days. The system is evidently indifferent between these alternatives. The rate of return both with and without replacement rounds to 14 percent. A decrease of approximately five percentage points resulted from the increase in feed cost.

### Change in Premiums and Discounts for Yield Grade

In the base runs for which yield grade was a pricing attribute, the premiums and discounts above and below yield grade 3 were assumed to be $1.00 per hundredweight on a carcass basis for Choice grade. Other researchers (5, 164) suggest the level of premiums and discounts associated with yield grade should be larger. In an attempt to evaluate the effect of larger premiums and discounts on subsystem optima, two separate sets of runs were made. One set of runs established premiums and discounts at 4.6 percent of the 600-pound carcass price for each quality grade. This gives a price differential per yield grade of $2.26 per hundredweight. Another series of runs set the yield grade price differential at 4.6 percent of the retail beef price which gives a price differential per yield grade of $4.15 per hundredweight.

The two sets of runs ar labeled information structures "#6-C" and "#6-R". Solution summaries are found in tables XLVII and XLVIII respectively. These results can be compared with information structure #6 in Table XLII.

## TABLE XLVII

## NET REVENUES, RATES OF RETURN, AND PRODUCT ATTRIBUTES FOR SEVEN DECISION FUNCTIONS UNDER INFORMATION STRUCTURE #6-C

| | | Subsystem or System Decision Function Maximized | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | Subsystem | | | | | Total System | |
| Item | Units | Cow Calf | Feeder No Repl | Feeder With Repl | Packer | Fabricator | No Repl | With Repl |
| Cow-calf NR | $ | 11 | -10 | -10 | -4 | -1 | -1 | 8 |
| Feeder NR, No Repl | $ | NA | 64 | 33 | 15 | 44 | 44 | 54 |
| Feeder NR, With Repl | $ | NA | 72 | 79 | 18 | 50 | 50 | 79 |
| Packer NR | $ | NA | 4 | -1 | 13 | 5 | 5 | 2 |
| Fabricator NR | $ | NA | 80 | 62 | 64 | 92 | 92 | 70 |
| System RR, No Repl | % | NA | 17 | 13 | 14 | 18 | 18 | 17 |
| System RR, With Repl | % | NA | 18 | 17 | 14 | 18 | 18 | 19 |
| | | | | | | | | |
| Total Cost per Steer | $ | NA | 398 | 300 | 399 | 395 | 396 | 347 |
| Live Weight | Lbs. | NA | 1302 | 962 | 1261 | 1330 | 1330 | 1162 |
| Carcass Weight | Lbs. | NA | 793 | 562 | 779 | 802 | 873 | 709 |
| Fabricated Cuts | Lbs. | NA | 532 | 408 | 475 | 530 | 608 | 539 |
| Trimmed Fat | Lbs. | NA | 158 | 85 | 216 | 170 | 170 | 139 |
| Production Cost/Lb. | ¢/lb. | NA | 75 | 73 | 84 | 75 | 75 | 73 |
| Quality - Quild Grade | Grade | NA | C-2 | G-1 | C-4 | C-3 | C-3 | C-2 |
| Breed of Steer | - | HEAN | CHHE | CHHE | SIHE | SIHE | SIHE | CHAN |
| Feeding Period | Days | NA | 335 | 155 | 335 | 335 | 335 | 255 |

## TABLE XLVIII

## NET REVENUES, RATES OF RETURN, AND PRODUCT ATTRIBUTES FOR SEVEN DECISION FUNCTIONS UNDER INFORMATION STRUCTURE #6-R

| | | Subsystem or System Decision Function Maximized | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | Subsystem | | | | | Total System | |
| Item | Units | Cow Calf | Feeder No Repl | Feeder With Repl | Packer | Fabricator | No Repl | With Repl |
| Cow-calf NR | $ | 11 | -10 | -10 | -1 | -1 | -1 | 8 |
| Feeder NR, No Repl | $ | NA | 80 | 54 | 44 | 44 | 44 | 68 |
| Feeder NR, With Repl | $ | NA | 89 | 130 | 50 | 50 | 50 | 100 |
| Packer NR | $ | NA | 4 | -2 | 5 | 5 | 5 | 2 |
| Fabricator NR | $ | NA | 64 | 42 | 92 | 92 | 92 | 56 |
| System RR, No Repl | % | NA | 17 | 13 | 18 | 18 | 18 | 17 |
| System RR, With Repl | % | NA | 18 | 19 | 18 | 18 | 18 | 19 |
| | | | | | | | | |
| Total Cost per Steer | $ | NA | 398 | 300 | 396 | 396 | 396 | 347 |
| Live Weight | Lbs. | NA | 1302 | 962 | 1330 | 1330 | 1330 | 1161 |
| Carcass Weight | Lbs. | NA | 792 | 573 | 802 | 802 | 802 | 709 |
| Fabricated Cuts | Lbs. | NA | 532 | 408 | 530 | 530 | 530 | 478 |
| Trimmed Fat | Lbs. | NA | 158 | 85 | 170 | 170 | 170 | 139 |
| Production Cost/Lb. | ¢/lb. | NA | 75 | 73 | 73 | 75 | 75 | 73 |
| Quality - Yield Grade | Grade | NA | C-2 | G-1 | C-3 | C-3 | C-3 | C-2 |
| Breed of Steer | - | HEAN | CHHE | CHHE | SIHE | SIHE | SIHE | CHAN |
| Feeding Period | Days | NA | 335 | 155 | 335 | 335 | 335 | 255 |

Information Structure #6-C: Carcass Grade and Weight with Yield Grade Differentials at 4.6 Percent of Carcass Price. Under this information structure, the price differentials equal $2.26 per hundredweight of carcass for Choice and $2.13 per hundredweight for Good for each one-grade deviation from yield grade 3. The feeder subsystem still requires a Charolais-Hereford (CHHE) fed 335 days without replacement but changes from Angus-Angus (ANAN) to Charolais-Hereford with Good yield grade 1 instead of Choice yield grade 2 attributes when replacement is allowed. The packer elects a heavy carcass from a South Devon-Hereford (SOHE) fed 335 days and the fabricator remains unchanged with a Simmental-Hereford (SIHE) fed 335 days. The total system decision variables are not affected by the change in yield grade price differentials. However, the distribution of revenue to the subsystems is changed. The feeder net revenue increases while the fabricator net revenue decreases.

Information Structure #6-R: Carcass Grade and Yield Grade With Yield Grade Differentials at 4.6 Percent of Retail Price. The differentials under this structure equal $4.15 per hundredweight per yield grade for Choice and $3.98 per yield grade for Good. The solution summary is presented in Table XLVIII and can be compared with information structure #6-C in Table XLVII. The only change in decision variables from #6-C is that the packer optimum reverts to the Simmental-Hereford fed 335 days as it was in information structure #6 in Table XLII. Revenue is transfered from the fabricator to the feeder subsystem.

## Minimum Cost Solutions

These solutions determine the decisions which are most desirable to the environment under the assumption that society wishes beef to be produced at the lowest possible cost with currently available technology. Under this strategy, the information structures have no influence and the decision minimizes the total cost for producing an amount of fabricated beef equal to or greater than a specified amount. The specified amount begins at 350 pounds and is incremented by 25-pound intervals. Two attributes are altered to affect the minimum cost solutions. The first set of solutions is for .3 inches fat cover with no constraint on quality grade. The second set is also for .3 inches fat cover but quality grade is constrained to Choice or better. The third and fourth sets repeat the first set of changes with regard to qulaity grade but allow a .75 inches fat cover.

Since the linear programming feeding activities segment feeding periods into 20-day intervals, possible weights produced are discontinuous. This explains the fact that the minimum cost solutions are a composite of two breeds rather than a single breed. Tables XLIX and L display the minimum cost solutions for .3 inches fat cover. The minimum total cost per pound of Good grade is obtained by breeding and feeding Limousin-Angus (LIAN) a combination of 2 an 3 periods with a total cost of $.72 per pound. The minimum cost per pound solution for producing Choice grade fabricated beef is a combination of Angus-Angus (ANAN) for three periods and Charolais-Angus (CHAN) for six periods.

Tables LI and LII display the minimum cost solutions for .75 inches fat cover. The minimum total cost per pound of Good grade is again obtained by breeding and feeding Limousin-Angus but for a combination

## TABLE XLIX

## MINIMUM COST AND CORRESPONDING PRODUCTION DECISIONS FOR PRODUCING SPECIFIED WEIGHTS OF CHOICE FABRICATED BEEF TRIMMED TO .3 INCHES

| Fabricated Beef From A Composite Steer | Total System Production Cost | Cost Per Lb. Of Beef | Steer Breed Type Or Composite | Days Fed | Quality Grade | Yield Grade |
|---|---|---|---|---|---|---|
| (lbs.) | ($) | (cents) | | | | |
| 391 | 306 | 78.1 | 1 ANAN | 195 | C | 3 |
| 400 | 310 | 77.0 | .90 ANAN | 195 | C | |
| | | | .10 CHAN | 255 | C | 2 |
| 425 | 322 | 75.7 | .61 ANAN | 195 | C | 3 |
| | | | .39 CHAN | 255 | C | 2 |
| 450 | 334 | 74.2 | .32 ANAN | 195 | C | 3 |
| | | | .68 CHAN | 255 | C | 2 |
| 475 | 346 | 72.7 | .04 ANAN | 195 | C | 3 |
| | | | .96 CHAN | 255 | C | 2 |
| 500 | 368 | 73.5 | .42 SIHE | 335 | C | 3 |
| | | | .58 CHAN | 255 | C | 2 |
| 525 | 391 | 74.4 | .89 SIHE | 335 | C | 3 |
| | | | .19 CHAN | 285 | C | 2 |

TABLE L

## MINIMUM COST AND CORRESPONDING PRODUCTION DECISIONS FOR PRODUCING SPECIFIED WEIGHTS OF GOOD OR CHOICE FABRICATED BEEF TRIMMED TO .3 INCHES

| Fabricated Beef From a Composite Steer | Total System Production Cost | Cost Per lb. of Beef | Steer Breed Type or Composite | Days Fed | Quality Grade | Yield Grade |
|---|---|---|---|---|---|---|
| (lbs) | ($) | (cents) | | | | |
| 350 | 276 | 78.9 | .74 HEAN | 155 | G | 2 |
| | | | .26 JEHE | 155 | G | 2 |
| 375 | 279 | 74.3 | .51 HEAN | 155 | G | 2 |
| | | | .49 LIAN | 155 | G | 2 |
| 400 | 284 | 70.8 | .72 LIAN | 155 | G | 2 |
| | | | .28 LIAN | 175 | G | 2 |
| 425 | 299 | 70.3 | .23 LIAN | 175 | G | 2 |
| | | | .77 LIAN | 195 | G | 2 |
| 450 | 317 | 70.5 | .53 LIAN | 215 | G | 2 |
| | | | .46 LIAN | 235 | G | 2 |
| 475 | 339 | 71.5 | .34 LIAN | 235 | G | 2 |
| | | | .66 SIHE | 255 | G | 2 |
| 500 | 362 | 72.3 | .78 SIHE | 275 | G | 2 |
| | | | .21 SIHE | 295 | G | 2 |
| 525 | 389 | 74.1 | .80 CHHE | 315 | G | 2 |
| | | | .20 CHHE | 335 | C | 2 |

## TABLE LI

## MINIMUM COST AND CORRESPONDING PRODUCTION DECISIONS FOR PRODUCING SPECIFIED WEIGHTS OF CHOICE FABRICATED BEEF TRIMMED TO .75 INCHES

| Fabricated Beef From a Composite Steer | Total System Production Cost | Cost Per lb. of Beef | Steer Breed Type or Composite | Days Fed | Quality Grade | Yield Grade |
|---|---|---|---|---|---|---|
| (lbs.) | ($) | (cents) | | | | |
| 454 | 306 | 67.3 | 1 ANAN | 195 | C | 3 |
| 475 | 316 | 66.5 | .25 CHAN | 255 | C | 2 |
| | | | .75 ANAN | 195 | C | 3 |
| 500 | 328 | 65.6 | .54 CHAN | 255 | C | 2 |
| | | | .46 ANAN | 195 | C | 3 |
| 525 | 340 | 64.8 | .83 CHAN | 255 | C | 2 |
| | | | .17 ANAN | 195 | C | 3 |
| 550 | 353 | 64.1 | .47 CHAN | 255 | C | 2 |
| | | | .53 SIAN | 275 | C | 3 |
| 575 | 369 | 64.2 | .10 SIAN | 275 | C | 3 |
| | | | .90 SIAN | 295 | C | 3 |
| 600 | 389 | 64.9 | .45 SIHE | 335 | C | 3 |
| | | | .55 SIAN | 315 | C | 3 |

## TABLE LII

## MINIMUM COST AND CORRESPONDING PRODUCTION DECISIONS FOR PRODUCING SPECIFIED WEIGHTS OF GOOD OR CHOICE FABRICATED BEEF TRIMMED TO .75 INCHES

| Fabricated Beef From a Composite Steer | Total System Production Cost | Cost per Lb. of Beef | Steer Breed Type or Composite | Days Fed | Quality Grade | Yield Grade |
|---|---|---|---|---|---|---|
| (Lbs.) | ($) | (Cents) | | | | |
| 370.3 | 275 | 74.4 | 1 JEHE | 155 | G | 2 |
| 375 | 276 | 73.5 | .15 HEAN | 155 | G | 2 |
| | | | .85 JEHE | 155 | G | 2 |
| 400 | 276 | 69.0 | .93 HEAN | 155 | G | 2 |
| | | | .06 JEHE | 155 | G | 2 |
| 425 | 280 | 65.9 | .14 HEAN | 155 | G | 2 |
| | | | .86 LIAN | 155 | G | 2 |
| 450 | 291 | 64.6 | .01 LIAN | 155 | G | 2 |
| | | | .99 LIAN | 175 | G | 2 |
| 475 | 303 | 64.0 | .78 LIAN | 195 | G | 2 |
| | | | .22 LIAN | 215 | G | 2 |
| 500 | 318 | 63.6 | .47 LIAN | 215 | G | 2 |
| | | | .53 LIAN | 235 | G | 2 |
| 525 | 334 | 63.5 | .07 LIAN | 235 | G | 2 |
| | | | .93 LIAN | 255 | G | |
| 550 | 351 | 63.8 | .56 LIAN | 275 | G | 2 |
| | | | .44 SIAN | 275 | C | 2 |
| 575 | 369 | 64.2 | .10 SIAN | 275 | C | 2 |
| | | | .90 SIAN | 295 | C | 2 |
| 600 | 389 | 64.9 | .45 SIHE | 335 | C | 3 |
| | | | .95 SIAN | 315 | C | 3 |

of five and six periods at a cost of $.635 per pound. The minimum cost combination for Choice is the combination Charolais-Angus for six periods and Simmental-Angus (SIAN) for seven periods at a cost of $.641 per pound.

Figure 6 shows minimum costs of producing specified weights of fabricated beef cuts for varying combinations of quality grade and fat cover. As would be expected, costs are lower with the .75 inches fat cover allowed. The minimum costs occurs at a higher composite weight with the .75 inches fat cover.

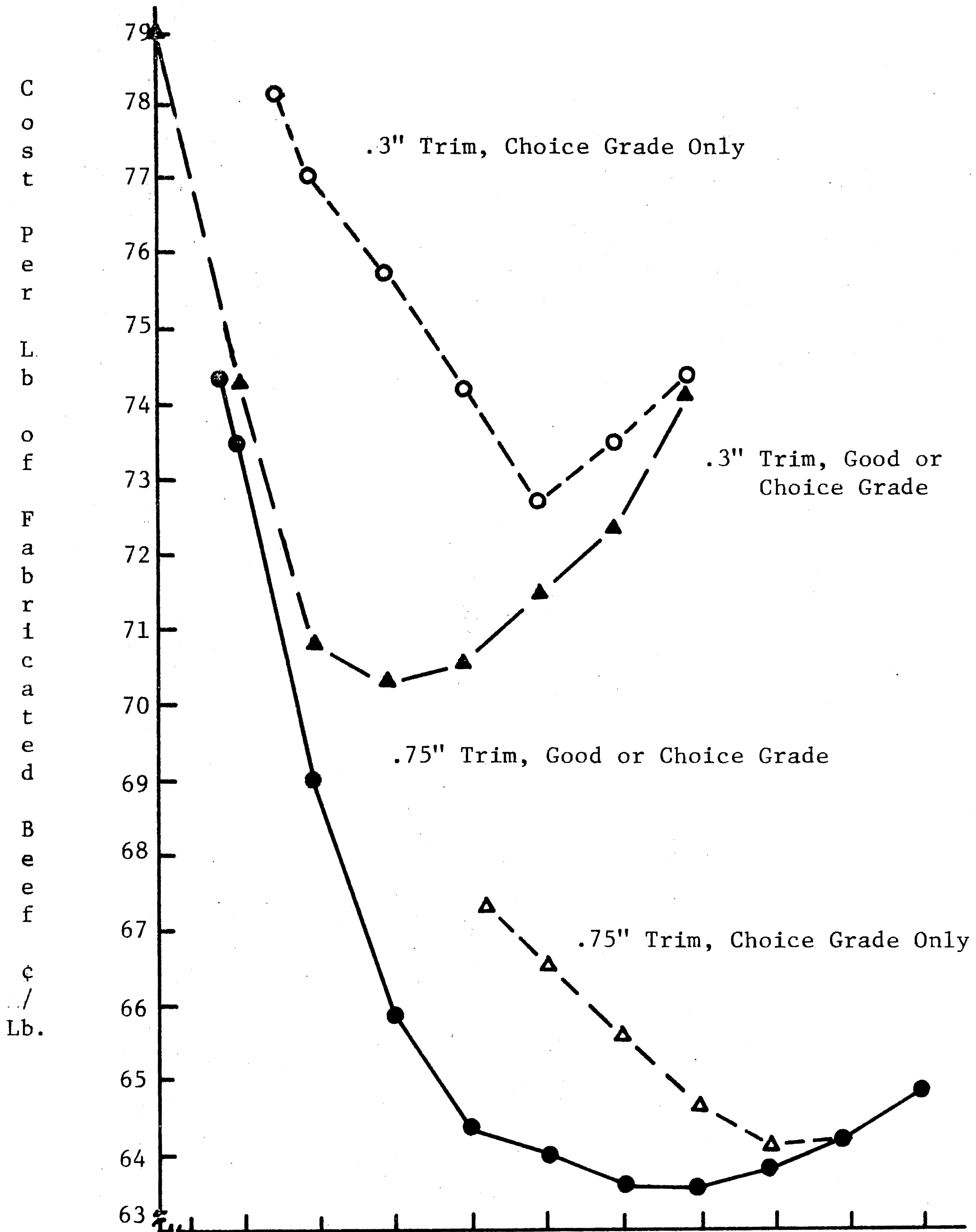

Figure 6. Minimum Production Cost Per Pound for Selected Weights of Fabricated Costs.

# CHAPTER VI

## SUMMARY AND CONCLUSIONS

Lean fabricated beef is the product of final interest to consumers. However, breeding and feeding decisions tend to be made early in the production chain somewhat isolated from final consumption. Typically, these decisions are made so as to maximize profits according to prices received for intermediate products whose attributes relate imperfectly to those of the final product. The market pricing mechanism must act as a communication system linking desires of consumers with production decisions. The primary purpose of this analysis was to analyze the effectiveness of this communication process and to quantify the implications of any barriers to more effective communication and therefore to a higher degree of interlevel coordination. It was hypothesized that individual subsystem decisions can be modeled for different pricing mechanisms or structures with varying degrees of precision. These decisions could then be compared with each other and with those decisions which would be made by a system operating with more nearly perfect information. A comparison can also be made with those decisions which produce fabricated beef with specified attributes at the minimum cost per pound.

A two part simulation and linear programming model was conceptualized, programmed, and executed to analyze selected aspects of communication and information in beef marketing. The system is comprised of four subsystems: the cow-calf, feeder, packer, and fabricator. The physical objects and attributes of the objects are determined in a Fortran simulation program called BEEFSIM. BEEFSIM computes the physical requirements necessary from each subsystem to produce and process one steer from each of 14 different breed types which can be fed for up to 10 consecutive 20-day feeding periods. The feeder's replacement policy is either to replace the steer and keep the lot full or feed one set of cattle per year. The simulator also computes attributes of liveweight, carcass weight, quality grade, yield grade, empty body weight, energy requirements and weight of fabricated product for each of two fat trim or fat thickness levels. The simulator then outputs these results in a form usable in a linear programming framework.

The second part of the model, an LP model, is specified such that it may be optimized under many combinations of decision functions and information structures. The decision or objective functions are formulated to maximize either the net revenue of individual subsystems or the rate of return on investment for the total system.

The information structures typify conditions of exchange within which the "price signals" received by individual subsystems can be manipulated so as to experiment with inter-subsystem transactions. The basic set of six information structures is defined in Table LIII. Selected modifications of the basic set are shown in Table LIV. The modifications are designed to investigate the importance of restrictions on breed type, the influence of level of fat cover on the retail cuts, the impact of rising energy costs, and the changes

TABLE LIII

DESCRIPTION OF THE SIX BASIC INFORMATION STRUCTURES

| Information Structure | Description |
|---|---|
| Information Structure #1 | Cattle are traded on the basis of live quality grade and live weight. Carcasses are traded on a carcass grade and weight basis. Quality grade at the live animal level is assumed known and no estimation is involved. |
| Information Structure #2 | Cattle are traded on the basis of live quality grade and yield grade. Carcasses are traded on a quality grade and yield grade basis. All grades are assumed known and no estimation is involved. |
| Information Structure #3 | Cattle are traded on the basis of estimated live quality grade and estimated yield grade. Carcasses are traded on a quality grade and yield grade basis. |
| Information Structure #4 | Cattle are traded on the basis of estimated live quality grade and live weight. Carcasses are traded on a carcass grade and weight basis. |
| Information Structure #5 | Cattle are traded on the basis of carcass quality grade and weight. Carcasses are traded on a quality grade and weight basis. No estimation of grades at the live or carcass levels is involved. |
| Information Structure #6 | Cattle are traded on the basis of carcass quality grade and yield grade. Carcasses are traded on a quality grade and yield grade basis. No estimation of grades at the live or carcass levels is involved. |

## TABLE LIV

## DESCRIPTION OF INFORMATION STRUCTURES WHICH ARE VARIATIONS FROM THE SIX BASIC STRUCTURES

| Information Structure | Description |
|---|---|
| Information Strucutre #1-HEAN | The bases for trade at the live cattle and carcass levels are the same as for Information Structure #1 in the basic set. All other subsystems are restricted to the Hereford-Angus (HEAN) breed type. |
| Information Strucutre #6-HEAN | The bases for trade at the live cattle and carcass levels are the same as for Information Structure #6 in the basic set. All other subsystems are restricted to the Hereford-Angus (HEAN) breed type. |
| Information Strucutre #6-.75 | The bases for trade at the live cattle and carcass levels are the same as for Information Structure #6 in the basic set. The maximum allowable fat cover at any one point on fabricated retail cuts is increased from the .3 inches used in the basic set of information structures to .75 inches. |
| Information Structure #1-50 | The bases for trade at the live cattle and carcass levels are the same as for Information Structure #1 in the basic set. The cost of energy in the feeding programs is increased by 50 percent relative to the energy costs used in the basic set. |
| Information Structure #6-50 | The bases for trade at the live cattle and carcass levels are the same as for Information Structure #6 in the basic set. The cost of energy in the feeding programs is increased by 50 percent relative to the energy costs used in the basic set. |

TABLE LIV (Continued)

| | |
|---|---|
| Information Structure #6-R | The bases for trade at the live cattle and carcass levels are the same as for Information Structure #6 in the basic set. Price differentials per yield grade are increased to 4.6 percent of retail price as compared to the $1.00 per hundredweight used in the basic set. |
| Information Structure #6-C | The bases for trade at the live cattle and carcass levels are the same as for Information Structure #6 in the basic set. Price differentials per yield grade are increased to 4.6 percent of carcass price as compared to the $1.00 per hundredweight used in the basic set. |

in optimal solutions which might occur when the price differentials for yield grade are altered.

The motivation for these experiments was to examine the influence of alternative information structures and decision functions on the decisions made within the beef system. Measures monitered included net revenue for each subsystem, the total cost of production per pound of fabricated beef, the rate of return on investment for the total system, the breed-type of calf chosen, and the length of feeding period used.

## Objectives

Specifically, the objectives of the system model were:

Major: Isolate, and measure implications of, barriers to more effective communication and more effective interlevel coordination for selected structures in the beef marketing system.

Sub: (1) Model pricing and decision processes for selected information structures;

(2) Measure the effect of communication inefficiencies, imprecise product valuation, and inadequate range or lack of appropriate price signals on subsystem and system performance;

(3) Compare communication effectiveness of alternative structures; and

(4) Infer changes in structure which are likely to be precipitated by communications problems.

## Summary of Analytical Process

In Chapter I, discussion covered wide-ranging industry estimates of benefits accruing from (1) a beef marketing system based on actual rather than estimated quality grades, and (2) carcass weight and yield grade rather than live weight categories. There has been speculation that failure to adopt improved pricing methods in beef marketing will increase pressures for vertical integration. In this study various pricing arrangements and decision functions examine these possibilities. Market channels as used here are in a communications context rather than a physical route of travel or a continuum of institutions performing marketing functions of assembly and distribution. The channels or information structures represent the set of attributes considered in pricing and the schedule of prices that correspond to the specified product attributes. Within an abstract model these constructs can neither be totally realistic nor all inclusive but can provide useful analogies to real-world conditions.

Beef cattle have traditionally been traded on the basis of live weight categories and quality grade and beef carcasses on the basis of weight categories and quality grade. This provides the motivation to examine information structure #1 within which steers and carcasses are traded on precisely these bases. Similar to information structure #1 is structure #4. The only difference is that steers trade on the basis of estimated rather than actual quality grades which introduces noise into the communication process.

A criticism of liveweight selling is that discounts levied for "over-weight" cattle, a proxy for "over-fat" cattle, are inadequate. The argument continues that yield grade designations should be applied and thus improve the ability of the market to differentiate between heavy lean cattle and heavy fat cattle.

This was the motivation for information structure #2 within which live cattle trade on the basis of quality grade and yield grade and carcasses trade on the basis of quality grade and yield grade. Information structure #3 adds noise to the system in that the live sales are based on estimated quality grade and estimated yield grade. The estimation errors are jointly determined in a probabilistic sense so that typical errors in one accompanies correlated errors in the other.

Information structures #5 and #6 avoid consideration of live weight and allow the feeder subsystem to make decisions on final carcass characteristics. Information structure #5 considers carcass quality grade and weight categories and #6 considers carcass quality grade and yield grade.

An important dimension lacking in both real world and modeled pricing mechanisms is a logical descriptive terminology for calves. The myriad of confusing, inconsistent, and possibly irrelevant terms that appear in the real world are impossible to identify and quantify. An overall perspective suggests that while in a given place on a given day there will be wide variation in prices for two beef calves for many reasons, a realistic hypothesis is that over a long period trade has tended to be on an equal price for equal weight basis. Therefore, within the model the cattle feeder pays equal price per pound for weaned calves. However, the model generates results which allow inferences about what a feeder might be able to pay for one breed type over another while giving due consideration to relevant prices and costs.

Variations to the six basis information structures, as described in Table LIV, were introduced to examine, among others, hypotheses that the base $1.00 per hundredweight value difference per yield grade was not of appropriate size. Increases in the absolute magnitude of value differences per yield grade were employed in structures labeled #6-C and #6-R.

Another variation considered was the hypothesis that the final cutout of lean fabricated beef is significantly affected by the thickness of fat left on retail cuts after trimming. The industry is not standarized with regard to procedure but evidence is available that the actual amount of fat remaining on fabricated cuts in the trade is greater than that used in laboratory investigations on cutability. Accordingly, cutout coefficients from primary data assembled as part of this study were applied in an information structure labeled #6-.75. The .75 indicates that fabricated cuts were trimmed to a maximum fat cover of .75 inches at any one point rather than the .3 inches thickenss which was used in the base data.

Still another variation involved parametric increases in the price of feed to test the sensitivity of optimal solutions to increased feed or energy costs. Analysis of the information structure designated #6-50, for example, involved a 50 percent increase in feed costs.

A set of runs in another variation limited the other subsystems and forced them to work with the breed-type found optimum by the cow-calf subsystem, the Hereford-Angus (HEAN) cross. These runs were designated information structures #1-HEAN and #6-HEAN.

The model was operated so that each individual subsystem maximized long run net revenue subject to each information structure. In addition, the maximum rate of return on investment for the total system was maximized for each information structure.

An important decision variable unique to the feeder subsystem was also considered. For the other subsystems it was considered reasonable to assume that capacity would be fully utilized and that maximizing revenue per head or maximizing revenue per unit of capacity could be assumed equivalent since time spent on production was considered to be independent of any of the factors considered. Time would be expected to influence costs but not the type of cattle or carcasses produced. However, the feeder's decision could be different under conditions which maximize net revenue for one animal fed in a year, as is often done, as opposed to maximizing returns per unit of capacity and replacing one steer with another at the appropriate time. Both of these alternatives were allowed by designating the former a "non-replacing feeder" and the latter a "replacing feeder." A replacement model developed as part of this study was incorporated into the model to generate replacement points when continuous feeding programs are considered.

## The Results

The first step in summarizing the results is to point out the type and magnitude of benefits potentially available from improvements in communication and coordination among subsystems. Attention will then be turned to summarizing the results of the analysis by subsystems and for the system as a whole.

### Potential Gains

The most graphic exposition of the differences in system performance is exhibited by comparing the total system optimum (or optima) with results under the information structure labeled #6-HEAN. Within the #6-HEAN structure the cow-calf subsystem is first optimized. The feeder stage is then optimized with the condition that the only possible breed-type to be fed is that which maximizes net revenue to the cow-calf subsystem the Hereford-Angus (HEAN) cross. Other subsystems and the total system are also optimized subject to this restraint on breed-type.

Given the HEAN calf to work with, the feeder maximizes net revenue by feeding 275 days. The optimum feeding period is 275 days with and without replacement. The resulting steer weighs 1118 pounds, yields a carcass grading Choice yield grade 3 weighing 681 pounds, and cuts out 430 pounds of fabricated beef cuts. The total cost per pound of fabricated beef is $.80. Cow-calf net revenue is $10.79 per head, the replacing feeder's net revenue is $31.25 ($22 per head), the packer's net revenue is $1.49 per head and the fabricator nets $57.37 per carcass. The rate of return on investment for the system is 14.8 percent.

In contrast, if the breeding and feeding decisions are made centrally with the objective of maximizing system rate of return with replacement, the results differ significantly. A Charolais-Angus (CHAN) steer is fed 255 days with a live weight of 1162 pounds and a carcass weight of 709 pounds. The carcass grades Choice-yield grade 2 and cuts out 478 pounds of fabricated beef. Production costs for fabricated beef are $.726 per pound. The system rate of return is 19 percent and if distribution of revenue is under information structure #6, the subsystems fare as follows on a per head basis: cow calf $8; replacing feeder $65 ($44 per head); packer $2; and fabricator $80.

Thus, within the model as specified and analyzed, perfectly coordinated decisions reduce the cost of retail cuts about $.08 per pound. The system rate of return is increased about 4 percent. This is accomplished with only a small reduction in the net revenue for the cow calf subsystem ($10 down to $8) and increasing that of each of the other three subsystems (increases to the feeder, packer and fabricator are $22.00, $.51, and $22.63 per head respectively). This decision on breed type and feeding program also corresponds with the one which produces Choice fabricated beef at the lowest possible cost per pound.

Chapter V detailed the results of a large number of combinations for the location of decision making and the form of the information structure. Details of the analysis reported in Chapter V will not be repeated here. Rather, an attempt will be made to generalize and draw inferences about the influence of alternative decision sets and information structures on performance of the beef marketing system.

## Feeder Subsystem Summary

The feeding subsystem determines what is produced by deciding what calf to feed and how long to feed it. This decision is affected by feeder purchase price, production costs, attributes considered in pricing, the prices attached to attributes, and whether the feeder desires to maximize revenue per head or per unit of capacity.

Non Replacing Feeder. The feeder subsystem, when maximizing net revenue per head, makes one of two decision for any of the six basic information structures. Either the Charolais-Hereford (CHHE) is fed 335 days or the Simmental-Hereford (SIHE) is fed 335 days. The CHHE solution has a total production cost per pound slightly less than the SIHE but rounds to equal the $.75 per pound of the SIHE. Structures #2, #5, and #6 resulted in the yield grade 2 CHHE. These are the comparatively more precise structures in terms of identifying actual product value. Examining system performance as measured by cost of production and rate of return indicates the system would be largely indifferent to the choice of breed types. Neither the system rate of return on investment nor the cost per pound to produce fabricated cuts differs significantly between the CHHE and SIHE types.

There is a noticable influence on cow calf net revenue and large trade offs in net revenue distribution between the feeder and packer across different information structures. The cow-calf subsystem fares poorly under structures #1, #3 and #4 where estimation and imperfect measurement of value prevail. In general, the feeder benefits at the expense of the packer under structure #1, #3 and #4.

The feeder decision, when restricted-to feeding the cow-calf sector's revenue maximizing HEAN breed type, was discussed earlier. System rate of return drops by five precent and ultimate production cost per pound of choice fabricated cuts increases by $.05. The feeder could easily afford to pay the cow calf subsystem to produce some other breed.

The effect on the non replacing feeding subsystem of increasing the size of premiums for yield grade served simply to shift revenue from the fabricator and packer to the feeder. The decision on breed type and feeding period was unchanged.

Increasing feed costs changed the breed-type to Angus-Angus (ANAN) fed 195 days under structure #1-50 and to CHHE fed 175 days under #6-50. Thus, there was a tendency to go to smaller cattle and to shorter feeding periods.

Replacing Feeder. The results of this study indicate strongly that the strategy of the feeding subsystem exerts influence on subsystem and system decisions. Maximizing returns per unit of feedlot capacity changed the breed type and length of feeding period optimal for the feeding subsystem. Angus-Angus (ANAN) was the optimal breed type for five of the six base structures and a 195-day feeding period with a Choice yield grade 3 carcass was the optimal in four. The two noisy information structures, #3 and #4, in which estimated rather than actual characteristics were used were the exceptions.

The ANAN-195 day combination is a relatively poor selection for the total system since the rate of return is 17 percent compared to a potential 19 percent and the total cost of production is $.78 per pound compared to a potential $.75 per pound.

The effect of increasing the premimum for yield grade to 4.6 percent of the carcass price is interesting. The replacing feeder switched to a Charolais-Hereford (CHHE) fed 155 days producing a Good yield grade 1 carcass. System rate of return was 17 percent and the production cost per pound is $.73. It is likely that there exists a premium rate between the base rate and the 4.6 percent carcass price rate that would induce the feeder to produce a Choice 2 carcass, possibly from a Charolais-Angus (CHAN), but this is not a simple matter to investigate.

The effect of a 50 percent increase in feed costs on feeder subsystem decisions depended upon information structure. The optimum was ANAN fed 195 days with a Choice yield grade 3 carcass under structure #1-50 and CHHE fed 195 days producing a Good yield grade 1 carcass under information structure #6-50.

### Packer Sub-System Summary

The decisions maximizing net revenue for the packer subsystem favored the large breeds of cattle with the better yield grades. Considering the basic six information structures, only information structure #6 generated a Choice carcass (Simmental-Hereford fed 335 days producing a Choice yield grade 3 carcass). Structures #1 through #5 all generated Good yield grade 2 carcasses with Limousin-Angus (LIAN) the most prevalent breed type. Carcass weights ranged from 606 up to 874 pounds lending support to the hypothesis that the packer's costs are constant on a per carcass basis. System rates of return ranged from 16 to 18 percent and the cost per pound of Choice fabricated beef was $.75.

Maximizing returns to the packer causes significant reductions in returns to both the feeder and fabricator subsystems. These results suggest the packer operates within an arena of confrontation with both the subsystem from which they buy and the subsystem to which they sell.

When the packer is restricted to the breed type which is optimal for the cow-calf subsystem (HEAN), net returns to the packer is $16 per carcass. This is $5 less than the $21 the packer realizes under information structure #5 without the restriction on breed. Increasing the price differentials for yield grade changes the optimal breed type to South Devon-Hereford (SOHE) and Simmental-Hereford (SIHE) for information structures #6-C and #6-R respectively. Net revenue to the packer decreases to $5 per carcass.

## Fabricator Sub-System Summary

As with the packer, revenue maximizing decisions at the fabricator level concentrate on the larger breed types. Either the Charolais-Hereford (CHHE) or the Simmental-Hereford (SIHE) are generated as the optimal breed type for the basic six information structures. All feeding periods are 335 days, the longest feeding period allowed in the model. Carcass weights ranged from 793 to 874 pounds and all graded Choice. System rates of return were 18 percent for all information structures and the cost of producing Choice fabricated cuts was $.75 per pound across all information structures.

Restricting the breed type to Hereford-Angus (HEAN) produced dramatic changes. Net returns to the fabricator dropped as much as $41 per carcass. Changing the price differentials for yield grade exerted no significant influence.

The variation which increased the allowable fat cover on fabricated cuts to .75 inches from the base .3 inches precipitated somewhat expected results in terms of the direction of change. The SIHE breed type was fed for 335 days producing a Choice yield grade 3 carcass. Net revenue per carcass increased to $158 as compared to a maximum of $98 under the six basic information structures. System rate of return increased to 23 percent. Cost of producing a pound of Choice fabricated cuts dropped to $.65 as the heavier fat cover produced more weight per carcass. There was no change in price of the Choice cuts, associated with the increase in fat cover, in the model.

### Total System Summary

Information structures do not effect the system optima but they do affect the distribution of revenues among subsystems. A Simmental-Hereford (SIHE), fed 335 days, maximized system rate of return without replacement at 18 percent for all of the six basic information structures. The total production cost per pound was $.75. Information structures #5 and #6 yield the most even distributions of income with only the cow-calf subsystem showing a loss.

For the total system with replacement the maximum return on investment for the system is attained when a Charolais-Angus (CHAN) is fed and replaced after 255 days on feed. The carcass is a Choice yield grade 2, the system rate of return on investment is 19 percent and the total production costs per pound is $.73 for all six information structures. Three information structures, #3, #5 and #6 distribute net revenue so that no subsystem has a negative net revenue.

The optimum for the system when replacement is allowed is unique. No information structure induces any subsystem to produce or have produced the output from a CHAN fed for 255 days.

Restricting the breed type to Hereford-Angus (HEAN) decreases the system rate of return to 14 percent (no replacement) and 15 percent (with replacement). The cost of producing a pound of Choice fabricated cuts increases to $.80 per pound.

Increasing feed costs by 50 percent eliminates the difference in decisions due to replacement. With the higher feed costs a CHAN fed for 255 days is the optimum breed type and feeding period for the system both with and without replacement. System rate of return is 14 percent and the cost of producing Choice fabricated cuts is $.82 and $.83 for information structures #6-50 and #1-50 respectively.

Increasing the price differentials associated with yield grade leave the system optima in terms of breed types and feeding periods unaffected. With replacement, revenue is transferred from the fabricator to the feeder. Without replacement, the fabricator benefits via a transfer of revenue primarily from the cow-calf subsystem.

If a .75 inches fat cover on fabricated cuts is allowed, the system optimum is a SIHE fed 335 days. This combination is optimum both with the without replacement.

## Conclusions

The more significant conclusions evolving from this analysis could be enumerated as follows:

1. Interlevel goal conflicts and operational inconsistencies within the beef marketing system persist and are largely unresolved by the current and ongoing price mechanism and pricing procedures;

2. Given the price and cost relationships which prevailed during the study period (1968-72), maximizing net revenue to any one level or subsystem of the beef marketing system leads to the production of a live beef animal or beef carcass which is often inconsistent with revenue-maximizing needs of technically related levels or subsystems;

3. When cattle are priced on bases which fail to accurately reflect final carcass value as determined by quality grade and yield of lean retail cuts as a percentage of carcass weight, the cow-calf sub-system may be motivated to produce a type of cattle which (a) decreases the revenue potential of other subsystems, (b) increases the cost of producing a pound of lean beef compared to other types of cattle, and (c) constrains the rate of return to total system investment
4. Changing (increasing) the price differentials associated with yield grade tends to precipitate an income transfer from the fabricating subsystem back toward the production

levels (feeder and cow-calf subsystems) when the price differentials are transferred accurately via exchange processes;

5. Increasing feed or energy costs tends to encourage the feeding of smaller -- not necessarily the smallest -- breeds of cattle for shorter time periods; and
6. Significant pressures toward vertical integration evolve from the ability of the centrally planned or "team" system to generate decision processes and related action programs which lead to the production of lean beef at a lower per pound cost and to a higher rate of return on investment than decision processes designed to maximize returns to individual subsystems.

The decisions which are made in the cow-calf and feeding subsystems are critically important to other subsystems and to the entire system. Once breeding and feeding decisions are made the attributes of the product which will be transferred to the packer and then to the fabricator are determined. Significant inconsistencies between what emerged from the feedlot and the needs of the packer-fabricator sector prevailed during the 1968-72 study period. The influence of these inconsistencies on the revenue positions of the packer and fabricator were of sufficient magnitude that the production sector could have been compensated for any increase in costs associated with producing another breed-type of cattle, paid a premium or be rewarded for doing so, and still increase revenues in the packer-fabricator sector. The price mechanism has apparently been unable to effect these transfers because of the poor communication which accompanies imprecise product description and the adversary orientation which often accompanies interlevel exchange processes in the beef marketing system.

The results of the analysis lead to another related if somewhat tentative conclusion. There is a general tendency for the more precise information structures, those which do not employ rather crude estimates of important value-related attributes such as quality grade and yield grade, to precipitate an income transfer from the packer-fabricator sector back to the production sector. Recognition of this possibility could be acting as an impediment to the acceptance of procedures which are amenable to more effective product description, pricing and communication by the packer and fabricator.

Overall, however, there is much inefficiency in the beef marketing system. The costs of producing lean beef could be decreased if the degree of interlevel or between subsystem coordination could be increased. But the sufficient condition for such coordination is a higher level of overall understanding and interlevel communication. Communication at the needed level did not exist during the study period on which this analysis is based. The logical inference is for continued pressures toward vertically integrated structures which would bring the benefits from coordination across the various subsystems of the total beef marketing system to the integrator.

## Limitations

The limitations of a study of this type should not be overlooked. First, the analysis is static. Changes in prices and costs that can and do occur between the time a breeding program is instituted and the beef is sold to a consumer are not considered.

The study is so strongly micro oriented that firm decisions and outcomes are defined in terms of a single steer. Traditional profit maximizing behavior is assumed. Except for the probability distributions of "eyeball" estimates of quality and yield grade attributes, the study is deterministic in nature.

The analysis assumes knowledge of all inputs and outputs for a given breed type and that costs and prices used are relevant ones. This study considered only steers ignoring heifers, bulls or late castrates. It also considered only one feeding program. Many other feeding rates, ration formulations, and stocker programs were ignored.

Results obtained are sensitive to violations of all the above factors. The model must therefore be considered an indicator rather than a complete answer.

## Need for Further Research

Severe gaps in available knowledge were encountered at many stages in the study. The basic physical relationships among type, energy intake, and body composition remain topics disputed within the biological sciences.

Resolution of these physical issues would enable the economist to better define the technical possibilities of production. For example, is there a way to consistently produce carcasses with adequate or abundant marbline but less outside fat?

Prices used were reported averages that were combined again into a five-year average. Much more specific price data could contribute to the accuracy of, and confidence placed in, the analysis.

Recently, a limited fabricated cut price series has been initiated and published which could improve on the constructed prices in this study if enough cuts were priced to estimate a composite carcass price. An alternative would be research demonstrating a technique to construct a carcass composite given the limited published prices.

More needs to be known about the existing amount of fat that is customarily allowed to remain on retail cuts of beef. It is academic to consider how much fat could be trimmed off if the product is considered acceptable in normal trade with a fatcover in excess of that employed in most cutability studies.

Similarly, more needs to be known about the demand structure for beef. For example, is there a significant number of beef consumers who prefer more fat cover to less fat cover? More information on the current and perhaps changing consumer preference patterns would help to assure the final product in an analysis such as this is consistent with the real-world desires of the consumer.

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# APPENDIX A

# COMPUTER PRINTOUTS OF GROWTH PARAMETERS AND SIMULATED OBJECTS AND ATTRIBUTES FOR EACH OF FOURTEEN BREED-TYPES BY FEEDING PERIOD AS GENERATED BY BEEFSIM

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                                   HEHE

                BIRTH WEIGHT  =   80.7            A0    = 0.0128180
                MATURE WEIGHT = 1244.9            ALPHA = 0.0042700

DAYS ON       LIVE       HOT CARCASS    MARGINAL     AVERAGE      YIELD    QUALITY   DRESSING
 FEED        WEIGHT        WEIGHT         GAIN      DAILY GAIN    GRADE     GRADE    PERCENT
-----------------------------------------------------------------------------------------------

 180          897.9        540.6          2.27         2.47        2.51      8.32      60.2
 190          920.4        555.0          2.23         2.46        2.58      8.45      60.3
 200          942.5        569.3          2.19         2.45        2.65      8.58      60.4
 210          964.2        583.3          2.14         2.43        2.72      8.71      60.5
 220          985.5        597.2          2.10         2.42        2.80      8.85      60.6
 230         1006.3        610.9          2.05         2.40        2.88      8.99      60.7
 240         1026.6        624.4          2.01         2.39        2.96      9.14      60.8
 250         1046.5        637.7          1.96         2.37        3.04      9.29      60.9
 260         1065.9        650.8          1.91         2.36        3.12      9.45      61.1
 270         1084.8        663.7          1.87         2.34        3.21      9.60      61.2
 280         1103.2        676.3          1.82         2.32        3.29      9.77      61.3
 290         1121.2        688.8          1.77         2.30        3.38      9.93      61.4
 300         1138.7        701.0          1.72         2.28        3.47     10.10      61.6
 310         1155.7        712.9          1.68         2.26        3.57     10.27      61.7
 320         1172.3        724.7          1.63         2.24        3.66     10.44      61.8

DAYS ON   PCT RETAIL      PCT FAT      PCT FAT IN    PCT PROTEIN      CUM  ENERGY    CUM ENERGY
 FEED     PROD .3 FAT   TRIM .3 FAT    EMPTY BODY  IN EMPTY BODY     MAINTENANCE        GAIN
-----------------------------------------------------------------------------------------------

 180         68.4          18.4           23.5          18.4             999.6          671.6
 190         68.1          18.8           24.2          18.3            1070.1          721.0
 200         67.8          19.2           24.9          18.1            1141.9          771.9
 210         67.5          19.6           25.7          17.9            1215.0          824.3
 220         67.2          20.0           26.5          17.7            1289.4          878.3
 230         66.8          20.4           27.3          17.5            1364.9          933.8
 240         66.5          20.8           28.1          17.3            1441.6          990.8
 250         66.1          21.3           29.0          17.2            1519.4         1049.4
 260         65.8          21.7           29.9          17.0            1598.3         1109.4
 270         65.4          22.2           30.8          16.8            1678.3         1170.9
 280         65.0          22.7           31.7          16.6            1759.3         1233.7
 290         64.6          23.2           32.6          16.4            1841.4         1297.9
 300         64.2          23.7           33.6          16.2            1924.4         1363.2
 310         63.8          24.2           34.5          16.0            2008.3         1429.8
 320         63.4          24.7           35.5          15.8            2093.2         1497.3
```

## ANAN

BIRTH WEIGHT = 73.8
MATURE WEIGHT = 1193.0

AO = 0.0147300
ALPHA = 0.0048440

| DAYS ON FEED | LIVE WEIGHT | HOT CARCASS WEIGHT | MARGINAL GAIN | AVERAGE DAILY GAIN | YIELD GRADE | QUALITY GRADE | DRESSING PERCENT |
|---|---|---|---|---|---|---|---|
| 180 | 953.0 | 578.0 | 2.22 | 2.58 | 3.05 | 9.79 | 60.7 |
| 190 | 975.0 | 592.6 | 2.17 | 2.56 | 3.14 | 9.95 | 60.8 |
| 200 | 996.4 | 606.9 | 2.11 | 2.54 | 3.23 | 10.12 | 60.9 |
| 210 | 1017.3 | 620.9 | 2.05 | 2.52 | 3.32 | 10.29 | 61.0 |
| 220 | 1037.6 | 634.7 | 2.00 | 2.50 | 3.42 | 10.47 | 61.2 |
| 230 | 1057.3 | 648.1 | 1.94 | 2.47 | 3.52 | 10.65 | 61.3 |
| 240 | 1076.4 | 661.4 | 1.88 | 2.45 | 3.62 | 10.83 | 61.4 |
| 250 | 1094.9 | 674.3 | 1.82 | 2.42 | 3.72 | 11.02 | 61.6 |
| 260 | 1112.8 | 687.0 | 1.76 | 2.40 | 3.82 | 11.21 | 61.7 |
| 270 | 1130.2 | 699.3 | 1.71 | 2.37 | 3.92 | 11.40 | 61.9 |
| 280 | 1147.0 | 711.4 | 1.65 | 2.35 | 4.03 | 11.59 | 62.0 |
| 290 | 1163.3 | 723.2 | 1.59 | 2.32 | 4.13 | 11.78 | 62.2 |
| 300 | 1178.9 | 734.7 | 1.54 | 2.30 | 4.23 | 11.98 | 62.3 |
| 310 | 1194.1 | 745.9 | 1.48 | 2.27 | 4.34 | 12.17 | 62.5 |
| 320 | 1208.7 | 756.8 | 1.43 | 2.25 | 4.44 | 12.36 | 62.6 |

| DAYS ON FEED | PCT RETAIL PROD .3 FAT | PCT FAT TRIM .3 FAT | PCT FAT IN EMPTY BODY | PCT PROTEIN IN EMPTY BODY | CUM ENERGY MAINTENANCE | CUM ENERGY GAIN |
|---|---|---|---|---|---|---|
| 180 | 66.1 | 21.4 | 26.8 | 17.6 | 1053.8 | 795.9 |
| 190 | 65.7 | 21.8 | 27.7 | 17.4 | 1127.5 | 856.1 |
| 200 | 65.3 | 22.3 | 28.7 | 17.2 | 1202.5 | 918.1 |
| 210 | 64.9 | 22.8 | 29.7 | 17.0 | 1278.6 | 981.8 |
| 220 | 64.5 | 23.4 | 30.7 | 16.8 | 1355.9 | 1047.2 |
| 230 | 64.0 | 23.9 | 31.7 | 16.6 | 1434.4 | 1114.1 |
| 240 | 63.6 | 24.4 | 32.7 | 16.3 | 1513.9 | 1182.5 |
| 250 | 63.2 | 25.0 | 33.8 | 16.1 | 1594.4 | 1252.3 |
| 260 | 62.7 | 25.5 | 34.9 | 15.9 | 1676.0 | 1323.4 |
| 270 | 62.3 | 26.1 | 35.9 | 15.7 | 1758.5 | 1395.5 |
| 280 | 61.8 | 26.7 | 37.0 | 15.5 | 1842.0 | 1468.7 |
| 290 | 61.4 | 27.2 | 38.1 | 15.2 | 1926.4 | 1542.7 |
| 300 | 60.9 | 27.8 | 39.2 | 15.0 | 2011.7 | 1617.4 |
| 310 | 60.5 | 28.4 | 40.3 | 14.8 | 2097.8 | 1692.6 |
| 320 | 60.0 | 28.9 | 41.4 | 14.6 | 2184.7 | 1768.2 |

## ANHE

BIRTH WEIGHT = 80.1
MATURE WEIGHT = 1244.9

AO = 0.0130590
ALPHA = 0.0042840

| DAYS ON FEED | LIVE WEIGHT | HOT CARCASS WEIGHT | MARGINAL GAIN | AVERAGE DAILY GAIN | YIELD GRADE | QUALITY GRADE | DRESSING PERCENT |
|---|---|---|---|---|---|---|---|
| 180 | 928.1 | 559.9 | 2.38 | 2.58 | 2.74 | 8.83 | 60.3 |
| 190 | 951.6 | 575.2 | 2.34 | 2.57 | 2.82 | 8.97 | 60.4 |
| 200 | 974.8 | 590.3 | 2.29 | 2.56 | 2.90 | 9.11 | 60.6 |
| 210 | 997.5 | 605.2 | 2.25 | 2.54 | 2.98 | 9.27 | 60.7 |
| 220 | 1019.8 | 619.9 | 2.20 | 2.53 | 3.06 | 9.42 | 60.8 |
| 230 | 1041.6 | 634.4 | 2.15 | 2.51 | 3.15 | 9.59 | 60.9 |
| 240 | 1062.9 | 648.8 | 2.11 | 2.50 | 3.24 | 9.76 | 61.0 |
| 250 | 1083.7 | 663.0 | 2.06 | 2.48 | 3.34 | 9.93 | 61.2 |
| 260 | 1104.1 | 676.9 | 2.01 | 2.46 | 3.43 | 10.11 | 61.3 |
| 270 | 1123.9 | 690.6 | 1.96 | 2.44 | 3.53 | 10.29 | 61.4 |
| 280 | 1143.3 | 704.1 | 1.91 | 2.43 | 3.63 | 10.48 | 61.6 |
| 290 | 1162.1 | 717.4 | 1.86 | 2.41 | 3.74 | 10.67 | 61.7 |
| 300 | 1180.5 | 730.5 | 1.81 | 2.39 | 3.84 | 10.86 | 61.9 |
| 310 | 1198.3 | 743.4 | 1.76 | 2.37 | 3.95 | 11.06 | 62.0 |
| 320 | 1215.7 | 756.0 | 1.71 | 2.35 | 4.06 | 11.26 | 62.2 |

| DAYS ON FEED | PCT RETAIL PROD .3 FAT | PCT FAT TRIM .3 FAT | PCT FAT IN EMPTY BODY | PCT PROTEIN IN EMPTY BODY | CUM ENERGY MAINTENANCE | CUM ENERGY GAIN |
|---|---|---|---|---|---|---|
| 180 | 67.4 | 19.7 | 24.4 | 18.2 | 1021.7 | 724.8 |
| 190 | 67.1 | 20.1 | 25.2 | 18.0 | 1094.1 | 780.1 |
| 200 | 66.7 | 20.5 | 26.1 | 17.8 | 1167.7 | 837.4 |
| 210 | 66.4 | 21.0 | 26.9 | 17.6 | 1242.7 | 896.6 |
| 220 | 66.0 | 21.4 | 27.8 | 17.4 | 1319.0 | 957.9 |
| 230 | 65.6 | 21.9 | 28.8 | 17.2 | 1396.5 | 1021.2 |
| 240 | 65.2 | 22.4 | 29.7 | 17.0 | 1475.2 | 1086.6 |
| 250 | 64.8 | 22.9 | 30.7 | 16.8 | 1555.0 | 1153.9 |
| 260 | 64.4 | 23.4 | 31.7 | 16.6 | 1636.1 | 1223.2 |
| 270 | 64.0 | 24.0 | 32.8 | 16.3 | 1718.2 | 1294.3 |
| 280 | 63.5 | 24.5 | 33.8 | 16.1 | 1801.4 | 1367.3 |
| 290 | 63.1 | 25.1 | 34.9 | 15.9 | 1885.7 | 1442.0 |
| 300 | 62.6 | 25.7 | 36.0 | 15.7 | 1971.0 | 1518.4 |
| 310 | 62.2 | 26.2 | 37.1 | 15.4 | 2057.2 | 1596.3 |
| 320 | 61.7 | 26.8 | 38.3 | 15.2 | 2144.4 | 1675.7 |

## HEAN

BIRTH WEIGHT = 79.0
MATURE WEIGHT = 1206.4

AO = 0.0140780
ALPHA = 0.0047752

| DAYS ON FEED | LIVE WEIGHT | HOT CARCASS WEIGHT | MARGINAL GAIN | AVERAGE DAILY GAIN | YIELD GRADE | QUALITY GRADE | DRESSING PERCENT |
|---|---|---|---|---|---|---|---|
| 180 | 932.0 | 563.7 | 2.13 | 2.48 | 2.90 | 8.62 | 60.5 |
| 190 | 953.1 | 577.5 | 2.08 | 2.46 | 2.98 | 8.77 | 60.6 |
| 200 | 973.7 | 591.1 | 2.03 | 2.44 | 3.05 | 8.91 | 60.7 |
| 210 | 993.7 | 604.3 | 1.97 | 2.42 | 3.14 | 9.06 | 60.8 |
| 220 | 1013.2 | 617.4 | 1.92 | 2.40 | 3.22 | 9.21 | 60.9 |
| 230 | 1032.1 | 630.1 | 1.86 | 2.37 | 3.30 | 9.37 | 61.1 |
| 240 | 1050.4 | 642.6 | 1.81 | 2.35 | 3.39 | 9.53 | 61.2 |
| 250 | 1068.3 | 654.8 | 1.75 | 2.33 | 3.48 | 9.69 | 61.3 |
| 260 | 1085.5 | 666.7 | 1.70 | 2.30 | 3.56 | 9.85 | 61.4 |
| 270 | 1102.2 | 678.4 | 1.64 | 2.28 | 3.55 | 10.02 | 61.5 |
| 280 | 1118.4 | 689.8 | 1.59 | 2.25 | 3.74 | 10.18 | 61.7 |
| 290 | 1134.1 | 700.9 | 1.54 | 2.23 | 3.83 | 10.35 | 61.8 |
| 300 | 1149.2 | 711.7 | 1.48 | 2.21 | 3.92 | 10.52 | 61.9 |
| 310 | 1163.8 | 722.2 | 1.43 | 2.18 | 4.01 | 10.68 | 62.1 |
| 320 | 1177.9 | 732.4 | 1.38 | 2.16 | 4.10 | 10.85 | 62.2 |

| DAYS ON FEED | PCT RETAIL PROD .3 FAT | PCT FAT TRIM .3 FAT | PCT FAT IN EMPTY BODY | PCT PROTEIN IN EMPTY BODY | CUM ENERGY MAINTENANCE | CUM ENERGY GAIN |
|---|---|---|---|---|---|---|
| 180 | 66.7 | 20.5 | 25.6 | 17.9 | 1040.9 | 734.2 |
| 190 | 66.4 | 21.0 | 26.4 | 17.7 | 1113.4 | 787.6 |
| 200 | 66.0 | 21.4 | 27.2 | 17.6 | 1187.0 | 842.3 |
| 210 | 65.7 | 21.8 | 28.1 | 17.4 | 1261.9 | 898.3 |
| 220 | 65.3 | 22.3 | 28.9 | 17.2 | 1337.8 | 955.6 |
| 230 | 65.0 | 22.7 | 29.8 | 17.0 | 1414.8 | 1014.0 |
| 240 | 64.6 | 23.2 | 30.7 | 16.8 | 1492.9 | 1073.6 |
| 250 | 64.2 | 23.7 | 31.6 | 16.6 | 1572.0 | 1134.1 |
| 260 | 63.8 | 24.2 | 32.6 | 16.4 | 1652.1 | 1195.6 |
| 270 | 63.5 | 24.6 | 33.5 | 16.2 | 1733.1 | 1257.9 |
| 280 | 63.1 | 25.1 | 34.4 | 16.0 | 1815.0 | 1320.9 |
| 290 | 62.7 | 25.6 | 35.4 | 15.8 | 1897.8 | 1384.5 |
| 300 | 62.3 | 26.1 | 36.3 | 15.6 | 1981.5 | 1448.6 |
| 310 | 61.9 | 26.6 | 37.3 | 15.4 | 2065.9 | 1513.1 |
| 320 | 61.5 | 27.1 | 38.2 | 15.2 | 2151.2 | 1577.8 |

## JEHE

BIRTH WEIGHT = 72.7
MATURE WEIGHT = 1181.5

AO = 0.0139060
ALPHA = 0.0045972

| DAYS ON FEED | LIVE WEIGHT | HOT CARCASS WEIGHT | MARGINAL GAIN | AVERAGE DAILY GAIN | YIELD GRADE | QUALITY GRADE | DRESSING PERCENT |
|---|---|---|---|---|---|---|---|
| 180 | 883.6 | 519.2 | 2.14 | 2.42 | 2.61 | 8.19 | 58.8 |
| 190 | 904.7 | 532.6 | 2.09 | 2.40 | 2.69 | 8.33 | 58.9 |
| 200 | 925.5 | 545.7 | 2.04 | 2.38 | 2.76 | 8.47 | 59.0 |
| 210 | 945.7 | 558.7 | 1.99 | 2.36 | 2.84 | 8.61 | 59.1 |
| 220 | 965.4 | 571.4 | 1.94 | 2.35 | 2.92 | 8.76 | 59.2 |
| 230 | 984.6 | 583.9 | 1.89 | 2.33 | 3.00 | 8.91 | 59.3 |
| 240 | 1003.3 | 596.2 | 1.84 | 2.31 | 3.08 | 9.06 | 59.4 |
| 250 | 1021.5 | 608.2 | 1.79 | 2.29 | 3.17 | 9.22 | 59.5 |
| 260 | 1039.2 | 620.0 | 1.74 | 2.27 | 3.26 | 9.38 | 59.7 |
| 270 | 1056.4 | 631.6 | 1.69 | 2.25 | 3.34 | 9.54 | 59.8 |
| 280 | 1073.1 | 642.9 | 1.64 | 2.23 | 3.43 | 9.71 | 59.9 |
| 290 | 1089.2 | 654.0 | 1.59 | 2.20 | 3.52 | 9.87 | 60.0 |
| 300 | 1104.9 | 664.8 | 1.54 | 2.18 | 3.61 | 10.04 | 60.2 |
| 310 | 1120.1 | 675.4 | 1.49 | 2.16 | 3.71 | 10.21 | 60.3 |
| 320 | 1134.8 | 685.7 | 1.44 | 2.14 | 3.80 | 10.38 | 60.4 |

| DAYS ON FEED | PCT RETAIL PROD .3 FAT | PCT FAT TRIM .3 FAT | PCT FAT IN EMPTY BODY | PCT PROTEIN IN EMPTY BODY | CUM ENERGY MAINTENANCE | CUM ENERGY GAIN |
|---|---|---|---|---|---|---|
| 180 | 68.0 | 19.0 | 24.5 | 18.2 | 991.8 | 666.1 |
| 190 | 67.6 | 19.4 | 25.3 | 18.0 | 1061.5 | 714.8 |
| 200 | 67.3 | 19.8 | 26.1 | 17.8 | 1132.3 | 764.9 |
| 210 | 67.0 | 20.2 | 26.9 | 17.6 | 1204.4 | 816.4 |
| 220 | 66.6 | 20.6 | 27.7 | 17.4 | 1277.6 | 869.2 |
| 230 | 66.3 | 21.1 | 28.6 | 17.2 | 1352.0 | 923.2 |
| 240 | 65.9 | 21.5 | 29.5 | 17.0 | 1427.4 | 978.6 |
| 250 | 65.5 | 22.0 | 30.4 | 16.9 | 1503.8 | 1035.1 |
| 260 | 65.2 | 22.5 | 31.3 | 16.7 | 1581.3 | 1092.7 |
| 270 | 64.8 | 23.0 | 32.2 | 16.5 | 1659.7 | 1151.3 |
| 280 | 64.4 | 23.4 | 33.1 | 16.3 | 1739.1 | 1211.0 |
| 290 | 64.0 | 23.9 | 34.1 | 16.1 | 1819.4 | 1271.4 |
| 300 | 63.6 | 24.4 | 35.0 | 15.9 | 1900.6 | 1332.7 |
| 310 | 63.2 | 24.9 | 36.0 | 15.7 | 1982.7 | 1394.6 |
| 320 | 62.8 | 25.4 | 37.0 | 15.5 | 2065.5 | 1457.0 |

## JEAN

BIRTH WEIGHT = 71.5
MATURE WEIGHT = 1138.7

AO = 0.0139340
ALPHA = 0.0046152

| DAYS ON FEED | LIVE WEIGHT | HOT CARCASS WEIGHT | MARGINAL GAIN | AVERAGE DAILY GAIN | YIELD GRADE | QUALITY GRADE | DRESSING PERCENT |
|---|---|---|---|---|---|---|---|
| 180 | 868.0 | 513.5 | 2.09 | 2.37 | 2.67 | 8.91 | 59.2 |
| 190 | 888.7 | 526.7 | 2.04 | 2.35 | 2.75 | 9.05 | 59.3 |
| 200 | 908.9 | 539.7 | 2.00 | 2.33 | 2.83 | 9.20 | 59.4 |
| 210 | 928.7 | 552.5 | 1.95 | 2.32 | 2.91 | 9.35 | 59.5 |
| 220 | 947.9 | 565.1 | 1.90 | 2.30 | 3.00 | 9.51 | 59.6 |
| 230 | 966.7 | 577.5 | 1.85 | 2.28 | 3.08 | 9.67 | 59.7 |
| 240 | 985.0 | 589.6 | 1.80 | 2.26 | 3.17 | 9.83 | 59.9 |
| 250 | 1002.7 | 601.5 | 1.75 | 2.24 | 3.26 | 10.00 | 60.0 |
| 260 | 1020.0 | 613.2 | 1.70 | 2.22 | 3.35 | 10.17 | 60.1 |
| 270 | 1036.7 | 624.6 | 1.65 | 2.20 | 3.45 | 10.34 | 60.2 |
| 280 | 1053.0 | 635.8 | 1.60 | 2.18 | 3.54 | 10.52 | 60.4 |
| 290 | 1068.8 | 646.8 | 1.55 | 2.16 | 3.64 | 10.70 | 60.5 |
| 300 | 1084.0 | 657.5 | 1.50 | 2.14 | 3.73 | 10.87 | 60.7 |
| 310 | 1098.8 | 668.0 | 1.45 | 2.11 | 3.83 | 11.05 | 60.8 |
| 320 | 1113.1 | 678.2 | 1.40 | 2.09 | 3.93 | 11.23 | 60.9 |

| DAYS ON FEED | PCT RETAIL PROD .3 FAT | PCT FAT TRIM .3 FAT | PCT FAT IN EMPTY BODY | PCT PROTEIN IN EMPTY BODY | CUM ENERGY MAINTENANCE | CUM ENERGY GAIN |
|---|---|---|---|---|---|---|
| 180 | 67.7 | 19.3 | 25.1 | 18.0 | 979.3 | 671.9 |
| 190 | 67.4 | 19.7 | 26.0 | 17.9 | 1048.1 | 721.8 |
| 200 | 67.0 | 20.1 | 26.8 | 17.7 | 1118.0 | 773.2 |
| 210 | 66.7 | 20.6 | 27.6 | 17.5 | 1189.1 | 826.1 |
| 220 | 66.3 | 21.1 | 28.5 | 17.3 | 1261.3 | 880.4 |
| 230 | 65.9 | 21.5 | 29.4 | 17.1 | 1334.7 | 936.1 |
| 240 | 65.5 | 22.0 | 30.4 | 16.8 | 1409.0 | 993.1 |
| 250 | 65.1 | 22.5 | 31.3 | 16.6 | 1484.4 | 1051.4 |
| 260 | 64.7 | 23.0 | 32.3 | 16.4 | 1560.8 | 1110.9 |
| 270 | 64.3 | 23.5 | 33.3 | 16.2 | 1638.2 | 1171.5 |
| 280 | 63.9 | 24.0 | 34.3 | 16.0 | 1716.5 | 1233.1 |
| 290 | 63.5 | 24.6 | 35.3 | 15.8 | 1795.6 | 1295.7 |
| 300 | 63.1 | 25.1 | 36.3 | 15.6 | 1875.7 | 1359.0 |
| 310 | 62.7 | 25.6 | 37.3 | 15.4 | 1956.5 | 1423.1 |
| 320 | 62.3 | 26.1 | 38.3 | 15.2 | 2038.2 | 1487.8 |

## SQHE

BIRTH WEIGHT = 85.9        AO = 0.0123630
MATURE WEIGHT = 1244.9        ALPHA = 0.0040991

| DAYS ON FEED | LIVE WEIGHT | HOT CARCASS WEIGHT | MARGINAL GAIN | AVERAGE DAILY GAIN | YIELD GRADE | QUALITY GRADE | DRESSING PERCENT |
|---|---|---|---|---|---|---|---|
| 180 | 928.9 | 560.4 | 2.42 | 2.58 | 2.61 | 8.42 | 60.3 |
| 190 | 952.9 | 575.9 | 2.38 | 2.57 | 2.69 | 8.56 | 60.4 |
| 200 | 976.5 | 591.3 | 2.34 | 2.56 | 2.77 | 8.71 | 60.6 |
| 210 | 999.7 | 606.6 | 2.30 | 2.55 | 2.85 | 8.87 | 60.7 |
| 220 | 1022.5 | 621.7 | 2.26 | 2.54 | 2.94 | 9.03 | 60.8 |
| 230 | 1044.9 | 636.7 | 2.21 | 2.52 | 3.03 | 9.20 | 60.9 |
| 240 | 1066.8 | 651.5 | 2.17 | 2.51 | 3.13 | 9.37 | 61.1 |
| 250 | 1088.3 | 666.1 | 2.12 | 2.49 | 3.22 | 9.56 | 61.2 |
| 260 | 1109.4 | 680.6 | 2.08 | 2.48 | 3.33 | 9.74 | 61.3 |
| 270 | 1130.0 | 694.8 | 2.03 | 2.46 | 3.43 | 9.93 | 61.5 |
| 280 | 1150.1 | 708.9 | 1.98 | 2.45 | 3.54 | 10.13 | 61.6 |
| 290 | 1169.7 | 722.8 | 1.94 | 2.43 | 3.64 | 10.33 | 61.8 |
| 300 | 1188.9 | 736.6 | 1.89 | 2.41 | 3.76 | 10.54 | 62.0 |
| 310 | 1207.6 | 750.1 | 1.84 | 2.39 | 3.87 | 10.75 | 62.1 |
| 320 | 1225.8 | 763.4 | 1.80 | 2.38 | 3.98 | 10.96 | 62.3 |

| DAYS ON FEED | PCT RETAIL PROD .3 FAT | PCT FAT TRIM .3 FAT | PCT FAT IN EMPTY BODY | PCT PROTEIN IN EMPTY BODY | CUM ENERGY MAINTENANCE | CUM ENERGY GAIN |
|---|---|---|---|---|---|---|
| 180 | 68.0 | 18.9 | 24.5 | 18.2 | 1021.6 | 725.0 |
| 190 | 67.6 | 19.4 | 25.3 | 18.0 | 1094.0 | 781.4 |
| 200 | 67.3 | 19.8 | 26.1 | 17.8 | 1167.7 | 840.1 |
| 210 | 66.9 | 20.3 | 27.0 | 17.6 | 1242.8 | 900.9 |
| 220 | 66.5 | 20.7 | 28.0 | 17.4 | 1319.2 | 964.1 |
| 230 | 66.1 | 21.2 | 28.9 | 17.2 | 1396.9 | 1029.6 |
| 240 | 65.7 | 21.8 | 29.9 | 16.9 | 1475.8 | 1097.5 |
| 250 | 65.3 | 22.3 | 30.9 | 16.7 | 1555.9 | 1167.7 |
| 260 | 64.9 | 22.9 | 32.0 | 16.5 | 1637.2 | 1240.3 |
| 270 | 64.4 | 23.4 | 33.1 | 16.3 | 1719.7 | 1315.2 |
| 280 | 64.0 | 24.0 | 34.2 | 16.0 | 1803.2 | 1392.3 |
| 290 | 63.5 | 24.6 | 35.4 | 15.8 | 1887.9 | 1471.7 |
| 300 | 63.0 | 25.2 | 36.5 | 15.6 | 1973.6 | 1553.1 |
| 310 | 62.5 | 25.8 | 37.7 | 15.3 | 2060.4 | 1636.7 |
| 320 | 62.0 | 26.4 | 38.9 | 15.1 | 2148.1 | 1722.1 |

## SOAN

BIRTH WEIGHT = 80.8　　AO = 0.0138300
MATURE WEIGHT = 1244.9　　ALPHA = 0.0046430

| DAYS ON FEED | LIVE WEIGHT | HOT CARCASS WEIGHT | MARGINAL GAIN | AVERAGE DAILY GAIN | YIELD GRADE | QUALITY GRADE | DRESSING PERCENT |
|---|---|---|---|---|---|---|---|
| 180 | 953.8 | 582.6 | 2.26 | 2.57 | 2.69 | 9.29 | 61.1 |
| 190 | 976.1 | 597.3 | 2.20 | 2.55 | 2.76 | 9.44 | 61.2 |
| 200 | 997.9 | 611.8 | 2.15 | 2.54 | 2.84 | 9.58 | 61.3 |
| 210 | 1019.2 | 626.0 | 2.10 | 2.52 | 2.93 | 9.73 | 61.4 |
| 220 | 1039.9 | 640.0 | 2.04 | 2.49 | 3.01 | 9.89 | 61.5 |
| 230 | 1060.1 | 653.7 | 1.99 | 2.47 | 3.10 | 10.05 | 61.7 |
| 240 | 1079.7 | 667.1 | 1.93 | 2.45 | 3.18 | 10.21 | 61.8 |
| 250 | 1098.8 | 680.3 | 1.88 | 2.43 | 3.27 | 10.38 | 61.9 |
| 260 | 1117.4 | 693.2 | 1.82 | 2.41 | 3.36 | 10.54 | 62.0 |
| 270 | 1135.3 | 705.9 | 1.77 | 2.38 | 3.46 | 10.71 | 62.2 |
| 280 | 1152.8 | 718.2 | 1.71 | 2.36 | 3.55 | 10.89 | 62.3 |
| 290 | 1169.7 | 730.3 | 1.66 | 2.34 | 3.64 | 11.06 | 62.4 |
| 300 | 1186.0 | 742.1 | 1.61 | 2.31 | 3.74 | 11.24 | 62.6 |
| 310 | 1201.9 | 753.6 | 1.55 | 2.29 | 3.83 | 11.41 | 62.7 |
| 320 | 1217.2 | 764.9 | 1.50 | 2.26 | 3.93 | 11.59 | 62.8 |

| DAYS ON FEED | PCT RETAIL PROD .3 FAT | PCT FAT TRIM .3 FAT | PCT FAT IN EMPTY BODY | PCT PROTEIN IN EMPTY BODY | CUM ENERGY MAINTENANCE | CUM ENERGY GAIN |
|---|---|---|---|---|---|---|
| 180 | 67.6 | 19.4 | 25.3 | 18.0 | 1054.3 | 758.8 |
| 190 | 67.3 | 19.8 | 26.1 | 17.8 | 1128.1 | 814.8 |
| 200 | 67.0 | 20.2 | 27.0 | 17.6 | 1203.1 | 872.4 |
| 210 | 66.6 | 20.7 | 27.8 | 17.4 | 1279.4 | 931.5 |
| 220 | 66.2 | 21.1 | 28.7 | 17.2 | 1356.8 | 992.2 |
| 230 | 65.9 | 21.6 | 29.6 | 17.0 | 1435.4 | 1054.3 |
| 240 | 65.5 | 22.1 | 30.5 | 16.8 | 1515.0 | 1117.8 |
| 250 | 65.1 | 22.6 | 31.5 | 16.6 | 1595.8 | 1182.7 |
| 260 | 64.7 | 23.1 | 32.4 | 16.4 | 1677.6 | 1248.8 |
| 270 | 64.3 | 23.6 | 33.4 | 16.2 | 1760.4 | 1316.0 |
| 280 | 63.9 | 24.1 | 34.4 | 16.0 | 1844.2 | 1384.2 |
| 290 | 63.5 | 24.6 | 35.4 | 15.8 | 1928.9 | 1453.4 |
| 300 | 63.1 | 25.1 | 36.4 | 15.6 | 2014.6 | 1523.3 |
| 310 | 62.7 | 25.6 | 37.4 | 15.4 | 2101.1 | 1593.9 |
| 320 | 62.3 | 26.1 | 38.4 | 15.2 | 2188.4 | 1665.1 |

## LIHE

BIRTH WEIGHT = 75.6
MATURE WEIGHT = 1371.8

AO = 0.0145770
ALPHA = 0.0048067

| DAYS ON FEED | LIVE WEIGHT | HOT CARCASS WEIGHT | MARGINAL GAIN | AVERAGE DAILY GAIN | YIELD GRADE | QUALITY GRADE | DRESSING PERCENT |
|---|---|---|---|---|---|---|---|
| 180 | 962.9 | 591.1 | 2.26 | 2.61 | 1.94 | 8.20 | 61.4 |
| 190 | 985.2 | 605.5 | 2.20 | 2.59 | 1.99 | 8.30 | 61.5 |
| 200 | 1006.9 | 619.7 | 2.14 | 2.57 | 2.05 | 8.41 | 61.5 |
| 210 | 1028.1 | 633.6 | 2.09 | 2.55 | 2.11 | 8.52 | 61.6 |
| 220 | 1048.7 | 647.2 | 2.03 | 2.52 | 2.17 | 8.63 | 61.7 |
| 230 | 1068.7 | 660.5 | 1.97 | 2.50 | 2.23 | 8.75 | 61.8 |
| 240 | 1088.2 | 673.5 | 1.91 | 2.48 | 2.30 | 8.86 | 61.9 |
| 250 | 1107.0 | 686.1 | 1.85 | 2.45 | 2.36 | 8.98 | 62.0 |
| 260 | 1125.3 | 698.5 | 1.79 | 2.43 | 2.43 | 9.10 | 62.1 |
| 270 | 1143.0 | 710.5 | 1.74 | 2.40 | 2.49 | 9.22 | 62.2 |
| 280 | 1160.1 | 722.2 | 1.68 | 2.38 | 2.56 | 9.34 | 62.3 |
| 290 | 1176.6 | 733.6 | 1.62 | 2.35 | 2.62 | 9.46 | 62.3 |
| 300 | 1192.6 | 744.7 | 1.57 | 2.33 | 2.69 | 9.58 | 62.4 |
| 310 | 1208.1 | 755.4 | 1.51 | 2.30 | 2.75 | 9.71 | 62.5 |
| 320 | 1223.0 | 765.9 | 1.46 | 2.27 | 2.82 | 9.83 | 62.6 |

| DAYS ON FEED | PCT RETAIL PROD .3 FAT | PCT FAT TRIM .3 FAT | PCT FAT IN EMPTY BODY | PCT PROTEIN IN EMPTY BODY | CUM ENERGY MAINTENANCE | CUM ENERGY GAIN |
|---|---|---|---|---|---|---|
| 180 | 70.9 | 15.3 | 22.8 | 18.6 | 1061.7 | 706.0 |
| 190 | 70.6 | 15.6 | 23.4 | 18.5 | 1136.0 | 753.2 |
| 200 | 70.4 | 15.9 | 24.0 | 18.3 | 1211.5 | 801.2 |
| 210 | 70.1 | 16.2 | 24.6 | 18.2 | 1288.3 | 850.0 |
| 220 | 69.9 | 16.6 | 25.2 | 18.0 | 1366.2 | 899.4 |
| 230 | 69.6 | 16.9 | 25.9 | 17.9 | 1445.3 | 949.6 |
| 240 | 69.3 | 17.3 | 26.5 | 17.7 | 1525.4 | 1000.3 |
| 250 | 69.0 | 17.6 | 27.2 | 17.6 | 1606.7 | 1051.5 |
| 260 | 68.8 | 17.9 | 27.9 | 17.4 | 1688.9 | 1103.3 |
| 270 | 68.5 | 18.3 | 28.6 | 17.2 | 1772.2 | 1155.4 |
| 280 | 68.2 | 18.7 | 29.3 | 17.1 | 1856.4 | 1207.8 |
| 290 | 67.9 | 19.0 | 30.0 | 16.9 | 1941.5 | 1260.5 |
| 300 | 67.6 | 19.4 | 30.6 | 16.8 | 2027.5 | 1313.4 |
| 310 | 67.3 | 19.7 | 31.3 | 16.6 | 2114.3 | 1366.3 |
| 320 | 67.1 | 20.1 | 32.0 | 16.5 | 2202.0 | 1419.2 |

## LIAN

BIRTH WEIGHT = 79.4
MATURE WEIGHT = 1357.3

AO = 0.0144950
ALPHA = 0.0048955

| DAYS ON FEED | LIVE WEIGHT | HOT CARCASS WEIGHT | MARGINAL GAIN | AVERAGE DAILY GAIN | YIELD GRADE | QUALITY GRADE | DRESSING PERCENT |
|---|---|---|---|---|---|---|---|
| 180 | 967.4 | 596.0 | 2.18 | 2.57 | 2.12 | 8.27 | 61.6 |
| 190 | 988.9 | 610.1 | 2.12 | 2.54 | 2.18 | 8.37 | 61.7 |
| 200 | 1009.9 | 623.9 | 2.06 | 2.52 | 2.24 | 8.48 | 61.8 |
| 210 | 1030.2 | 637.3 | 2.00 | 2.50 | 2.30 | 8.59 | 61.9 |
| 220 | 1050.0 | 650.4 | 1.94 | 2.47 | 2.36 | 8.70 | 61.9 |
| 230 | 1069.2 | 663.2 | 1.88 | 2.45 | 2.42 | 8.82 | 62.0 |
| 240 | 1087.8 | 675.7 | 1.83 | 2.42 | 2.48 | 8.93 | 62.1 |
| 250 | 1105.7 | 687.9 | 1.77 | 2.40 | 2.54 | 9.05 | 62.2 |
| 260 | 1123.2 | 699.7 | 1.71 | 2.37 | 2.61 | 9.17 | 62.3 |
| 270 | 1140.0 | 711.2 | 1.65 | 2.34 | 2.67 | 9.28 | 62.4 |
| 280 | 1156.3 | 722.4 | 1.60 | 2.32 | 2.73 | 9.40 | 62.5 |
| 290 | 1172.0 | 733.3 | 1.54 | 2.29 | 2.80 | 9.52 | 62.6 |
| 300 | 1187.1 | 743.9 | 1.49 | 2.27 | 2.86 | 9.64 | 62.7 |
| 310 | 1201.7 | 754.1 | 1.43 | 2.24 | 2.93 | 9.76 | 62.8 |
| 320 | 1215.8 | 764.0 | 1.38 | 2.21 | 2.99 | 9.88 | 62.9 |

| DAYS ON FEED | PCT RETAIL PROD .3 FAT | PCT FAT TRIM .3 FAT | PCT FAT IN EMPTY BODY | PCT PROTEIN IN EMPTY BODY | CUM ENERGY MAINTENANCE | CUM ENERGY GAIN |
|---|---|---|---|---|---|---|
| 180 | 70.1 | 16.3 | 23.2 | 18.5 | 1072.1 | 709.3 |
| 190 | 69.8 | 16.6 | 23.8 | 18.4 | 1146.6 | 756.3 |
| 200 | 69.6 | 16.9 | 24.4 | 18.2 | 1222.4 | 804.0 |
| 210 | 69.3 | 17.2 | 25.0 | 18.1 | 1299.3 | 852.3 |
| 220 | 69.1 | 17.6 | 25.6 | 17.9 | 1377.3 | 901.1 |
| 230 | 68.8 | 17.9 | 26.3 | 17.8 | 1456.4 | 950.6 |
| 240 | 68.5 | 18.2 | 26.9 | 17.6 | 1536.5 | 1000.4 |
| 250 | 68.3 | 18.6 | 27.6 | 17.5 | 1617.7 | 1050.7 |
| 260 | 68.0 | 18.9 | 28.3 | 17.3 | 1699.9 | 1101.3 |
| 270 | 67.7 | 19.3 | 28.9 | 17.2 | 1783.0 | 1152.2 |
| 280 | 67.4 | 19.6 | 29.6 | 17.0 | 1867.0 | 1203.2 |
| 290 | 67.2 | 20.0 | 30.3 | 16.9 | 1951.9 | 1254.2 |
| 300 | 66.9 | 20.3 | 31.0 | 16.7 | 2037.6 | 1305.3 |
| 310 | 66.6 | 20.7 | 31.6 | 16.6 | 2124.1 | 1356.3 |
| 320 | 66.3 | 21.0 | 32.3 | 16.4 | 2211.4 | 1407.2 |

## SIHE

BIRTH WEIGHT = 77.8
MATURE WEIGHT = 1457.0
AO = 0.0143060
ALPHA = 0.0046244

| DAYS ON FEED | LIVE WEIGHT | HOT CARCASS WEIGHT | MARGINAL GAIN | AVERAGE DAILY GAIN | YIELD GRADE | QUALITY GRADE | DRESSING PERCENT |
|---|---|---|---|---|---|---|---|
| 180 | 1006.3 | 599.3 | 2.48 | 2.79 | 1.98 | 8.13 | 59.5 |
| 190 | 1030.9 | 614.7 | 2.43 | 2.77 | 2.04 | 8.23 | 59.6 |
| 200 | 1054.9 | 629.9 | 2.37 | 2.75 | 2.09 | 8.34 | 59.7 |
| 210 | 1078.3 | 644.8 | 2.31 | 2.73 | 2.15 | 8.45 | 59.8 |
| 220 | 1101.2 | 659.4 | 2.26 | 2.71 | 2.21 | 8.57 | 59.9 |
| 230 | 1123.5 | 673.8 | 2.20 | 2.69 | 2.28 | 8.68 | 60.0 |
| 240 | 1145.2 | 687.8 | 2.14 | 2.67 | 2.34 | 8.80 | 60.1 |
| 250 | 1166.3 | 701.6 | 2.08 | 2.65 | 2.41 | 8.92 | 60.2 |
| 260 | 1186.9 | 715.1 | 2.02 | 2.62 | 2.48 | 9.05 | 60.2 |
| 270 | 1206.8 | 728.2 | 1.96 | 2.60 | 2.54 | 9.17 | 60.3 |
| 280 | 1226.2 | 741.1 | 1.90 | 2.57 | 2.61 | 9.30 | 60.4 |
| 290 | 1244.9 | 753.7 | 1.84 | 2.55 | 2.68 | 9.43 | 60.5 |
| 300 | 1263.1 | 765.9 | 1.79 | 2.53 | 2.75 | 9.56 | 60.6 |
| 310 | 1280.7 | 777.9 | 1.73 | 2.50 | 2.82 | 9.69 | 60.7 |
| 320 | 1297.8 | 789.5 | 1.67 | 2.47 | 2.89 | 9.82 | 60.8 |

| DAYS ON FEED | PCT RETAIL PROD .3 FAT | PCT FAT TRIM .3 FAT | PCT FAT IN EMPTY BODY | PCT PROTEIN IN EMPTY BODY | CUM ENERGY MAINTENANCE | CUM ENERGY GAIN |
|---|---|---|---|---|---|---|
| 180 | 70.7 | 15.5 | 22.4 | 18.7 | 1089.2 | 719.2 |
| 190 | 70.5 | 15.8 | 23.0 | 18.6 | 1166.1 | 768.4 |
| 200 | 70.2 | 16.1 | 23.6 | 18.4 | 1244.2 | 818.5 |
| 210 | 69.9 | 16.5 | 24.2 | 18.3 | 1323.8 | 869.6 |
| 220 | 69.7 | 16.8 | 24.9 | 18.1 | 1404.6 | 921.7 |
| 230 | 69.4 | 17.1 | 25.5 | 18.0 | 1486.6 | 974.7 |
| 240 | 69.1 | 17.5 | 26.2 | 17.8 | 1569.9 | 1028.5 |
| 250 | 68.8 | 17.9 | 26.9 | 17.6 | 1654.3 | 1083.3 |
| 260 | 68.6 | 18.2 | 27.6 | 17.5 | 1739.9 | 1138.8 |
| 270 | 68.3 | 18.6 | 28.3 | 17.3 | 1826.6 | 1195.0 |
| 280 | 68.0 | 19.0 | 29.0 | 17.1 | 1914.3 | 1251.8 |
| 290 | 67.7 | 19.3 | 29.8 | 17.0 | 2003.1 | 1309.2 |
| 300 | 67.4 | 19.7 | 30.5 | 16.8 | 2092.8 | 1367.1 |
| 310 | 67.1 | 20.1 | 31.2 | 16.7 | 2183.5 | 1425.4 |
| 320 | 66.7 | 20.5 | 32.0 | 16.5 | 2275.2 | 1484.0 |

## SIAN

BIRTH WEIGHT = 80.3
MATURE WEIGHT = 1357.2

AO = 0.0142930
ALPHA = 0.0047093

| DAYS ON FEED | LIVE WEIGHT | HOT CARCASS WEIGHT | MARGINAL GAIN | AVERAGE DAILY GAIN | YIELD GRADE | QUALITY GRADE | DRESSING PERCENT |
|---|---|---|---|---|---|---|---|
| 180 | 1006.1 | 606.8 | 2.40 | 2.74 | 2.37 | 8.76 | 60.3 |
| 190 | 1029.9 | 622.1 | 2.34 | 2.72 | 2.44 | 8.89 | 60.4 |
| 200 | 1053.0 | 637.2 | 2.29 | 2.70 | 2.51 | 9.02 | 60.5 |
| 210 | 1075.6 | 651.9 | 2.23 | 2.68 | 2.59 | 9.15 | 60.6 |
| 220 | 1097.6 | 666.4 | 2.17 | 2.66 | 2.66 | 9.29 | 60.7 |
| 230 | 1119.0 | 680.6 | 2.11 | 2.63 | 2.74 | 9.44 | 60.8 |
| 240 | 1139.8 | 694.6 | 2.05 | 2.61 | 2.82 | 9.58 | 60.9 |
| 250 | 1160.1 | 708.2 | 1.99 | 2.59 | 2.90 | 9.73 | 61.0 |
| 260 | 1179.7 | 721.5 | 1.93 | 2.56 | 2.98 | 9.88 | 61.2 |
| 270 | 1198.7 | 734.5 | 1.87 | 2.54 | 3.06 | 10.03 | 61.3 |
| 280 | 1217.1 | 747.3 | 1.81 | 2.51 | 3.14 | 10.18 | 61.4 |
| 290 | 1235.0 | 759.7 | 1.75 | 2.49 | 3.23 | 10.34 | 61.5 |
| 300 | 1252.3 | 771.8 | 1.70 | 2.46 | 3.31 | 10.49 | 61.6 |
| 310 | 1269.0 | 783.6 | 1.64 | 2.43 | 3.40 | 10.65 | 61.8 |
| 320 | 1285.1 | 795.1 | 1.58 | 2.41 | 3.48 | 10.81 | 61.9 |

| DAYS ON FEED | PCT RETAIL PROD .3 FAT | PCT FAT TRIM .3 FAT | PCT FAT IN EMPTY BODY | PCT PROTEIN IN EMPTY BODY | CUM ENERGY MAINTENANCE | CUM ENERGY GAIN |
|---|---|---|---|---|---|---|
| 180 | 69.0 | 17.7 | 24.3 | 18.3 | 1095.0 | 767.5 |
| 190 | 68.7 | 18.0 | 25.0 | 18.1 | 1171.7 | 822.3 |
| 200 | 68.4 | 18.4 | 25.7 | 17.9 | 1249.8 | 878.5 |
| 210 | 68.1 | 18.8 | 26.5 | 17.7 | 1329.2 | 936.0 |
| 220 | 67.7 | 19.2 | 27.3 | 17.5 | 1409.9 | 994.8 |
| 230 | 67.4 | 19.7 | 28.1 | 17.4 | 1491.7 | 1054.8 |
| 240 | 67.1 | 20.1 | 28.9 | 17.2 | 1574.7 | 1116.0 |
| 250 | 66.7 | 20.5 | 29.8 | 17.0 | 1658.8 | 1178.3 |
| 260 | 66.4 | 21.0 | 30.6 | 16.8 | 1744.0 | 1241.5 |
| 270 | 66.0 | 21.4 | 31.5 | 16.6 | 1830.3 | 1305.7 |
| 280 | 65.7 | 21.9 | 32.4 | 16.4 | 1917.5 | 1370.7 |
| 290 | 65.3 | 22.3 | 33.3 | 16.2 | 2005.8 | 1436.4 |
| 300 | 64.9 | 22.8 | 34.1 | 16.0 | 2095.0 | 1502.7 |
| 310 | 64.6 | 23.2 | 35.0 | 15.9 | 2185.1 | 1569.5 |
| 320 | 64.2 | 23.7 | 35.9 | 15.7 | 2276.1 | 1636.6 |

## CHHE

BIRTH WEIGHT = 84.1
MATURE WEIGHT = 1494.4

AO = 0.0142670
ALPHA = 0.0048229

| DAYS ON FEED | LIVE WEIGHT | HOT CARCASS WEIGHT | MARGINAL GAIN | AVERAGE DAILY GAIN | YIELD GRADE | QUALITY GRADE | DRESSING PERCENT |
|---|---|---|---|---|---|---|---|
| 180 | 1009.2 | 610.6 | 2.30 | 2.69 | 1.96 | 8.53 | 60.5 |
| 190 | 1032.0 | 625.0 | 2.24 | 2.66 | 2.00 | 8.62 | 60.6 |
| 200 | 1054.1 | 639.2 | 2.18 | 2.64 | 2.05 | 8.71 | 60.6 |
| 210 | 1075.7 | 653.0 | 2.12 | 2.62 | 2.10 | 8.80 | 60.7 |
| 220 | 1096.6 | 666.5 | 2.06 | 2.59 | 2.16 | 8.90 | 60.8 |
| 230 | 1116.9 | 679.7 | 2.00 | 2.57 | 2.21 | 8.99 | 60.9 |
| 240 | 1136.7 | 692.6 | 1.94 | 2.54 | 2.26 | 9.09 | 60.9 |
| 250 | 1155.8 | 705.1 | 1.88 | 2.52 | 2.31 | 9.19 | 61.0 |
| 260 | 1174.3 | 717.3 | 1.82 | 2.49 | 2.37 | 9.29 | 61.1 |
| 270 | 1192.2 | 729.1 | 1.76 | 2.46 | 2.42 | 9.39 | 61.2 |
| 280 | 1209.6 | 740.7 | 1.70 | 2.44 | 2.48 | 9.49 | 61.2 |
| 290 | 1226.3 | 751.9 | 1.64 | 2.41 | 2.53 | 9.59 | 61.3 |
| 300 | 1242.5 | 762.7 | 1.59 | 2.38 | 2.58 | 9.69 | 61.4 |
| 310 | 1258.1 | 773.3 | 1.53 | 2.36 | 2.64 | 9.79 | 61.5 |
| 320 | 1273.2 | 783.5 | 1.48 | 2.33 | 2.69 | 9.89 | 61.5 |

| DAYS ON FEED | PCT RETAIL PROD .3 FAT | PCT FAT TRIM .3 FAT | PCT FAT IN EMPTY BODY | PCT PROTEIN IN EMPTY BODY | CUM ENERGY MAINTENANCE | CUM ENERGY GAIN |
|---|---|---|---|---|---|---|
| 180 | 70.8 | 15.4 | 21.9 | 18.8 | 1105.3 | 695.0 |
| 190 | 70.6 | 15.7 | 22.4 | 18.7 | 1182.2 | 739.4 |
| 200 | 70.4 | 15.9 | 22.9 | 18.6 | 1260.4 | 784.3 |
| 210 | 70.2 | 16.2 | 23.4 | 18.5 | 1339.8 | 829.6 |
| 220 | 69.9 | 16.5 | 24.0 | 18.3 | 1420.4 | 875.3 |
| 230 | 69.7 | 16.8 | 24.5 | 18.2 | 1502.2 | 921.4 |
| 240 | 69.5 | 17.1 | 25.1 | 18.1 | 1585.0 | 967.8 |
| 250 | 69.3 | 17.3 | 25.6 | 17.9 | 1668.9 | 1014.4 |
| 260 | 69.0 | 17.6 | 26.2 | 17.8 | 1753.8 | 1061.2 |
| 270 | 68.8 | 17.9 | 26.8 | 17.7 | 1839.8 | 1108.2 |
| 280 | 68.5 | 18.2 | 27.3 | 17.5 | 1926.7 | 1155.2 |
| 290 | 68.3 | 18.5 | 27.9 | 17.4 | 2014.5 | 1202.3 |
| 300 | 68.1 | 18.8 | 28.5 | 17.3 | 2103.2 | 1249.3 |
| 310 | 67.8 | 19.1 | 29.1 | 17.1 | 2192.7 | 1296.1 |
| 320 | 67.6 | 19.4 | 29.6 | 17.0 | 2283.1 | 1342.8 |

# CHAN

BIRTH WEIGHT = 87.7
MATURE WEIGHT = 1377.6

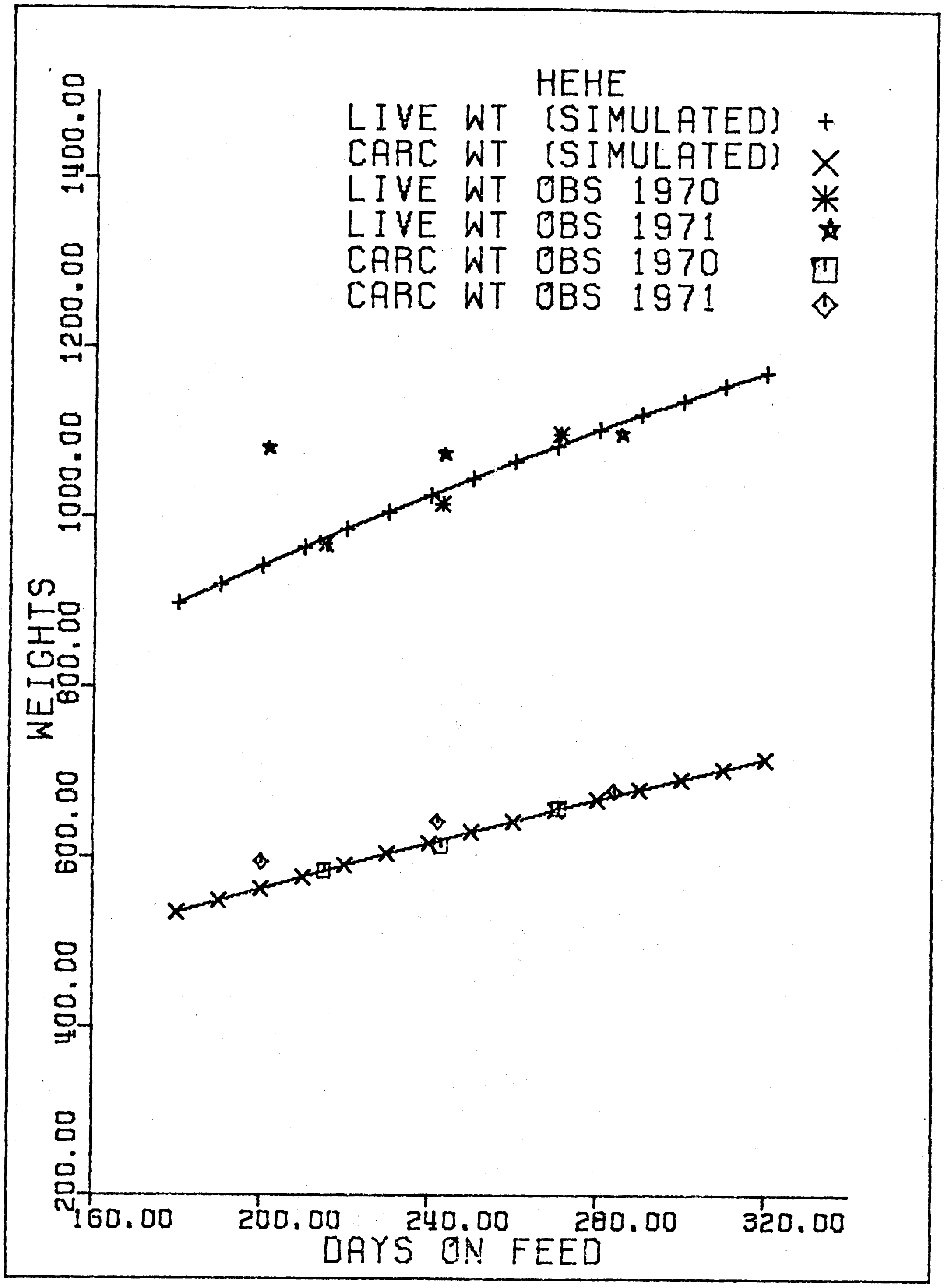
AO = 0.0134670
ALPHA = 0.0045778

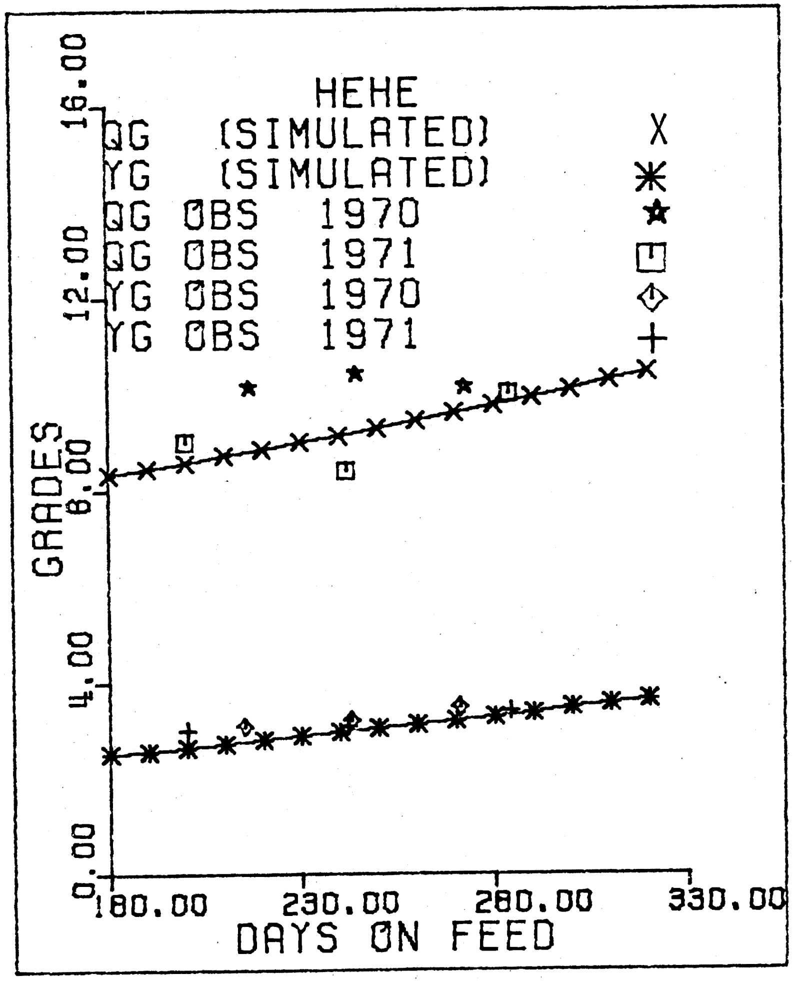
| DAYS ON FEED | LIVE WEIGHT | HOT CARCASS WEIGHT | MARGINAL GAIN | AVERAGE DAILY GAIN | YIELD GRADE | QUALITY GRADE | DRESSING PERCENT |
|---|---|---|---|---|---|---|---|
| 180 | 991.4 | 605.3 | 2.34 | 2.66 | 2.19 | 9.19 | 61.1 |
| 190 | 1014.6 | 620.4 | 2.29 | 2.64 | 2.25 | 9.30 | 61.1 |
| 200 | 1037.3 | 635.2 | 2.24 | 2.62 | 2.31 | 9.42 | 61.2 |
| 210 | 1059.4 | 649.7 | 2.18 | 2.60 | 2.38 | 9.54 | 61.3 |
| 220 | 1080.9 | 663.9 | 2.13 | 2.58 | 2.45 | 9.67 | 61.4 |
| 230 | 1101.9 | 677.9 | 2.07 | 2.56 | 2.52 | 9.79 | 61.5 |
| 240 | 1122.4 | 691.6 | 2.01 | 2.54 | 2.59 | 9.92 | 61.6 |
| 250 | 1142.3 | 705.0 | 1.96 | 2.51 | 2.66 | 10.06 | 61.7 |
| 260 | 1161.6 | 718.1 | 1.90 | 2.49 | 2.73 | 10.19 | 61.8 |
| 270 | 1180.4 | 730.9 | 1.85 | 2.47 | 2.80 | 10.33 | 61.9 |
| 280 | 1198.6 | 743.5 | 1.79 | 2.44 | 2.88 | 10.46 | 62.0 |
| 290 | 1216.2 | 755.7 | 1.74 | 2.42 | 2.95 | 10.60 | 62.1 |
| 300 | 1233.4 | 767.7 | 1.68 | 2.40 | 3.03 | 10.74 | 62.2 |
| 310 | 1249.9 | 779.3 | 1.63 | 2.37 | 3.11 | 10.88 | 62.3 |
| 320 | 1266.0 | 790.7 | 1.58 | 2.35 | 3.18 | 11.03 | 62.5 |

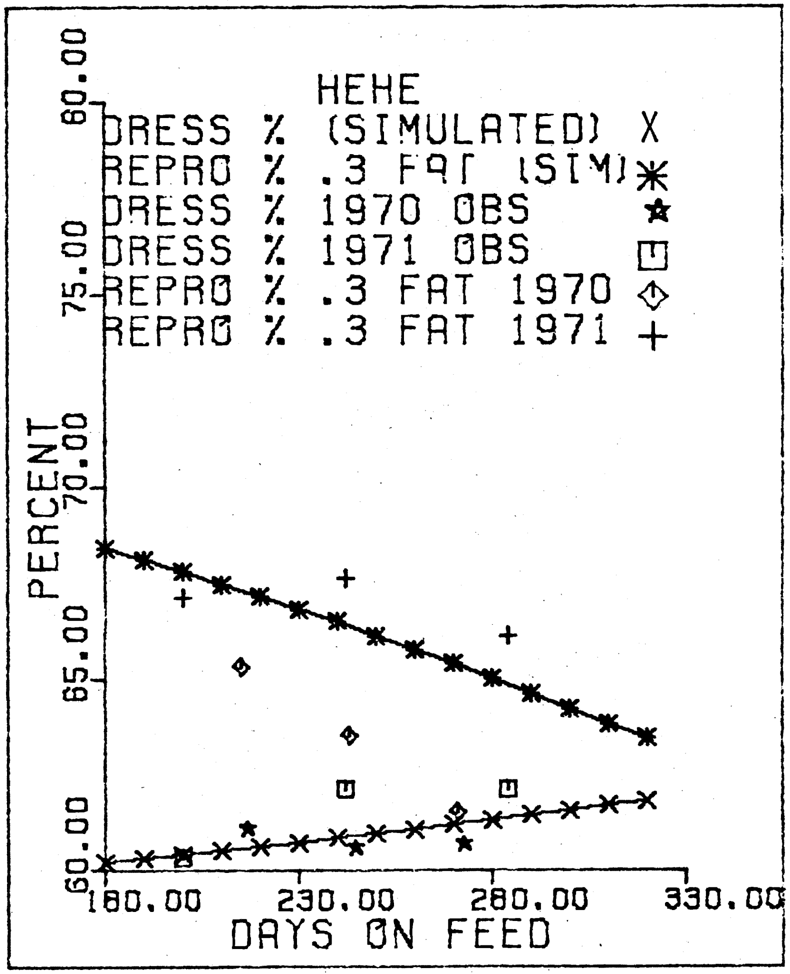
| DAYS ON FEED | PCT RETAIL PROD .3 FAT | PCT FAT TRIM .3 FAT | PCT FAT IN EMPTY BODY | PCT PROTEIN IN EMPTY BODY | CUM ENERGY MAINTENANCE | CUM ENERGY GAIN |
|---|---|---|---|---|---|---|
| 180 | 69.8 | 16.7 | 23.4 | 18.5 | 1086.6 | 733.6 |
| 190 | 69.5 | 17.0 | 24.1 | 18.3 | 1162.6 | 784.7 |
| 200 | 69.3 | 17.3 | 24.8 | 18.1 | 1239.8 | 836.9 |
| 210 | 69.0 | 17.7 | 25.4 | 18.0 | 1318.3 | 890.3 |
| 220 | 68.7 | 18.1 | 26.1 | 17.8 | 1398.0 | 944.7 |
| 230 | 68.4 | 18.4 | 26.9 | 17.6 | 1478.9 | 1000.2 |
| 240 | 68.1 | 18.8 | 27.6 | 17.5 | 1560.9 | 1056.7 |
| 250 | 67.8 | 19.2 | 28.4 | 17.3 | 1644.1 | 1114.1 |
| 260 | 67.4 | 19.6 | 29.1 | 17.1 | 1728.3 | 1172.3 |
| 270 | 67.1 | 20.0 | 29.9 | 17.0 | 1813.6 | 1231.4 |
| 280 | 66.8 | 20.4 | 30.7 | 16.8 | 1899.8 | 1291.1 |
| 290 | 66.5 | 20.8 | 31.5 | 16.6 | 1987.1 | 1351.5 |
| 300 | 66.1 | 21.2 | 32.3 | 16.4 | 2075.3 | 1412.4 |
| 310 | 65.8 | 21.7 | 33.1 | 16.3 | 2164.3 | 1473.8 |
| 320 | 65.5 | 22.1 | 33.9 | 16.1 | 2254.3 | 1535.4 |

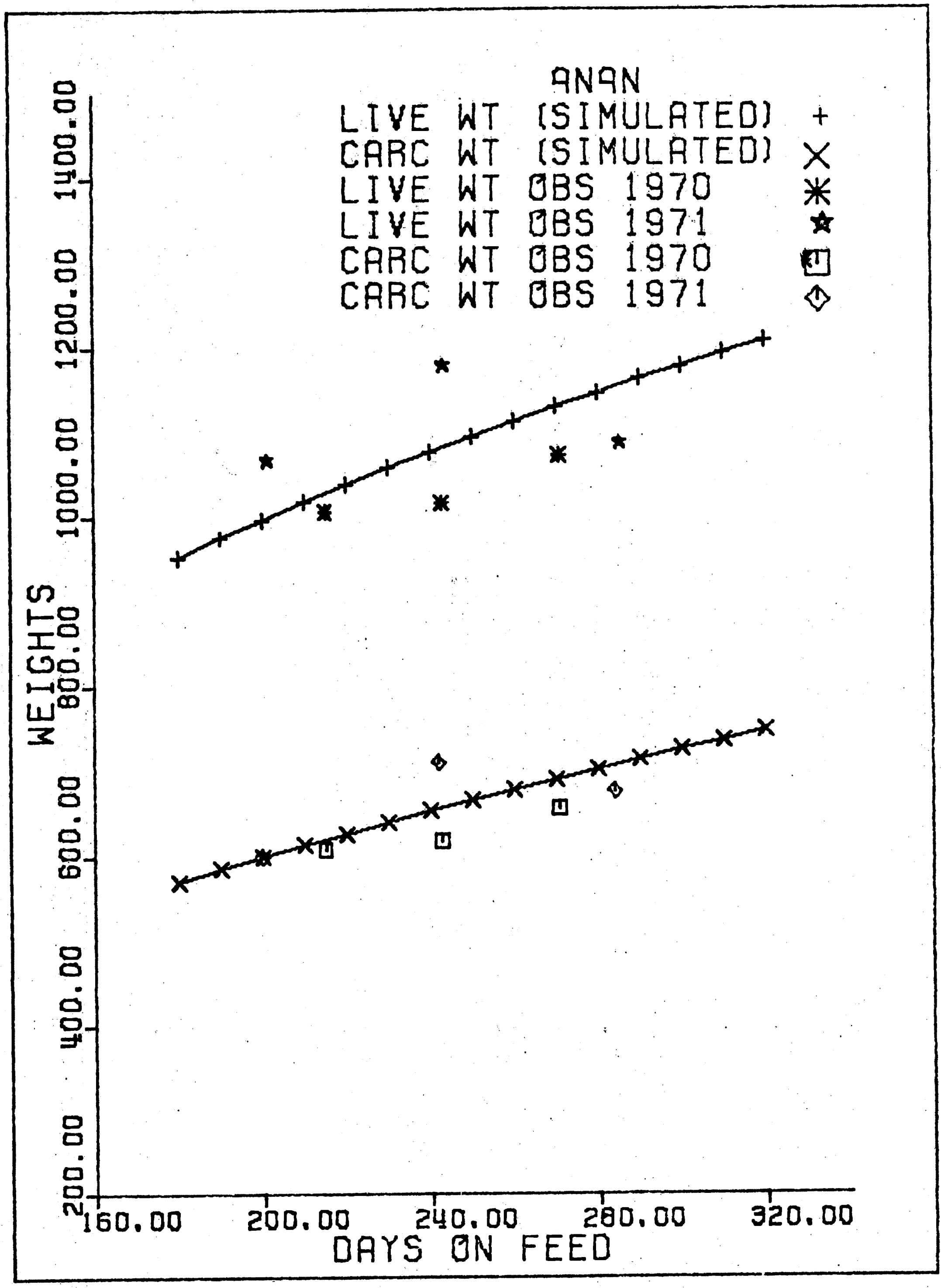
# APPENDIX B

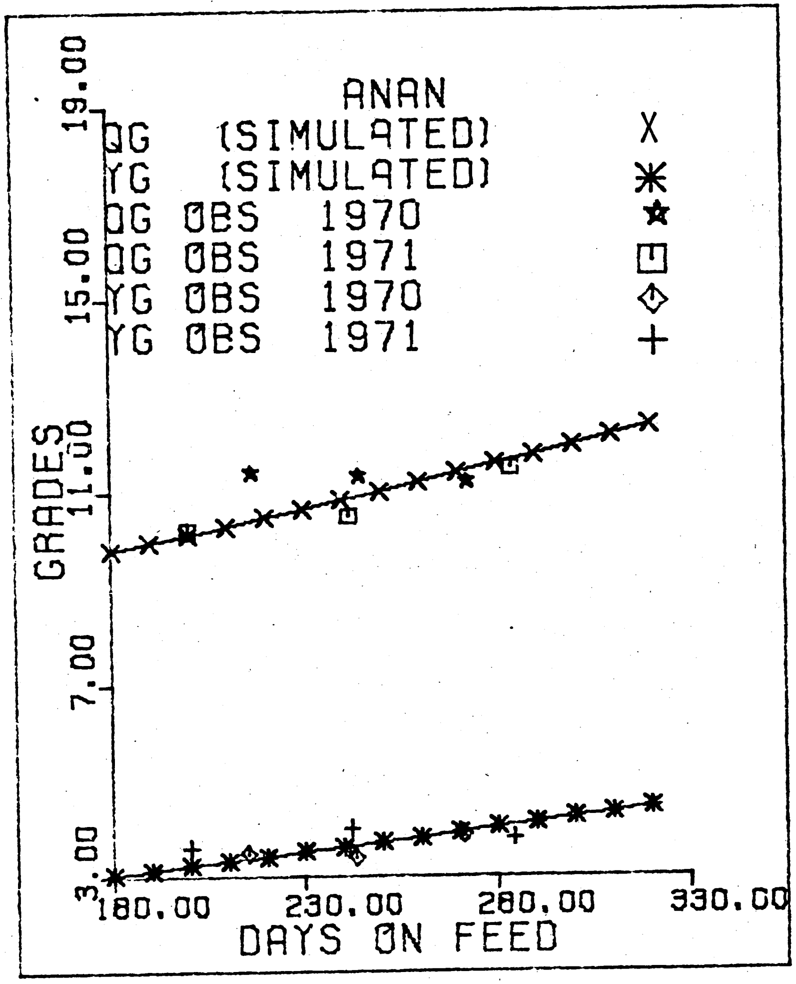
# COMPUTER PLOTS OF ACTUAL AND SIMULATED PHYSICAL ATTRIBUTES OF FOURTEEN BREED-TYPES VERSUS DAYS ON FEED AS GENERATED FROM BEEFSIM

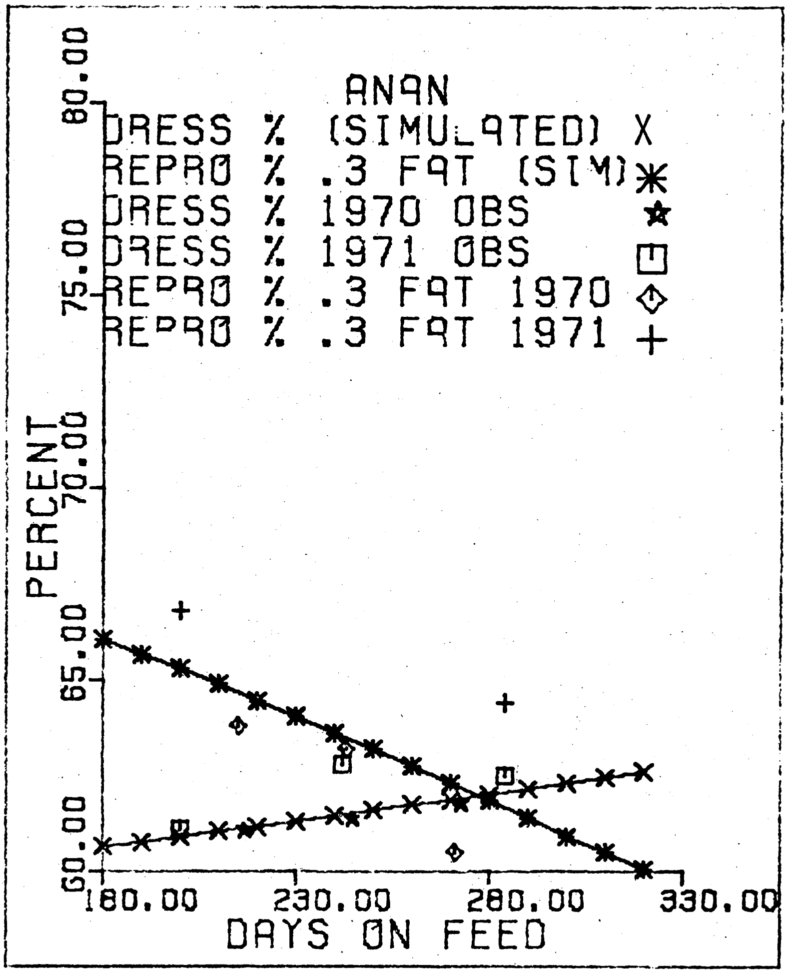

HEHE
LIVE WT (SIMULATED) +
CARC WT (SIMULATED) ×
LIVE WT ØBS 1970 ✱
LIVE WT ØBS 1971 ★
CARC WT ØBS 1970 □
CARC WT ØBS 1971 ◇
WEIGHTS
200.00
400.00
600.00
800.00
1000.00
1200.00
1400.00
160.00
200.00
240.00
280.00
320.00
DAYS ØN FEED

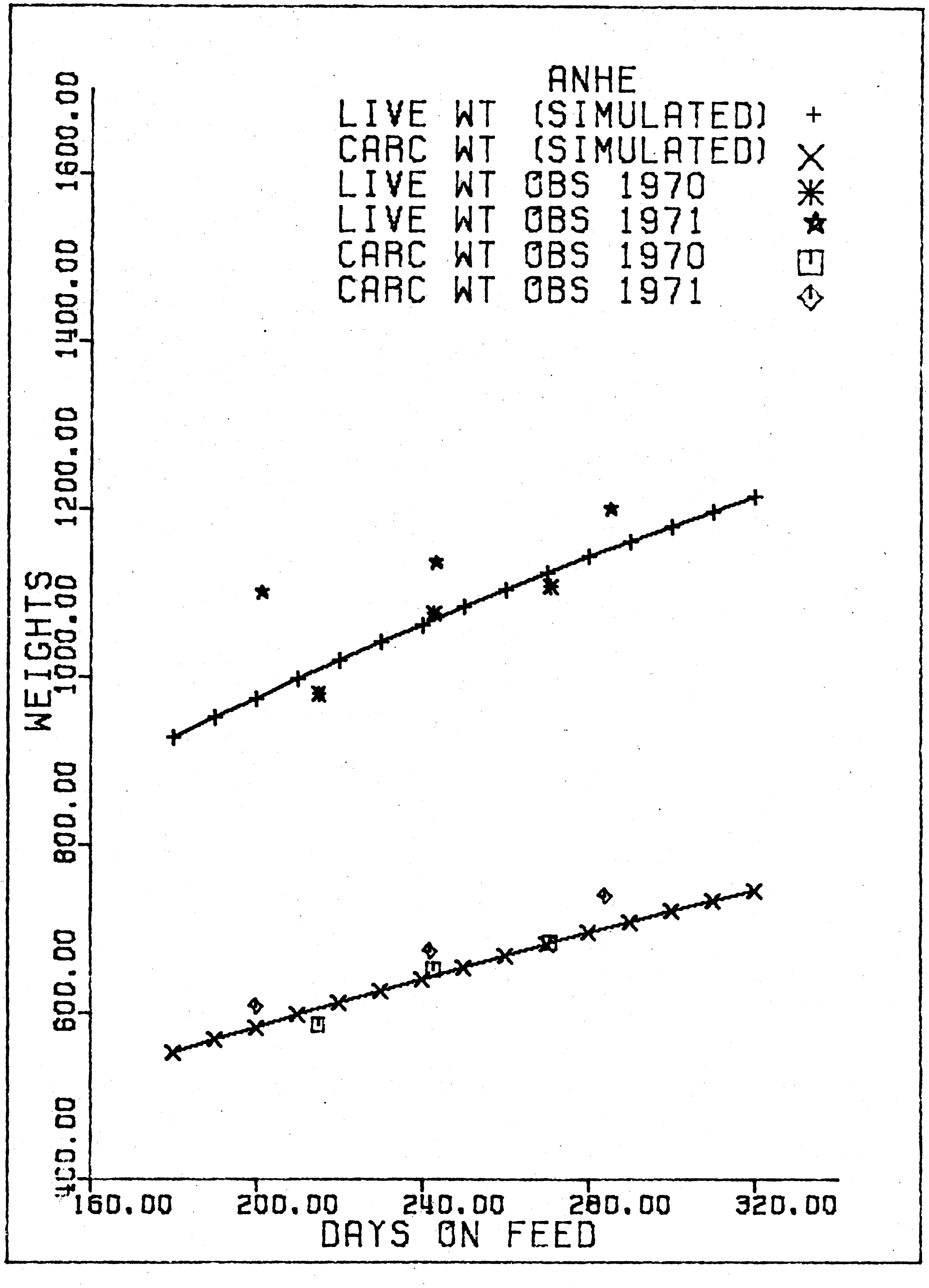

HEHE
QG (SIMULATED) X
YG (SIMULATED) ✳
QG OBS 1970 ★
QG OBS 1971 ⊡
YG OBS 1970 ◇
YG OBS 1971 +
GRADES
0.00
4.00
8.00
12.00
16.00
180.00
230.00
280.00
330.00
DAYS ON FEED

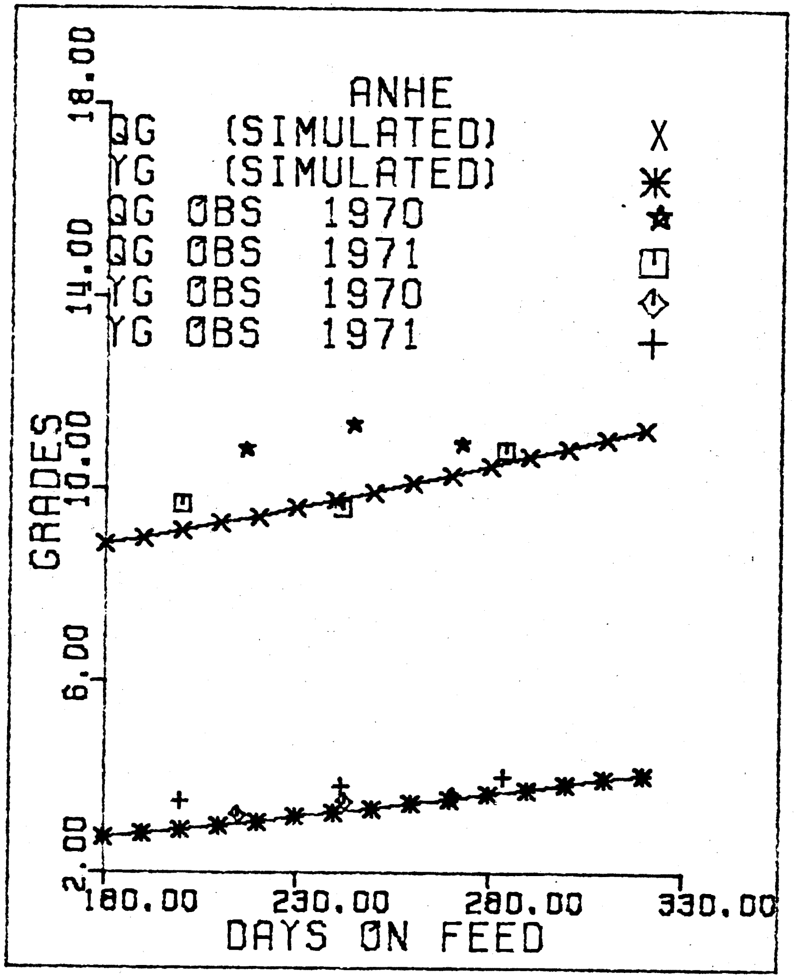

HEHE
DRESS % (SIMULATED) X
REPRO % .3 FAT (SIM) ✳
DRESS % 1970 OBS ★
DRESS % 1971 OBS ⊡
REPRO % .3 FAT 1970 ◇
REPRO % .3 FAT 1971 +
PERCENT
60.00
65.00
70.00
75.00
80.00
180.00
230.00
280.00
330.00
DAYS ON FEED

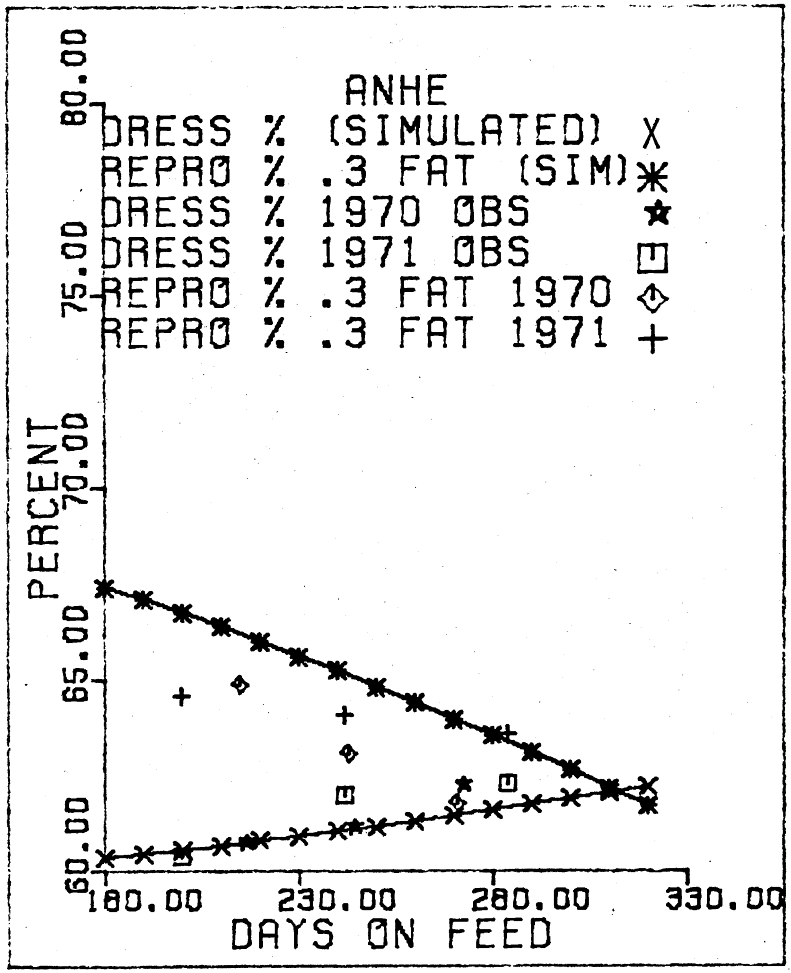

ANAN
LIVE WT (SIMULATED) +
CARC WT (SIMULATED) ×
LIVE WT OBS 1970 ✳
LIVE WT OBS 1971 ★
CARC WT OBS 1970 ☐
CARC WT OBS 1971 ◇
WEIGHTS
200.00
400.00
600.00
800.00
1000.00
1200.00
1400.00
160.00
200.00
240.00
280.00
320.00
DAYS ON FEED

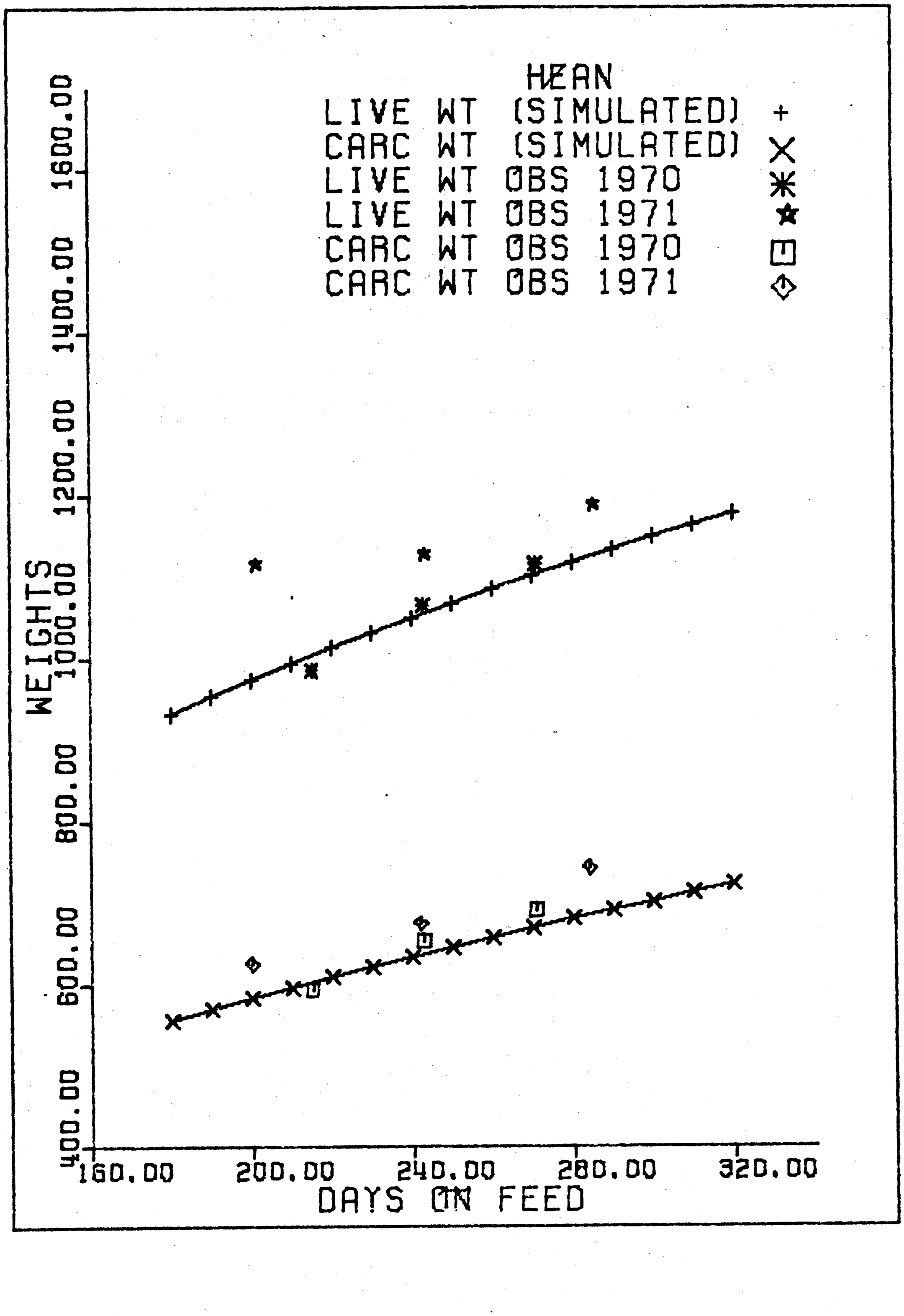

ANAN
QG (SIMULATED) X
YG (SIMULATED) ✳
QG OBS 1970 ★
QG OBS 1971 ⊡
YG OBS 1970 ◇
YG OBS 1971 +
GRADES
3.00
7.00
11.00
15.00
19.00
180.00
230.00
280.00
330.00
DAYS ON FEED

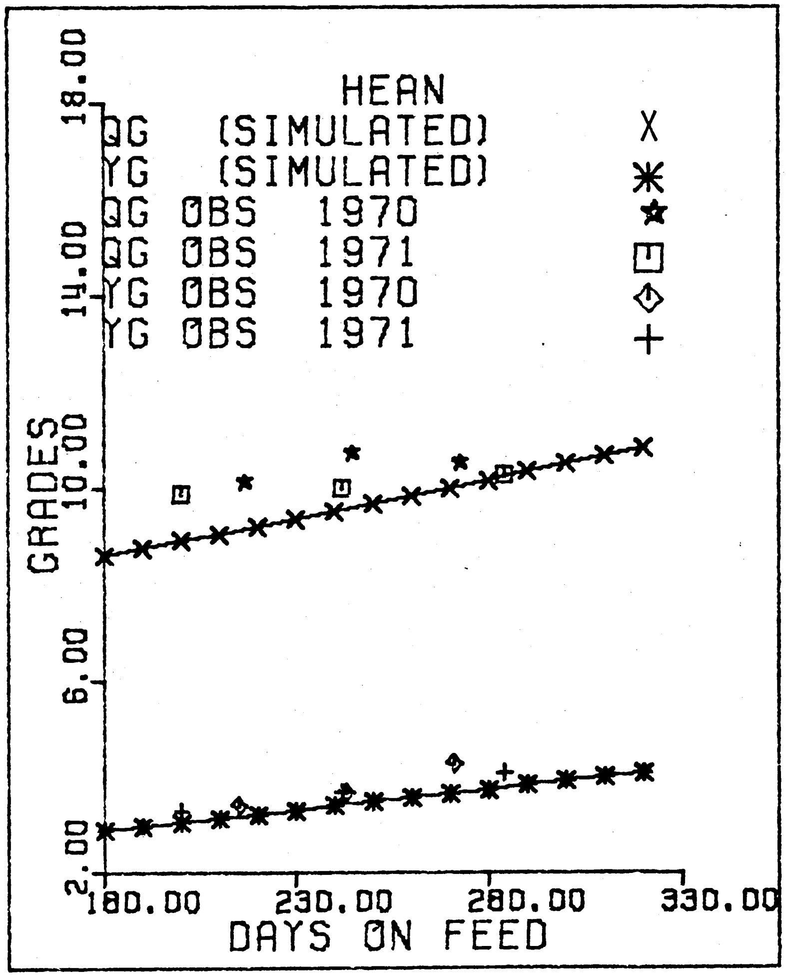

ANAN
DRESS % (SIMULATED) X
REPRO % .3 FAT (SIM) ✳
DRESS % 1970 OBS ★
DRESS % 1971 OBS ⊡
REPRO % .3 FAT 1970 ◇
REPRO % .3 FAT 1971 +
PERCENT
60.00
65.00
70.00
75.00
80.00
180.00
230.00
280.00
330.00
DAYS ON FEED

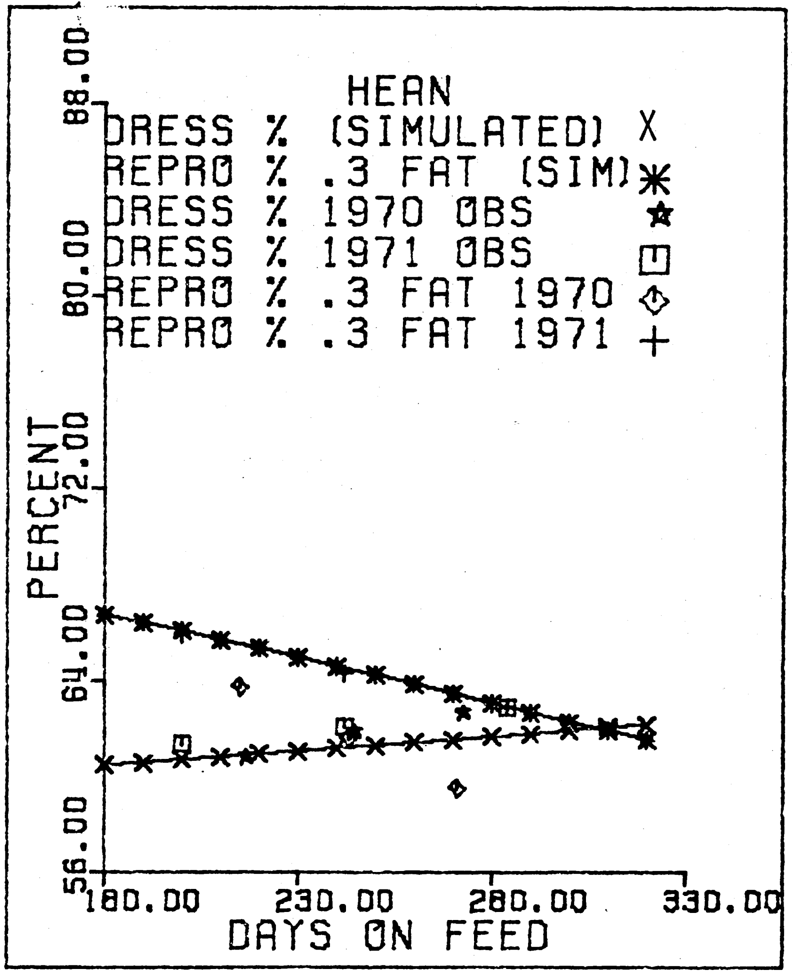

ANHE
LIVE WT (SIMULATED) +
CARC WT (SIMULATED) ×
LIVE WT OBS 1970 ✳
LIVE WT OBS 1971 ★
CARC WT OBS 1970 □
CARC WT OBS 1971 ◇
WEIGHTS
400.00
600.00
800.00
1000.00
1200.00
1400.00
1600.00
160.00
200.00
240.00
280.00
320.00
DAYS ON FEED

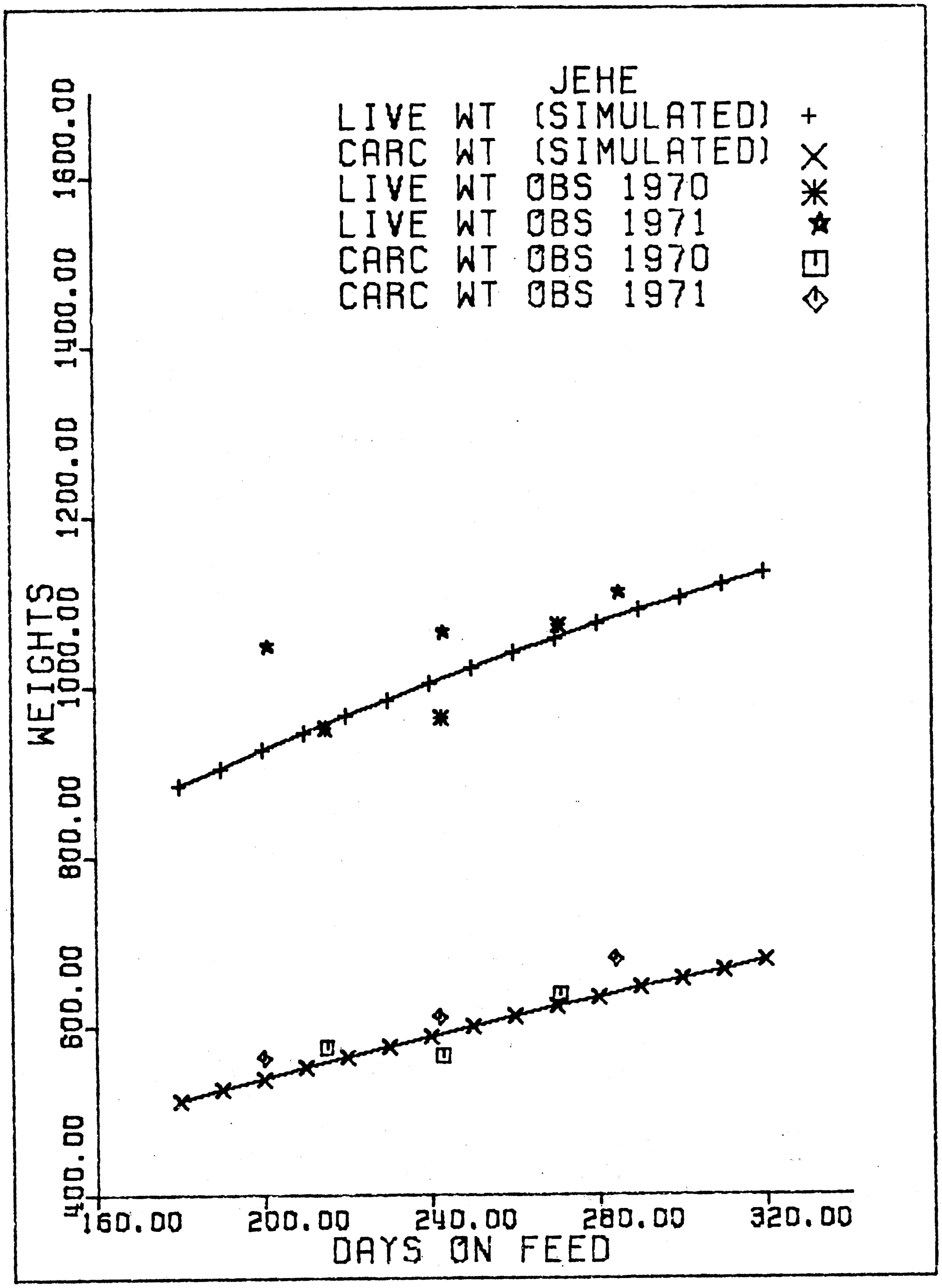

ANHE
QG (SIMULATED) X
YG (SIMULATED) ✳
QG OBS 1970 ★
QG OBS 1971 ⊡
YG OBS 1970 ◇
YG OBS 1971 +
GRADES
2.00
6.00
10.00
14.00
18.00
180.00
230.00
280.00
330.00
DAYS ON FEED

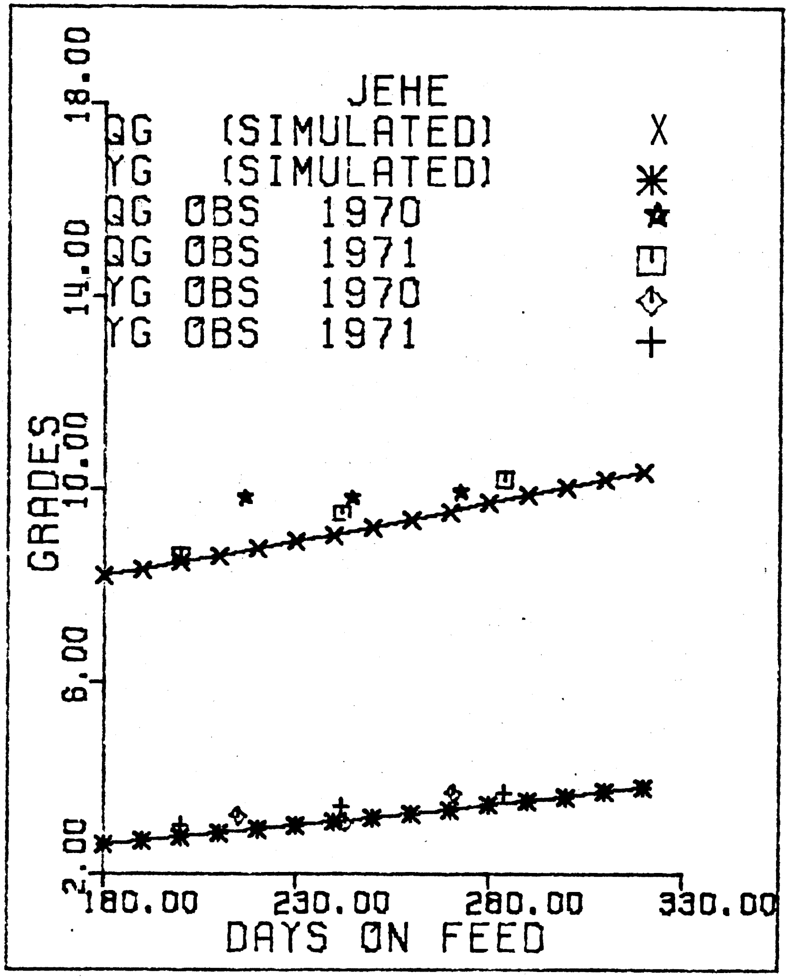

ANHE
DRESS % (SIMULATED) X
REPRO % .3 FAT (SIM) ✳
DRESS % 1970 OBS ★
DRESS % 1971 OBS ⊡
REPRO % .3 FAT 1970 ◇
REPRO % .3 FAT 1971 +
PERCENT
60.00
65.00
70.00
75.00
80.00
180.00
230.00
280.00
330.00
DAYS ON FEED

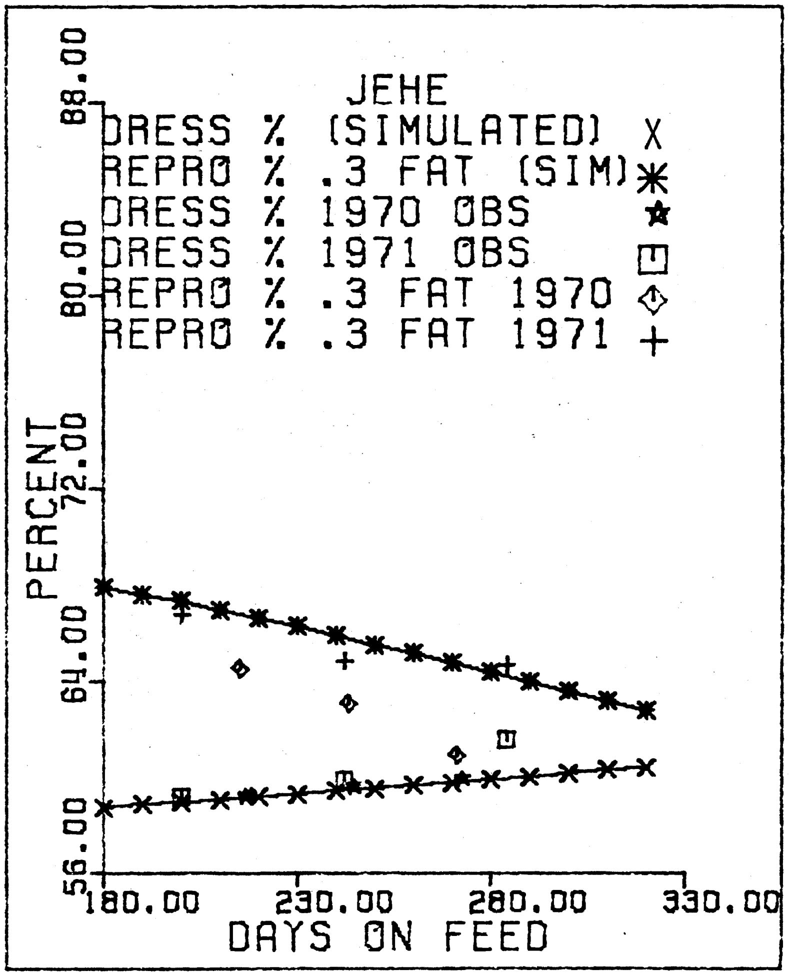

MEAN
LIVE WT (SIMULATED) +
CARC WT (SIMULATED) ×
LIVE WT OBS 1970 ✳
LIVE WT OBS 1971 ★
CARC WT OBS 1970 ⊡
CARC WT OBS 1971 ◇
WEIGHTS
400.00
600.00
800.00
1000.00
1200.00
1400.00
1600.00
160.00
200.00
240.00
280.00
320.00
DAYS ON FEED

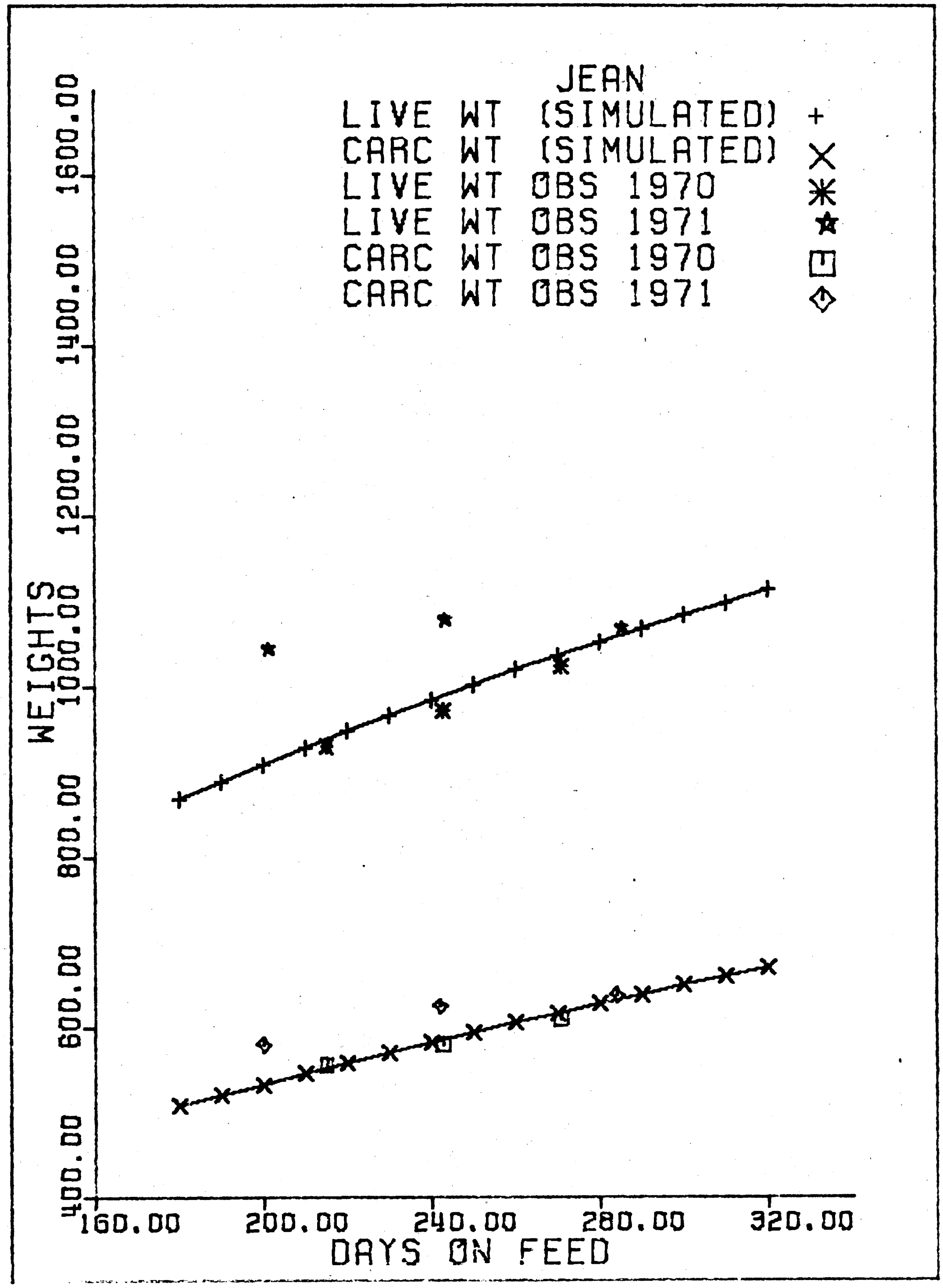

HEAN
QG (SIMULATED) X
YG (SIMULATED) ✳
QG OBS 1970 ✫
QG OBS 1971 ⊡
YG OBS 1970 ◇
YG OBS 1971 +
GRADES
2.00
6.00
10.00
14.00
18.00
180.00
230.00
280.00
330.00
DAYS ON FEED

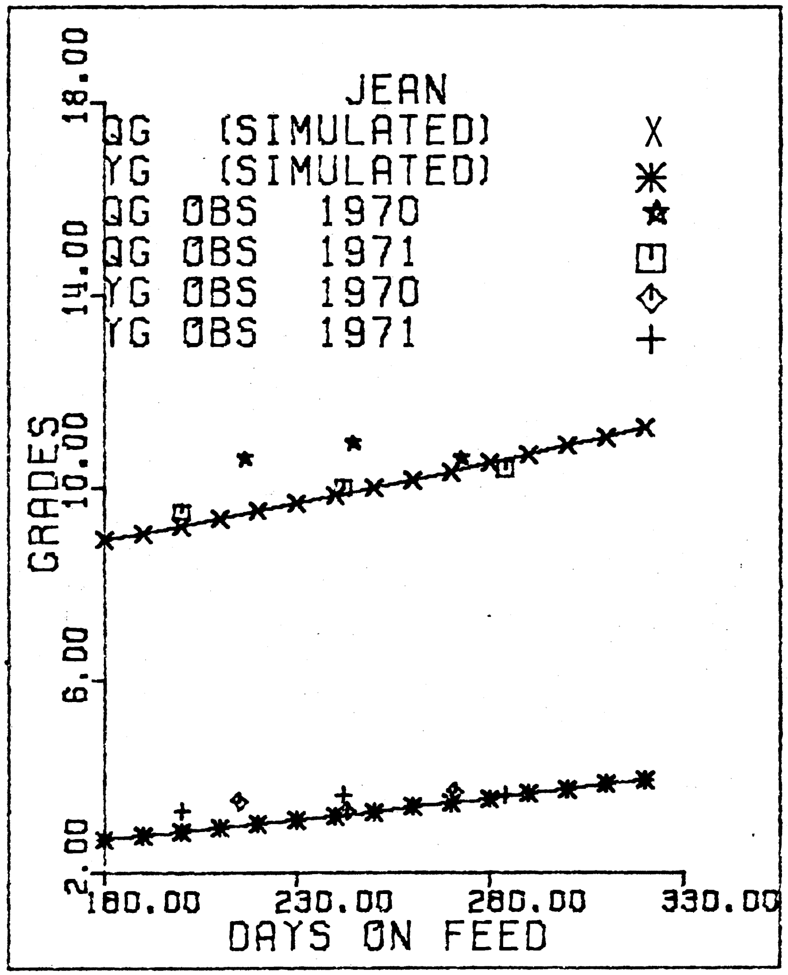

HEAN
DRESS % (SIMULATED) X
REPRO % .3 FAT (SIM) ✳
DRESS % 1970 OBS ✫
DRESS % 1971 OBS ⊡
REPRO % .3 FAT 1970 ◇
REPRO % .3 FAT 1971 +
PERCENT
56.00
64.00
72.00
80.00
88.00
180.00
230.00
280.00
330.00
DAYS ON FEED


JEHE
LIVE WT (SIMULATED) +
CARC WT (SIMULATED) ×
LIVE WT OBS 1970 ✳
LIVE WT OBS 1971 ★
CARC WT OBS 1970 ⊡
CARC WT OBS 1971 ◇
WEIGHTS
400.00
600.00
800.00
1000.00
1200.00
1400.00
1600.00
160.00
200.00
240.00
280.00
320.00
DAYS ON FEED

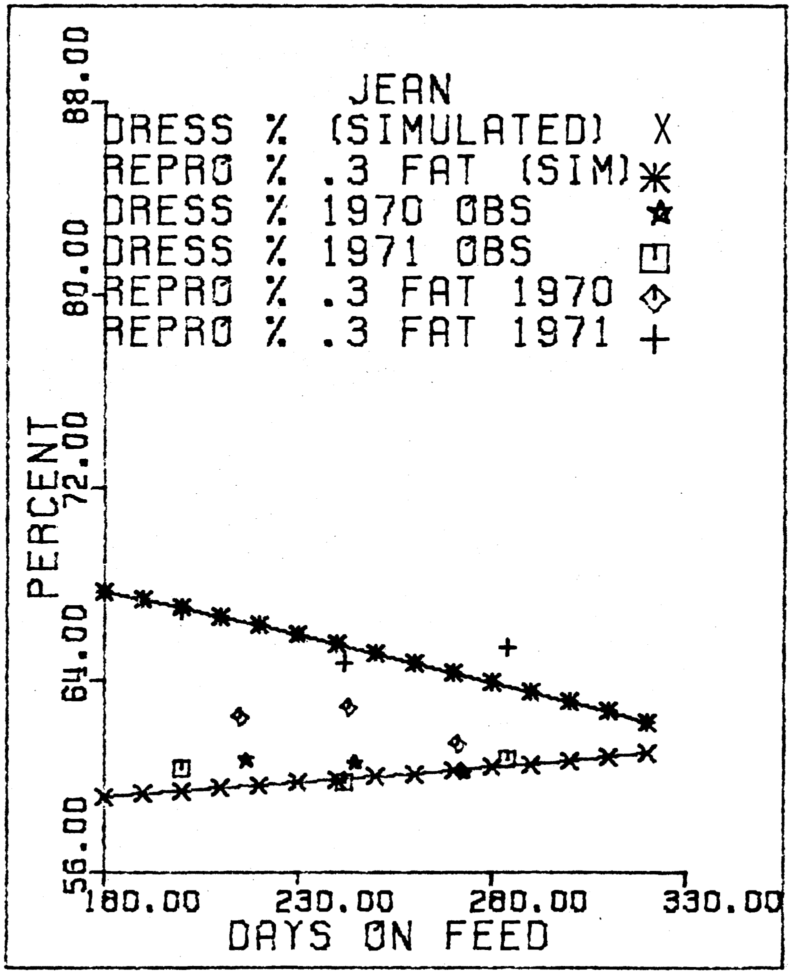

JEHE
QG (SIMULATED) X
YG (SIMULATED) ✳
QG OBS 1970 ★
QG OBS 1971 ⊟
YG OBS 1970 ◇
YG OBS 1971 +
GRADES
2.00
6.00
10.00
14.00
18.00
180.00
230.00
280.00
330.00
DAYS ON FEED


JEHE
DRESS % (SIMULATED) X
REPRO % .3 FAT (SIM) ✳
DRESS % 1970 OBS ★
DRESS % 1971 OBS ⊟
REPRO % .3 FAT 1970 ◇
REPRO % .3 FAT 1971 +
PERCENT
56.00
64.00
72.00
80.00
88.00
180.00
230.00
280.00
330.00
DAYS ON FEED

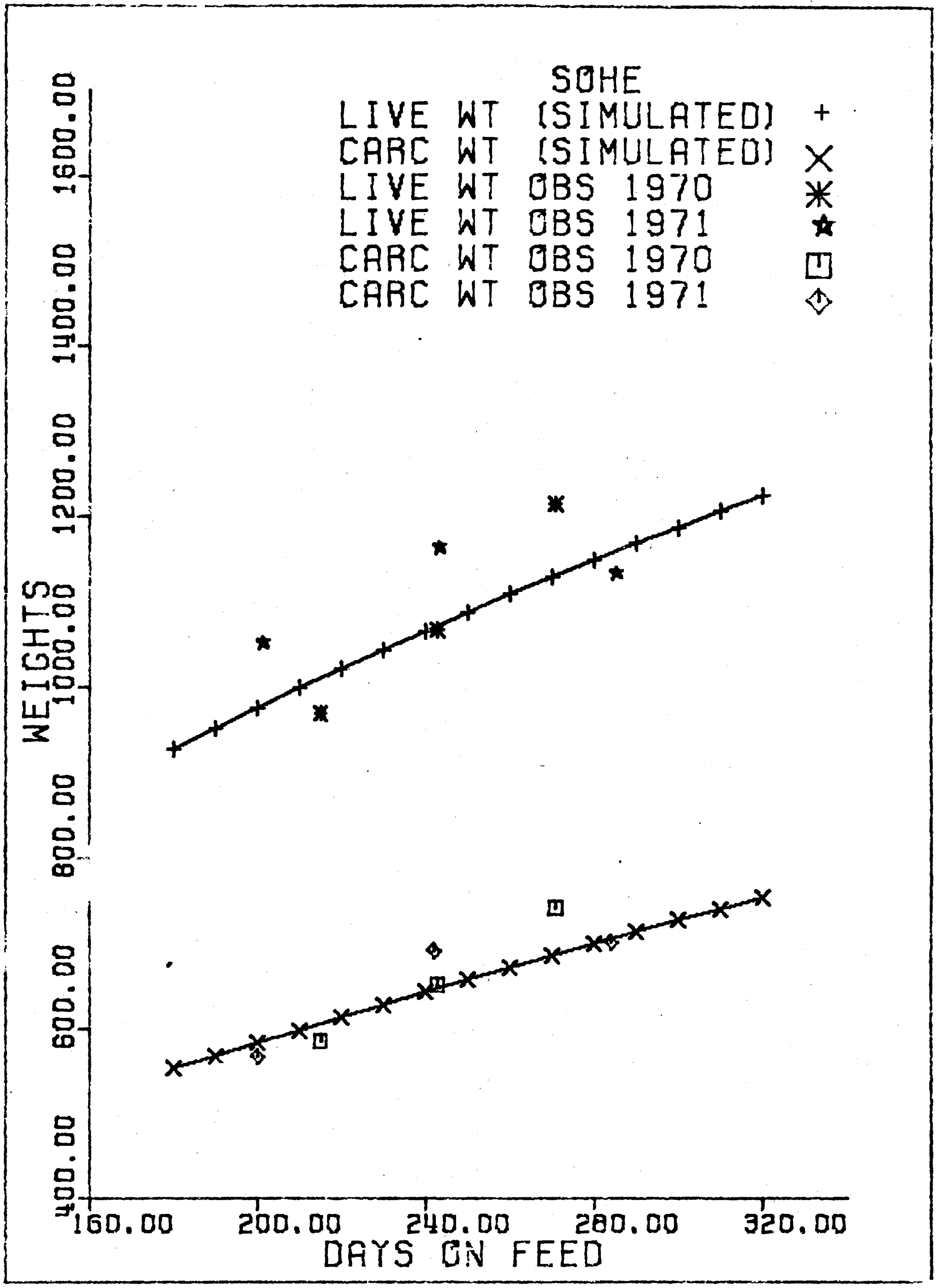

JEAN
LIVE WT (SIMULATED) +
CARC WT (SIMULATED) ×
LIVE WT OBS 1970 ✳
LIVE WT OBS 1971 ★
CARC WT OBS 1970 ☐
CARC WT OBS 1971 ◇
WEIGHTS
400.00
600.00
800.00
1000.00
1200.00
1400.00
1600.00
160.00
200.00
240.00
280.00
320.00
DAYS ON FEED

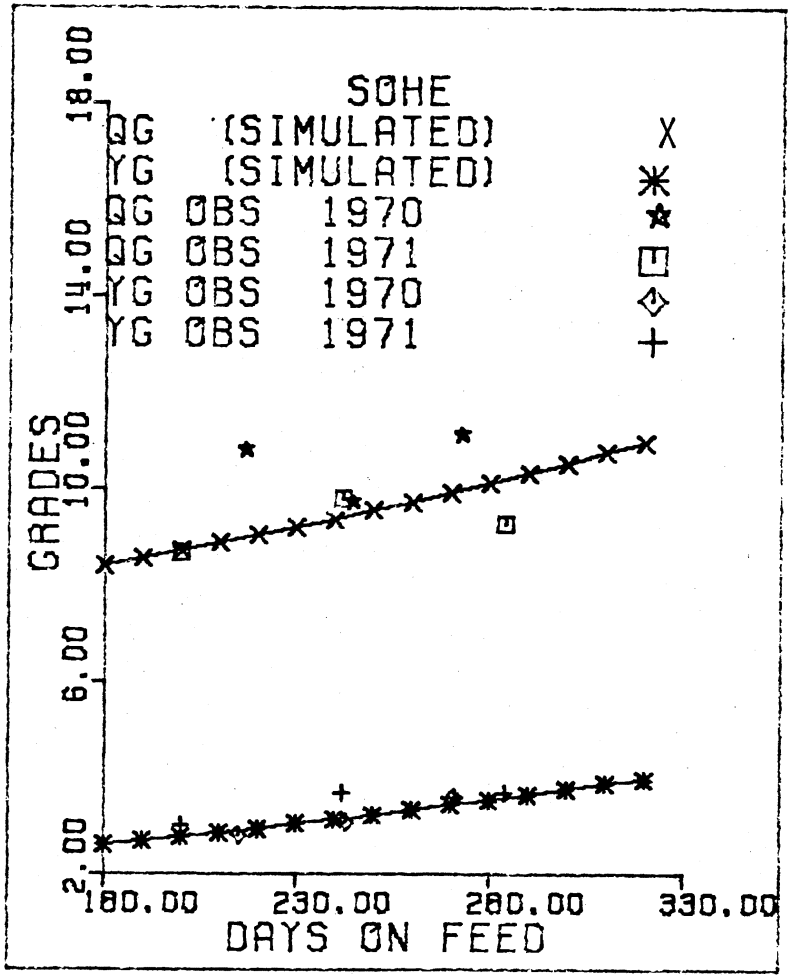


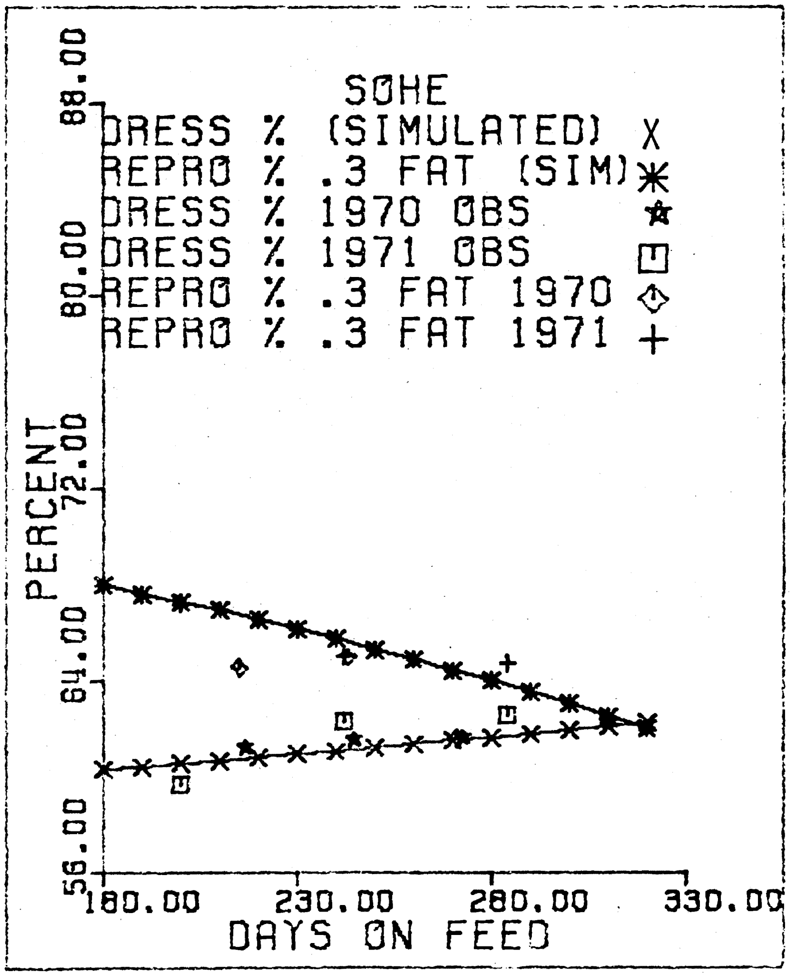
JEAN
QG (SIMULATED) X
YG (SIMULATED) ✳
QG OBS 1970 ★
QG OBS 1971 ⊡
YG OBS 1970 ◇
YG OBS 1971 +
GRADES
2.00
6.00
10.00
14.00
18.00
180.00
230.00
280.00
330.00
DAYS ON FEED

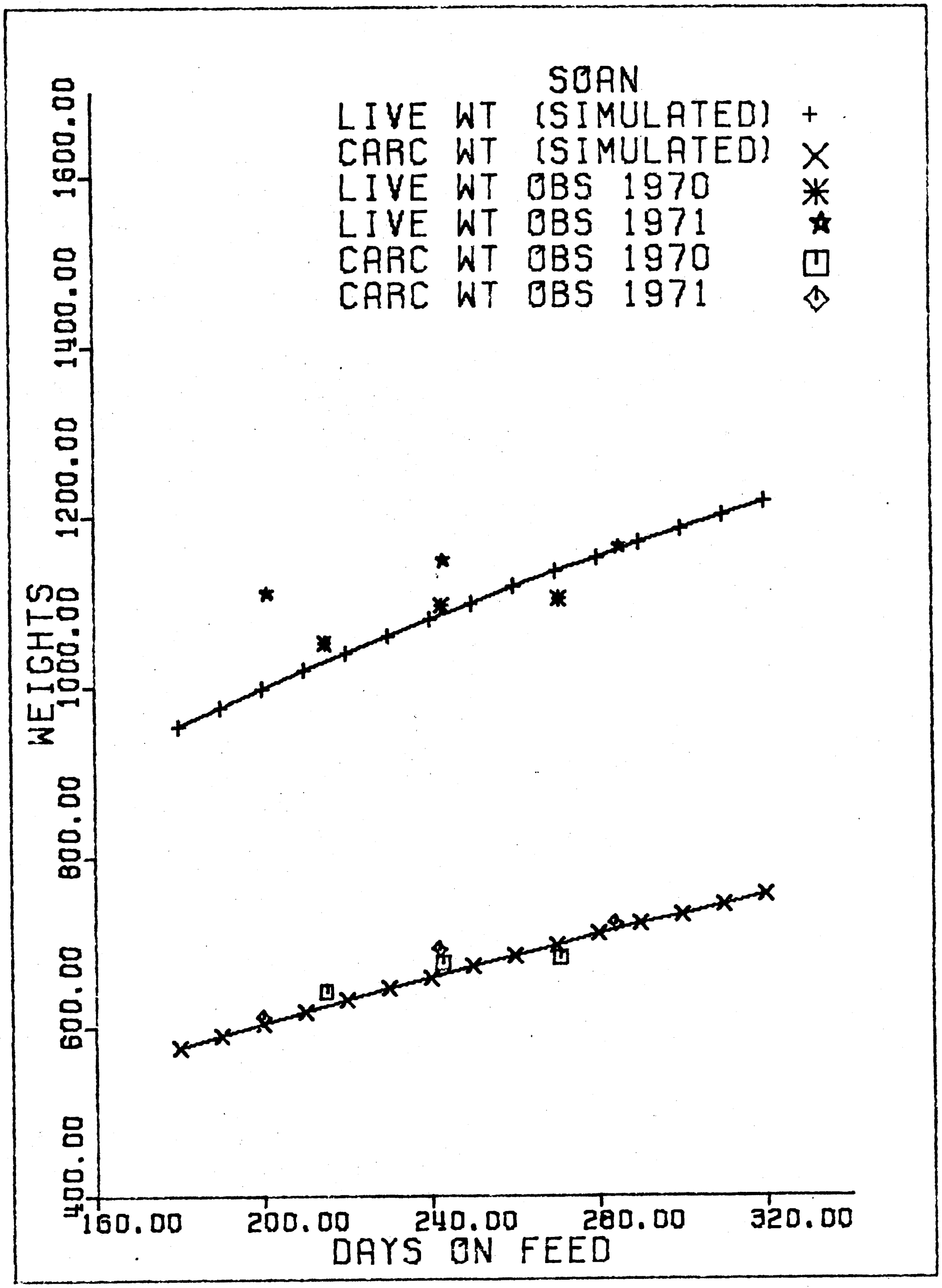


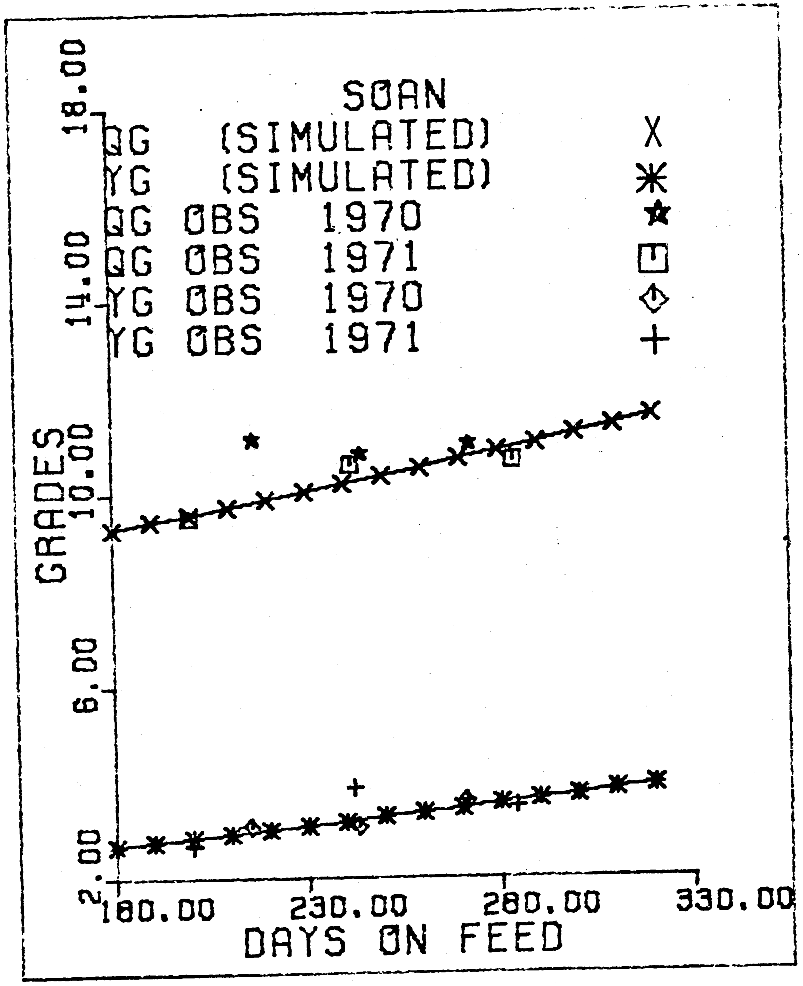
JEAN
DRESS % (SIMULATED) X
REPRO % .3 FAT (SIM) ✳
DRESS % 1970 OBS ★
DRESS % 1971 OBS ⊡
REPRO % .3 FAT 1970 ◇
REPRO % .3 FAT 1971 +
PERCENT
56.00
64.00
72.00
80.00
88.00
180.00
230.00
280.00
330.00
DAYS ON FEED

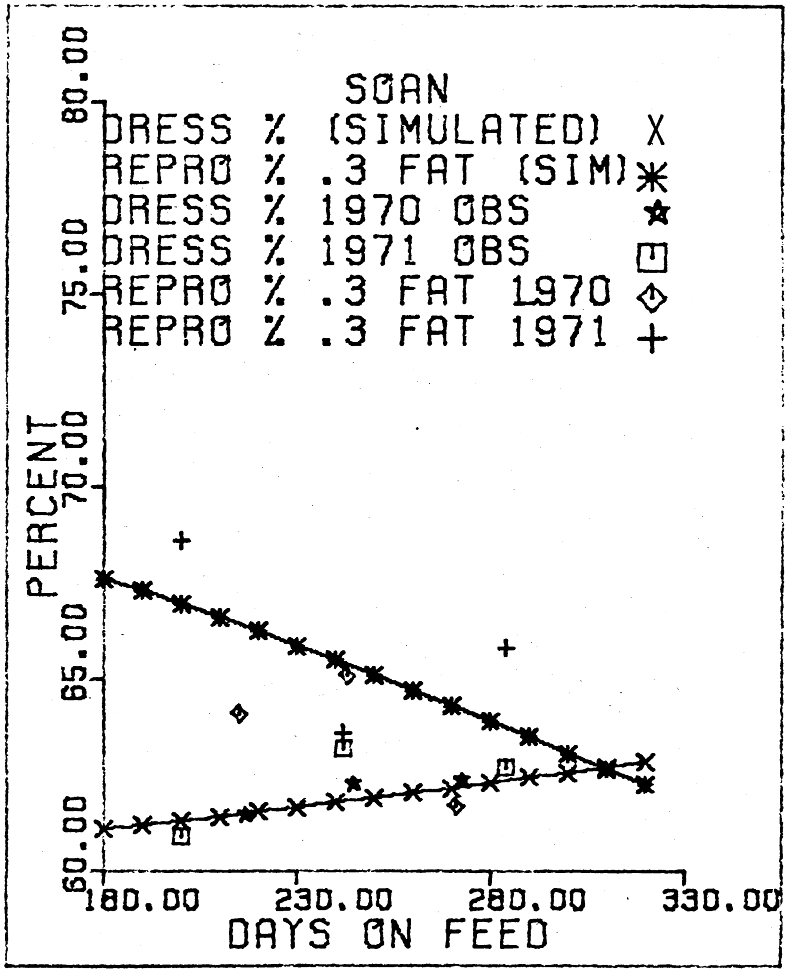

SOHE
LIVE WT (SIMULATED) +
CARC WT (SIMULATED) ×
LIVE WT OBS 1970 ✳
LIVE WT OBS 1971 ★
CARC WT OBS 1970 ⊡
CARC WT OBS 1971 ◇
WEIGHTS
400.00
600.00
800.00
1000.00
1200.00
1400.00
1600.00
160.00
200.00
240.00
280.00
320.00
DAYS ON FEED

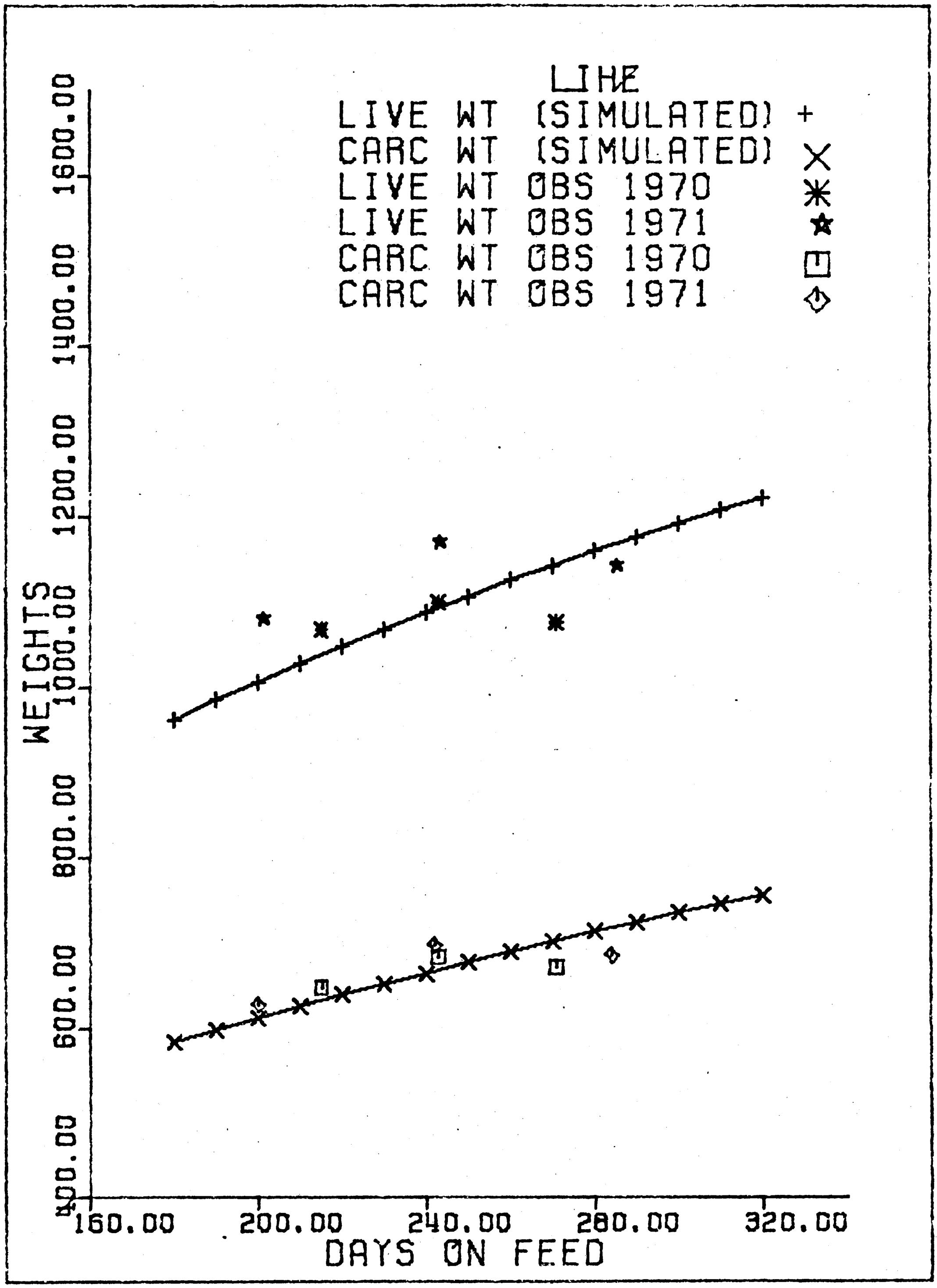

SOHE
QG (SIMULATED) X
YG (SIMULATED) ✳
QG OBS 1970 ★
QG OBS 1971 ⊡
YG OBS 1970 ◇
YG OBS 1971 +
GRADES
2.00
6.00
10.00
14.00
18.00
180.00
230.00
280.00
330.00
DAYS ON FEED

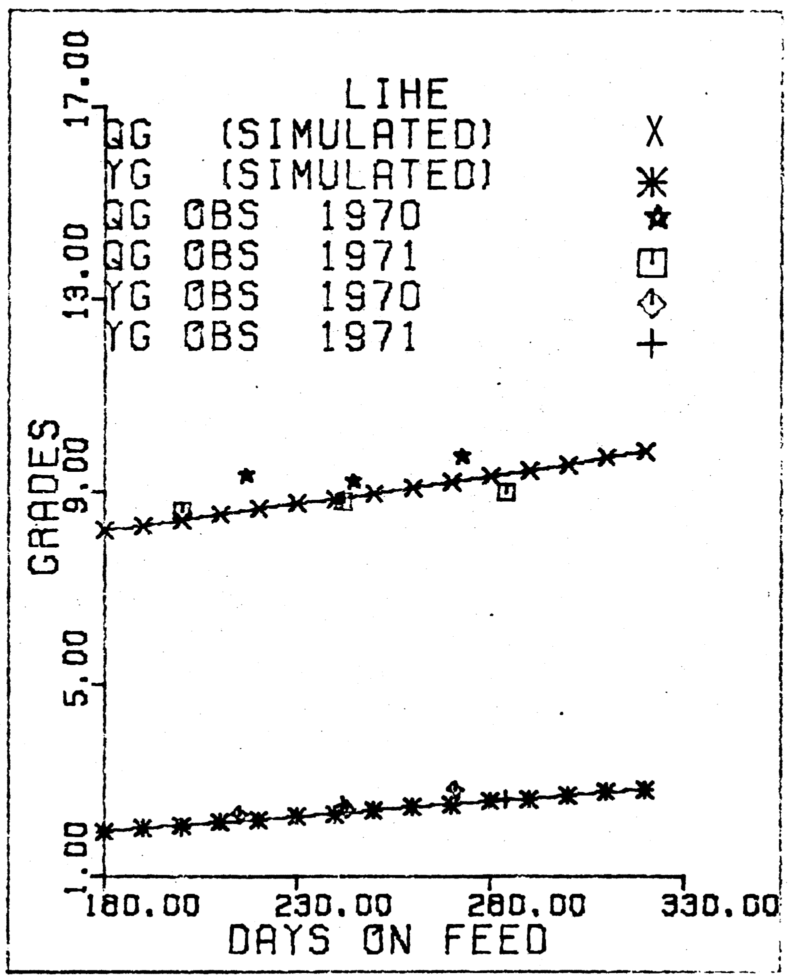

SOHE
DRESS % (SIMULATED) X
REPRO % .3 FAT (SIM) ✳
DRESS % 1970 OBS ★
DRESS % 1971 OBS ⊡
REPRO % .3 FAT 1970 ◇
REPRO % .3 FAT 1971 +
PERCENT
56.00
64.00
72.00
80.00
88.00
180.00
230.00
280.00
330.00
DAYS ON FEED

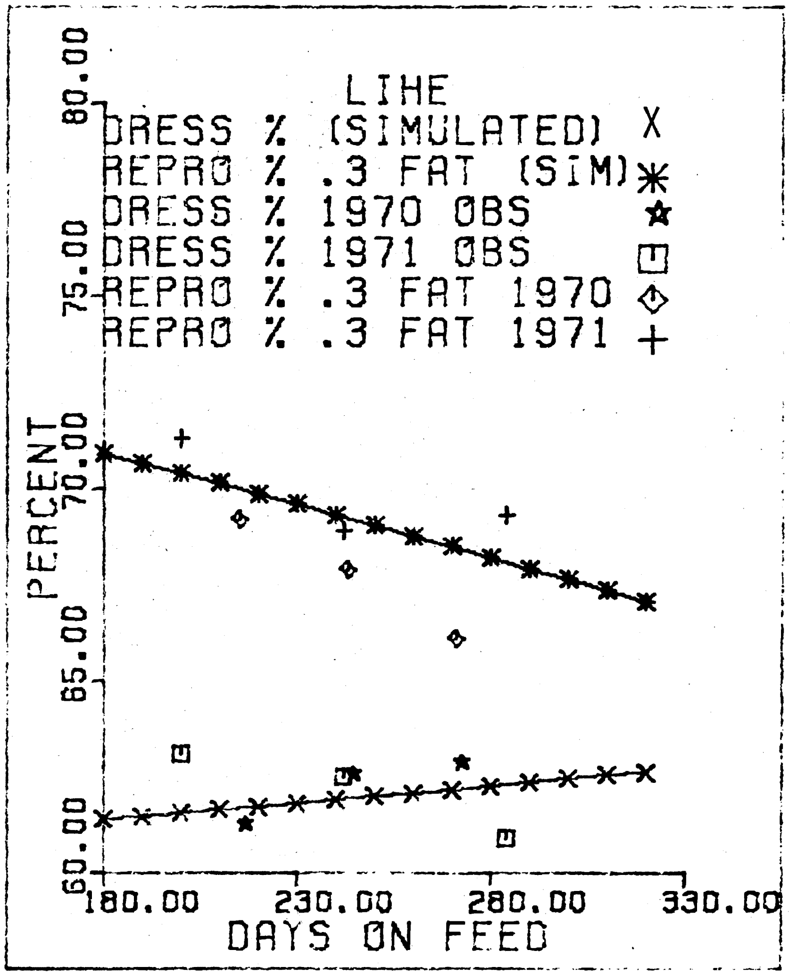

SØAN
LIVE WT (SIMULATED) +
CARC WT (SIMULATED) ×
LIVE WT ØBS 1970 ✳
LIVE WT ØBS 1971 ★
CARC WT ØBS 1970 □
CARC WT ØBS 1971 ◇
WEIGHTS
400.00
600.00
800.00
1000.00
1200.00
1400.00
1600.00
160.00
200.00
240.00
280.00
320.00
DAYS ØN FEED

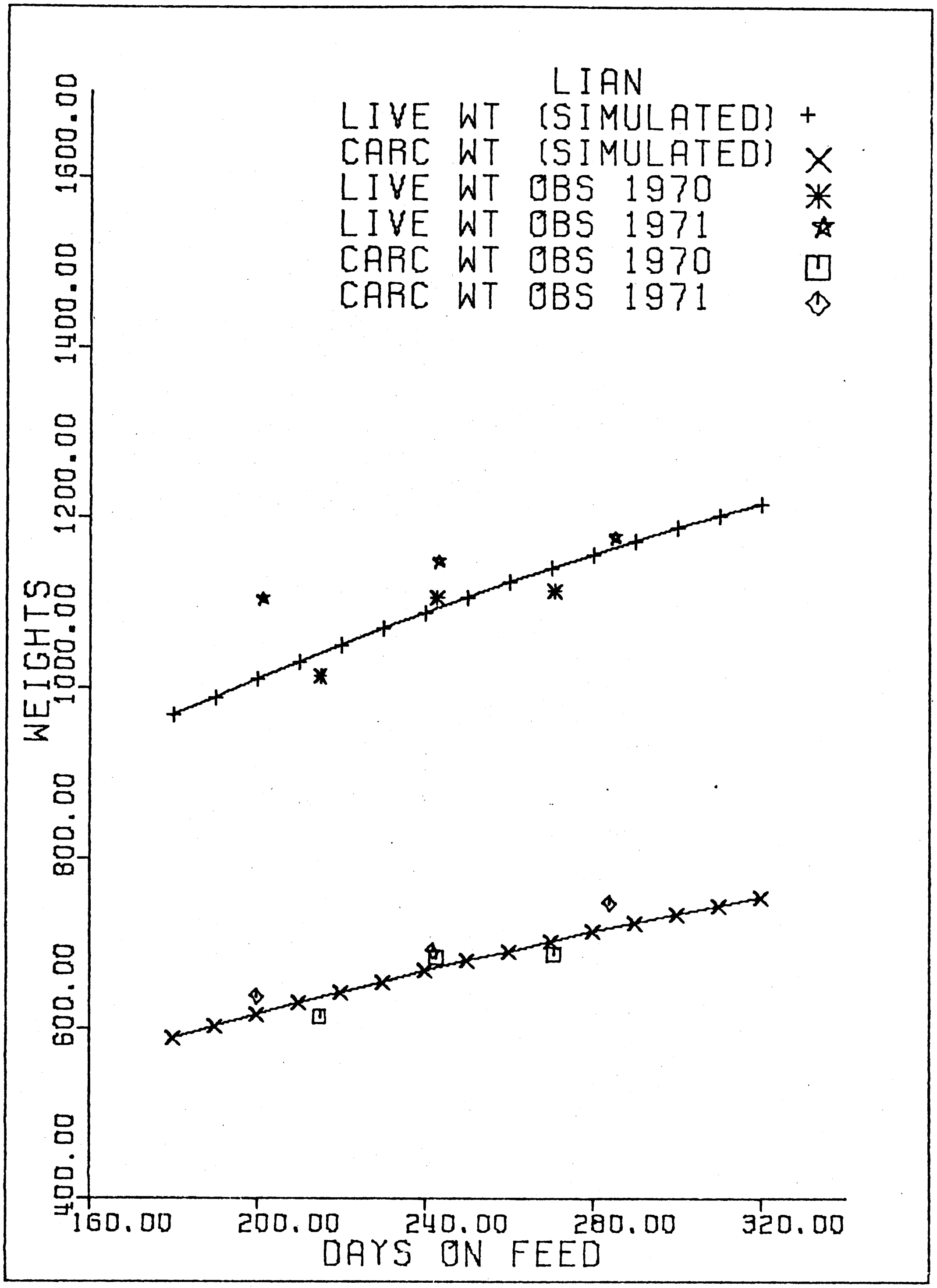

SOAN
QG (SIMULATED) X
YG (SIMULATED) ✳
QG OBS 1970 ★
QG OBS 1971 ⊡
YG OBS 1970 ◇
YG OBS 1971 +
GRADES
2.00
6.00
10.00
14.00
18.00
180.00
230.00
280.00
330.00
DAYS ON FEED

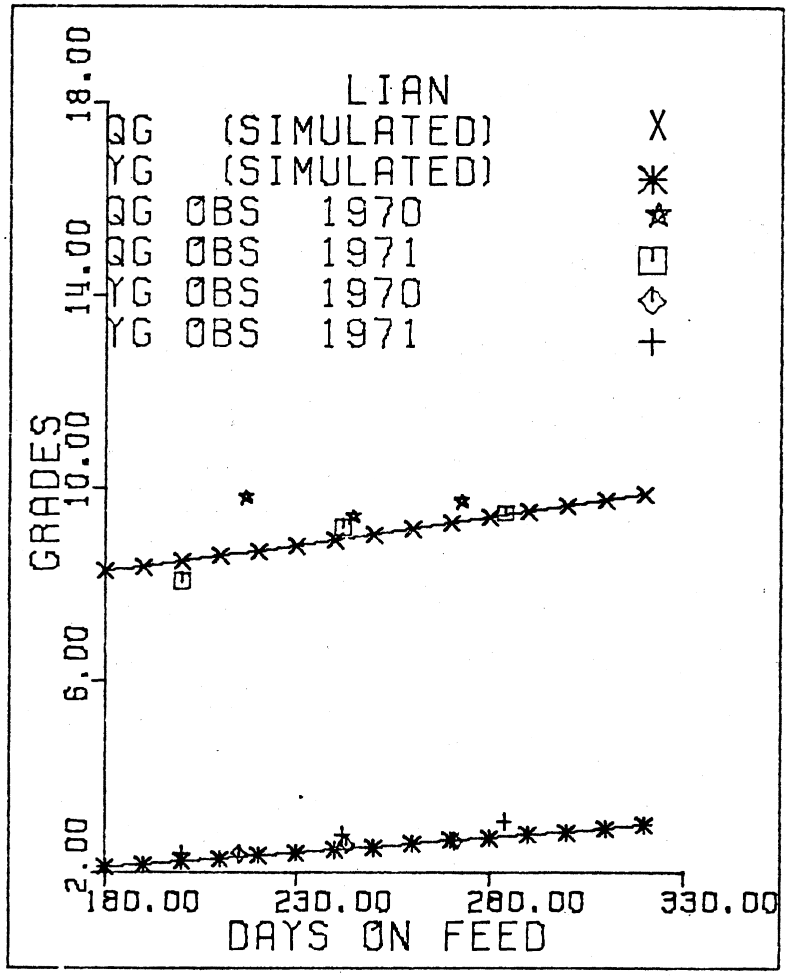

SOAN
DRESS % (SIMULATED) X
REPRO % .3 FAT (SIM) ✳
DRESS % 1970 OBS ★
DRESS % 1971 OBS ⊡
REPRO % .3 FAT 1970 ◇
REPRO % .3 FAT 1971 +
PERCENT
60.00
65.00
70.00
75.00
80.00
180.00
230.00
280.00
330.00
DAYS ON FEED

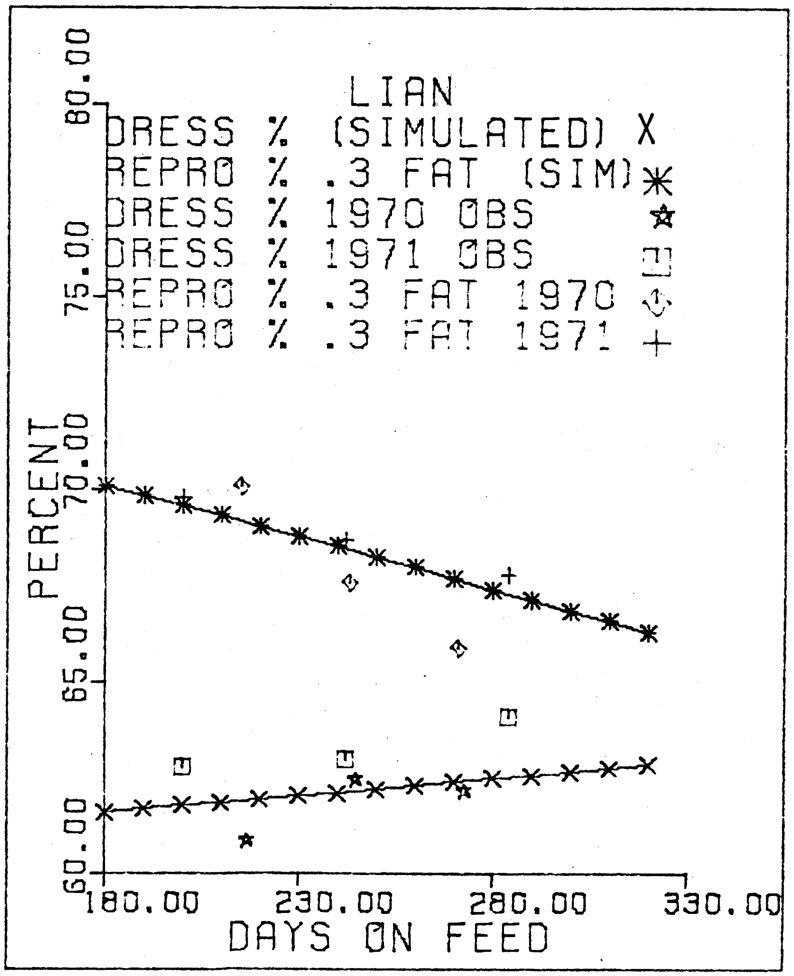

LIHE
LIVE WT (SIMULATED) +
CARC WT (SIMULATED) ×
LIVE WT OBS 1970 ✳
LIVE WT OBS 1971 ★
CARC WT OBS 1970 □
CARC WT OBS 1971 ◇
WEIGHTS
400.00
600.00
800.00
1000.00
1200.00
1400.00
1600.00
160.00
200.00
240.00
280.00
320.00
DAYS ON FEED

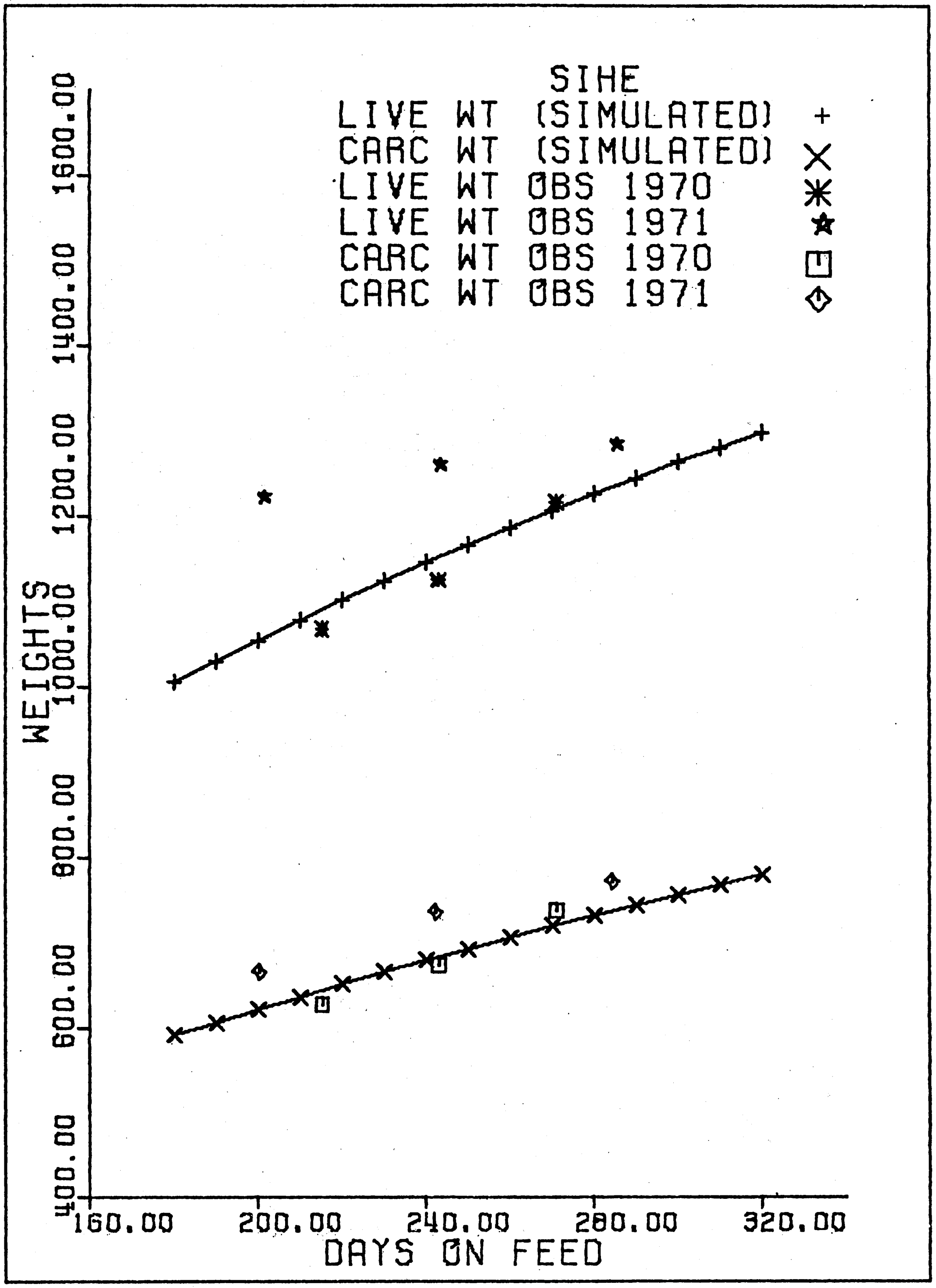

LIHE
QG (SIMULATED) X
YG (SIMULATED) ✳
QG OBS 1970 ★
QG OBS 1971 ⊡
YG OBS 1970 ◇
YG OBS 1971 +
GRADES
17.00
13.00
9.00
5.00
1.00
180.00
230.00
280.00
330.00
DAYS ON FEED

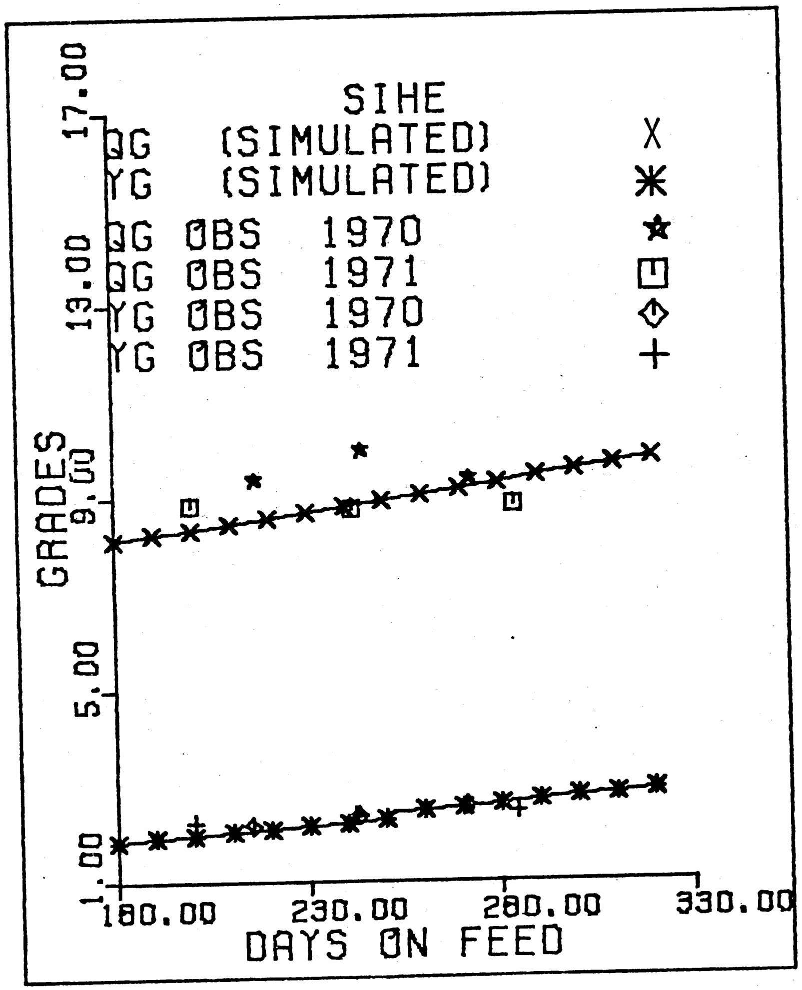

LIHE
DRESS % (SIMULATED) X
REPRO % .3 FAT (SIM) ✳
DRESS % 1970 OBS ★
DRESS % 1971 OBS ⊡
REPRO % .3 FAT 1970 ◇
REPRO % .3 FAT 1971 +
PERCENT
80.00
75.00
70.00
65.00
60.00
180.00
230.00
280.00
330.00
DAYS ON FEED

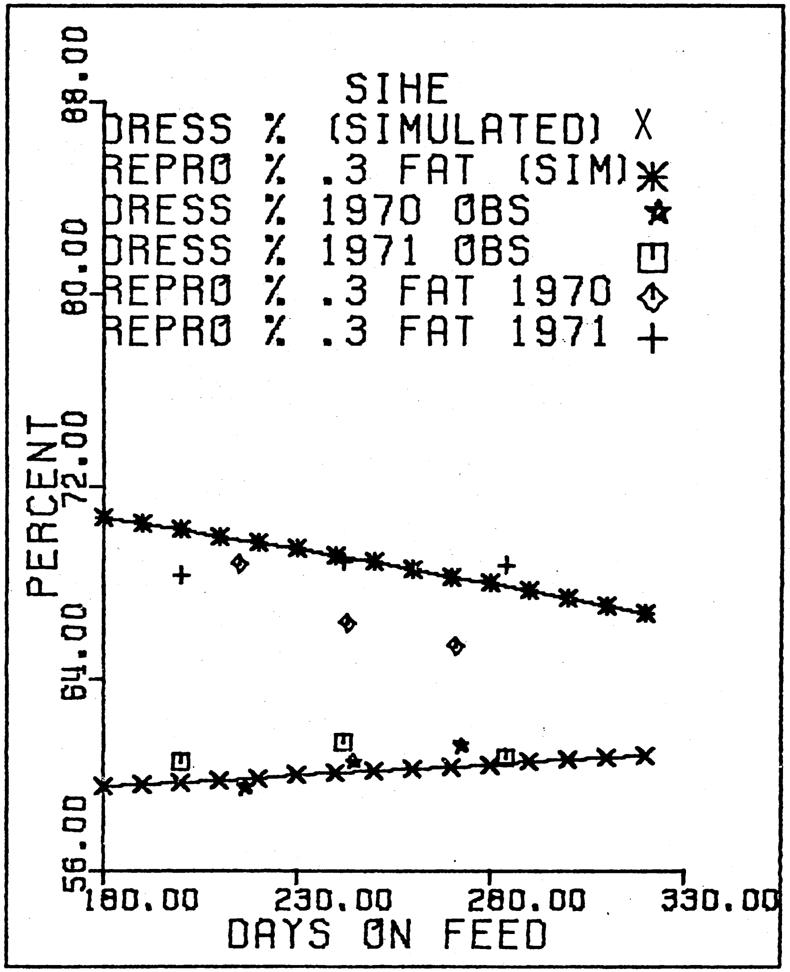

LIAN
LIVE WT (SIMULATED) +
CARC WT (SIMULATED) ×
LIVE WT ØBS 1970 ✳
LIVE WT ØBS 1971 ★
CARC WT ØBS 1970 □
CARC WT ØBS 1971 ◇
WEIGHTS
400.00
600.00
800.00
1000.00
1200.00
1400.00
1600.00
160.00
200.00
240.00
280.00
320.00
DAYS ØN FEED

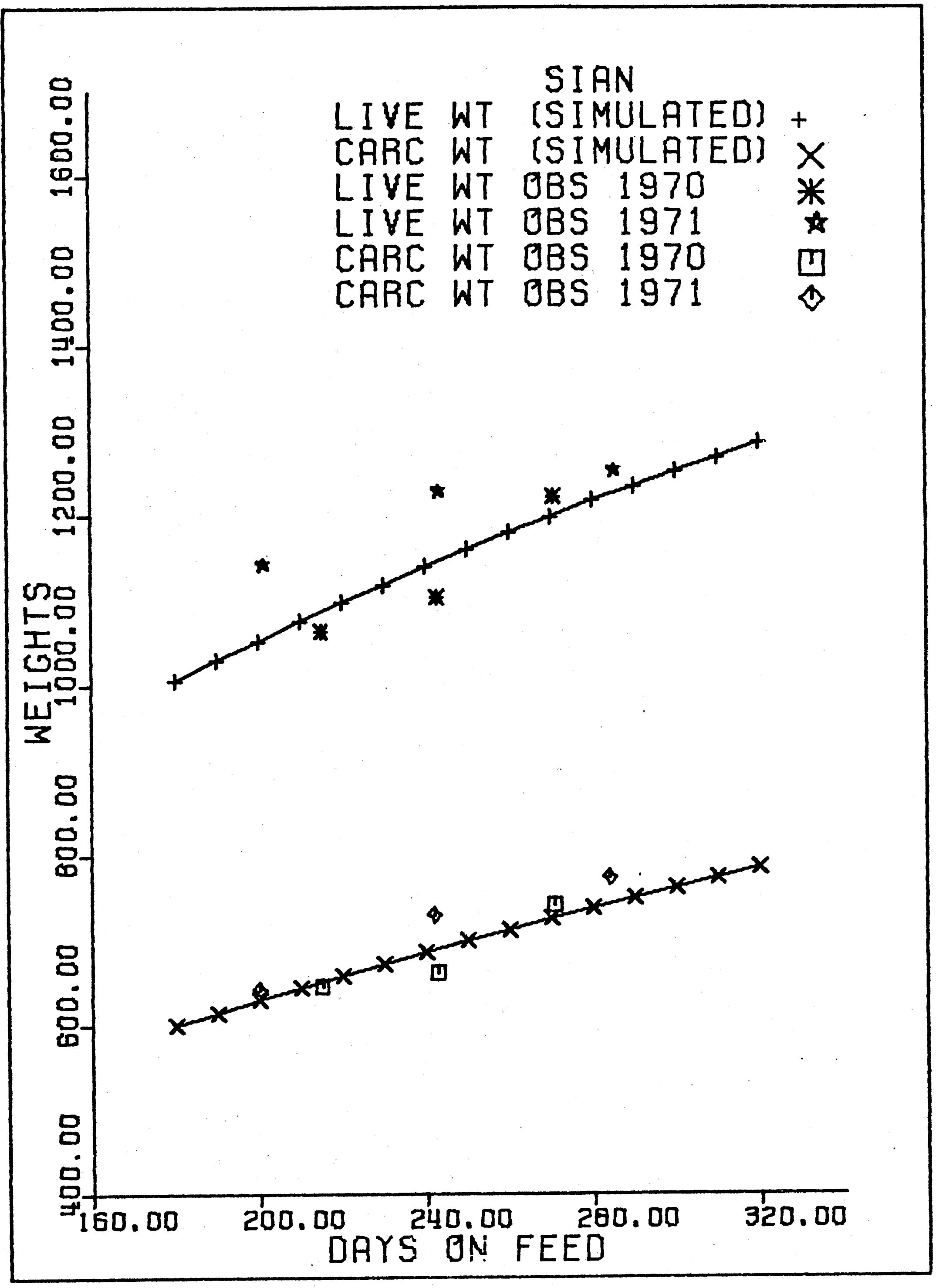

LIAN
QG (SIMULATED) X
YG (SIMULATED) ✳
QG OBS 1970 ☆
QG OBS 1971 ⊡
YG OBS 1970 ◇
YG OBS 1971 +
GRADES
2.00
6.00
10.00
14.00
18.00
180.00
230.00
280.00
330.00
DAYS ON FEED

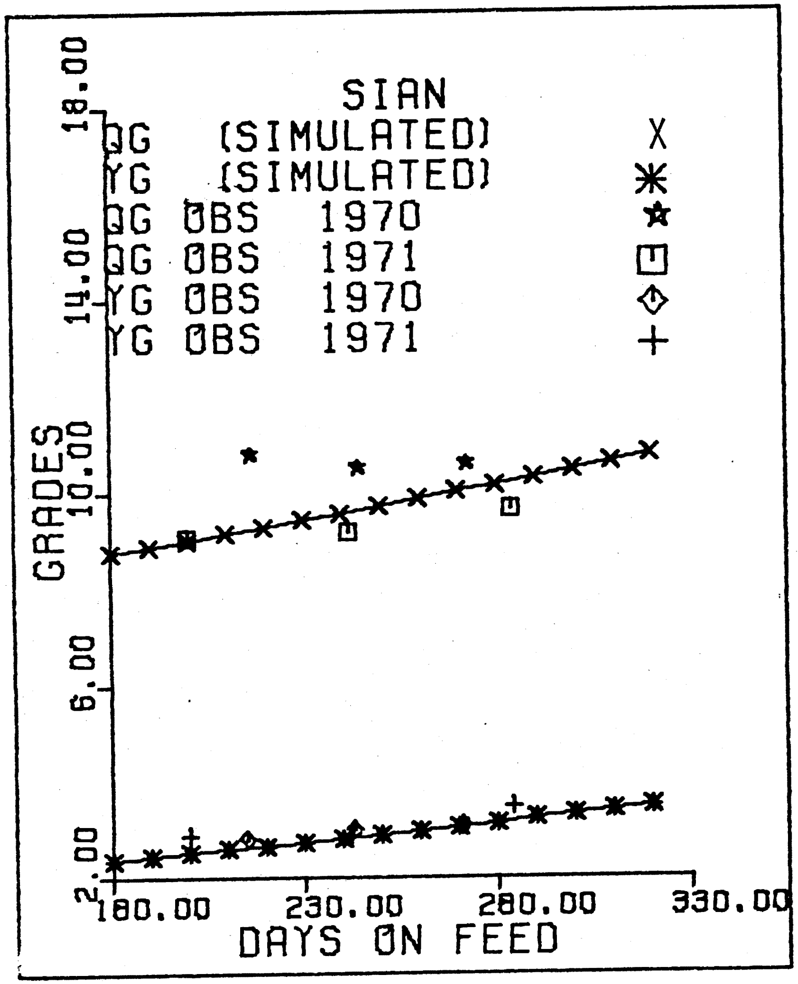

LIAN
DRESS % (SIMULATED) X
REPRO % .3 FAT (SIM) ✳
DRESS % 1970 OBS ☆
DRESS % 1971 OBS ⊡
REPRO % .3 FAT 1970 ◇
REPRO % .3 FAT 1971 +
PERCENT
60.00
65.00
70.00
75.00
80.00
180.00
230.00
280.00
330.00
DAYS ON FEED

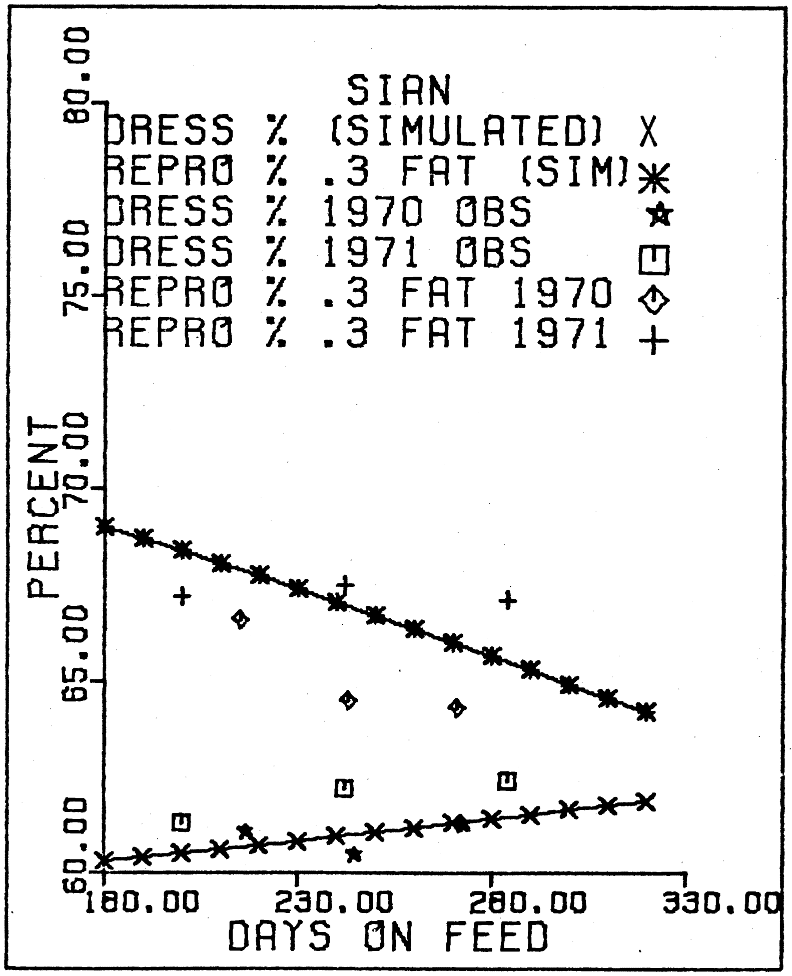

SIHE
LIVE WT (SIMULATED) +
CARC WT (SIMULATED) ×
LIVE WT OBS 1970 ✳
LIVE WT OBS 1971 ★
CARC WT OBS 1970 □
CARC WT OBS 1971 ◇
WEIGHTS
400.00
600.00
800.00
1000.00
1200.00
1400.00
1600.00
160.00
200.00
240.00
280.00
320.00
DAYS ON FEED

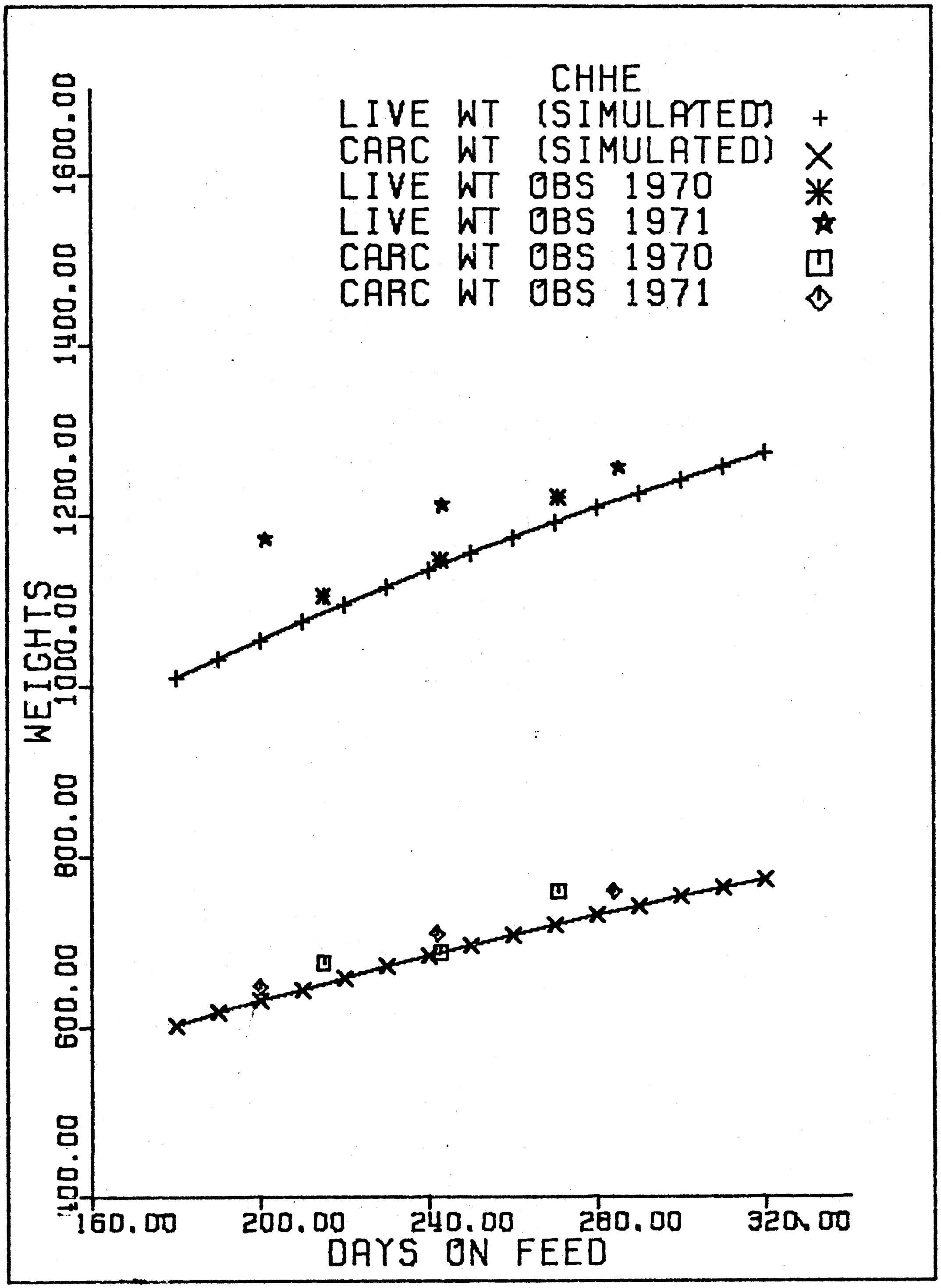

SIHE
QG (SIMULATED) X
YG (SIMULATED) ✳
QG OBS 1970 ★
QG OBS 1971 ⊡
YG OBS 1970 ◇
YG OBS 1971 +
GRADES
17.00
13.00
9.00
5.00
1.00
180.00
230.00
280.00
330.00
DAYS ON FEED

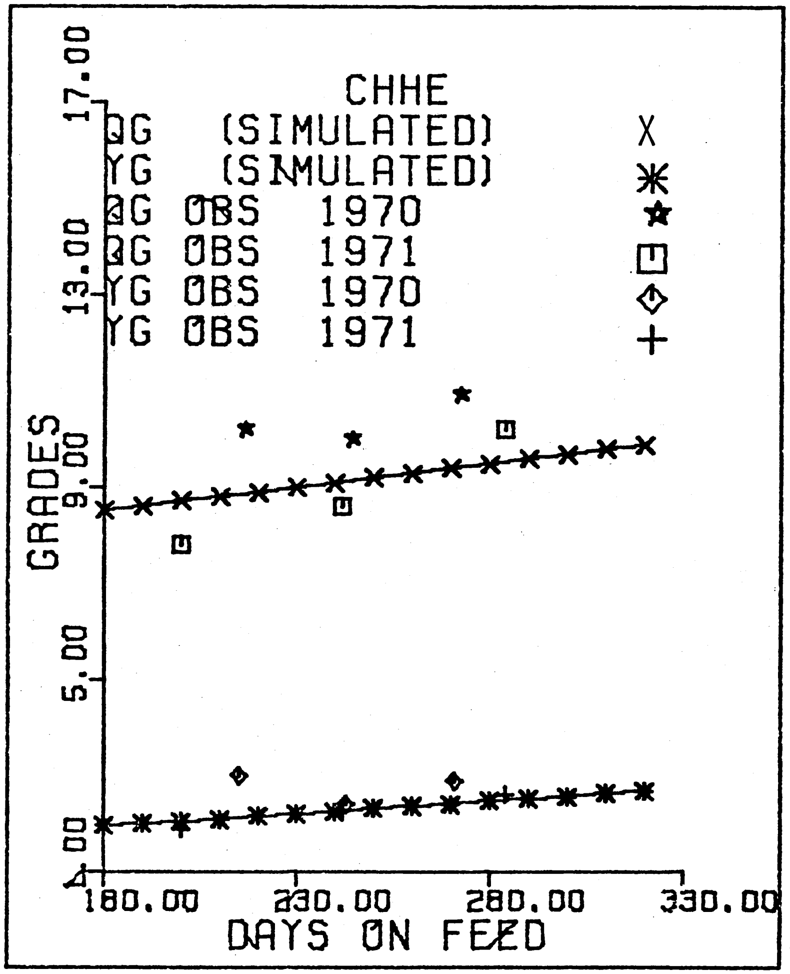

SIHE
DRESS % (SIMULATED) X
REPRO % .3 FAT (SIM) ✳
DRESS % 1970 OBS ★
DRESS % 1971 OBS ⊡
REPRO % .3 FAT 1970 ◇
REPRO % .3 FAT 1971 +
PERCENT
88.00
80.00
72.00
64.00
56.00
180.00
230.00
280.00
330.00
DAYS ON FEED

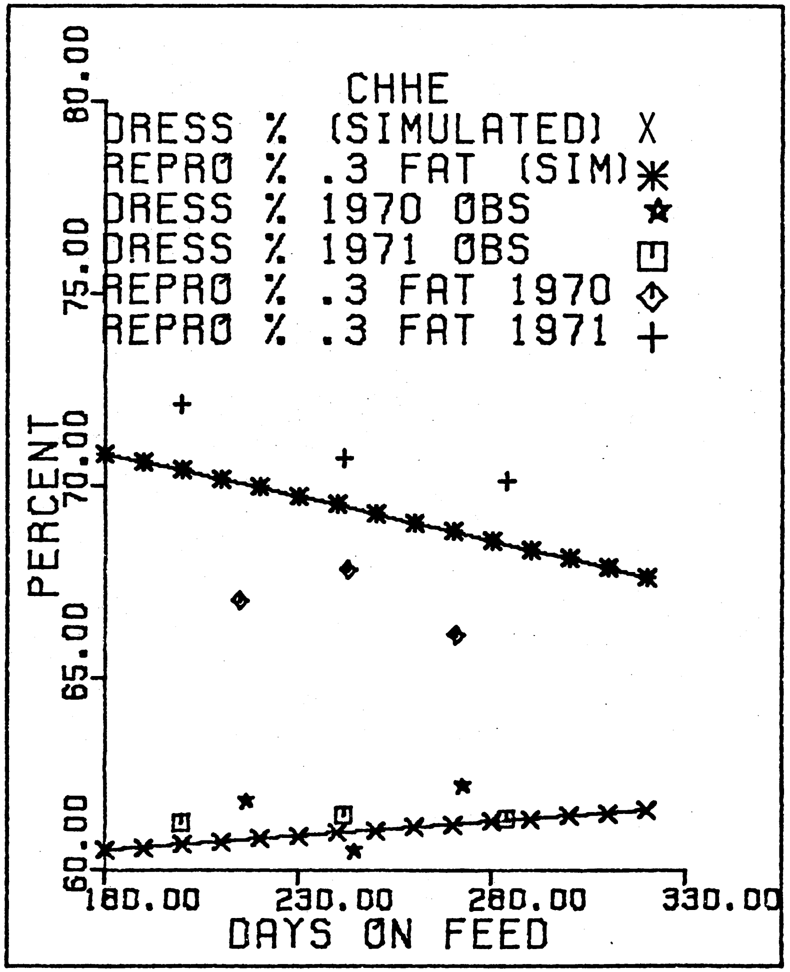

SIAN
LIVE WT (SIMULATED) +
CARC WT (SIMULATED) ×
LIVE WT OBS 1970 ✳
LIVE WT OBS 1971 ★
CARC WT OBS 1970 □
CARC WT OBS 1971 ◇
WEIGHTS
400.00
600.00
800.00
1000.00
1200.00
1400.00
1600.00
160.00
200.00
240.00
280.00
320.00
DAYS ON FEED

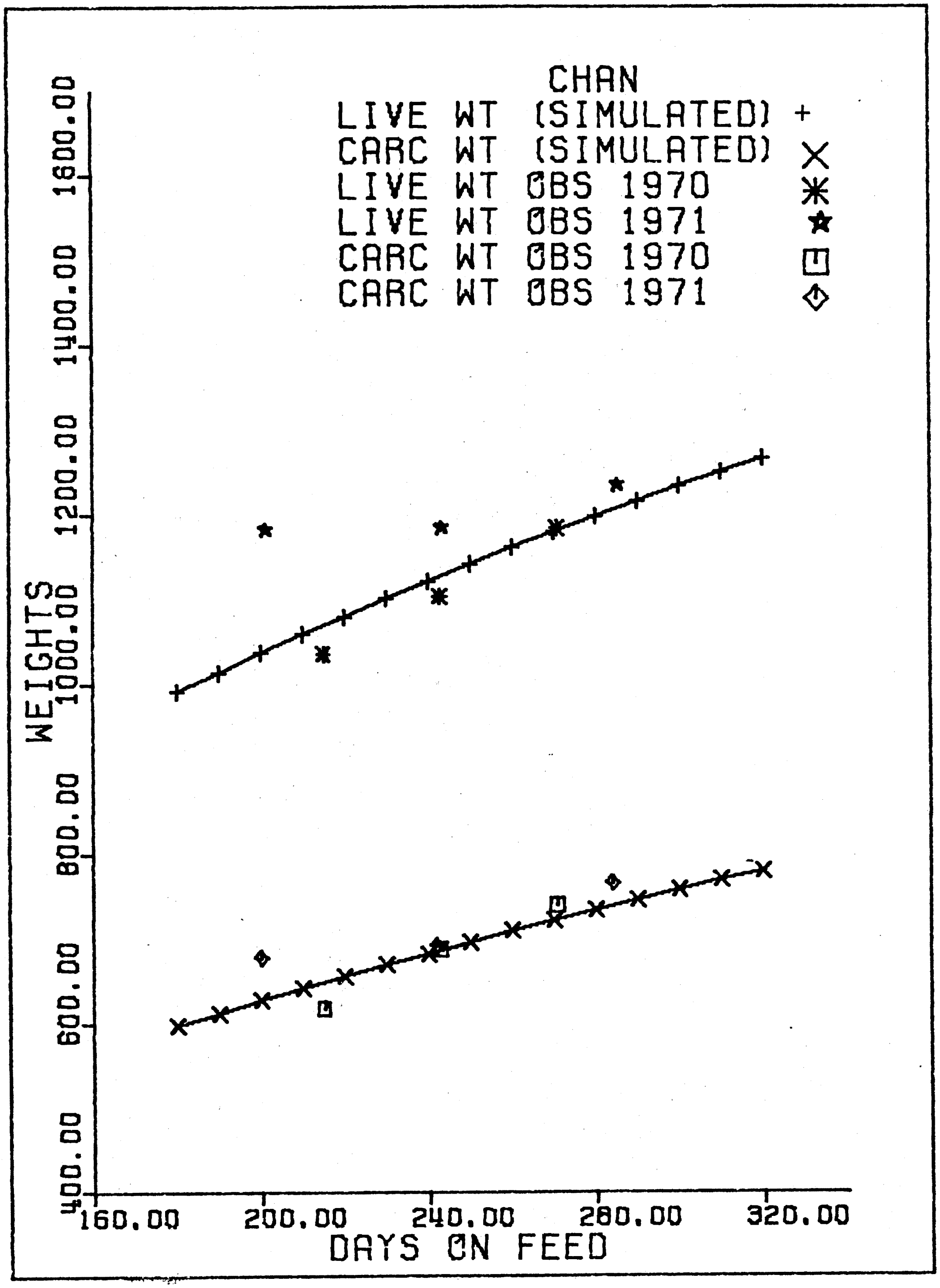

SIAN
QG (SIMULATED) X
YG (SIMULATED) ✳
QG OBS 1970 ★
QG OBS 1971 ⊡
YG OBS 1970 ◇
YG OBS 1971 +
GRADES
18.00
14.00
10.00
6.00
2.00
180.00
230.00
280.00
330.00
DAYS ON FEED

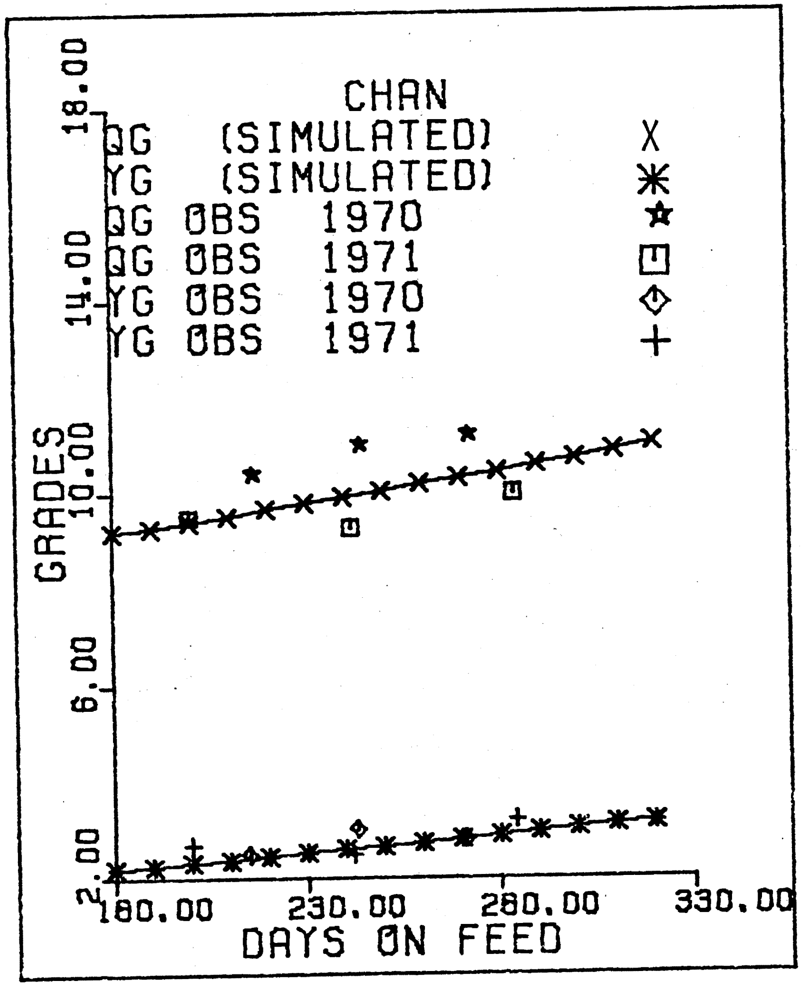

SIAN
DRESS % (SIMULATED) X
REPRO % .3 FAT (SIM) ✳
DRESS % 1970 OBS ★
DRESS % 1971 OBS ⊡
REPRO % .3 FAT 1970 ◇
REPRO % .3 FAT 1971 +
PERCENT
80.00
75.00
70.00
65.00
60.00
180.00
230.00
280.00
330.00
DAYS ON FEED

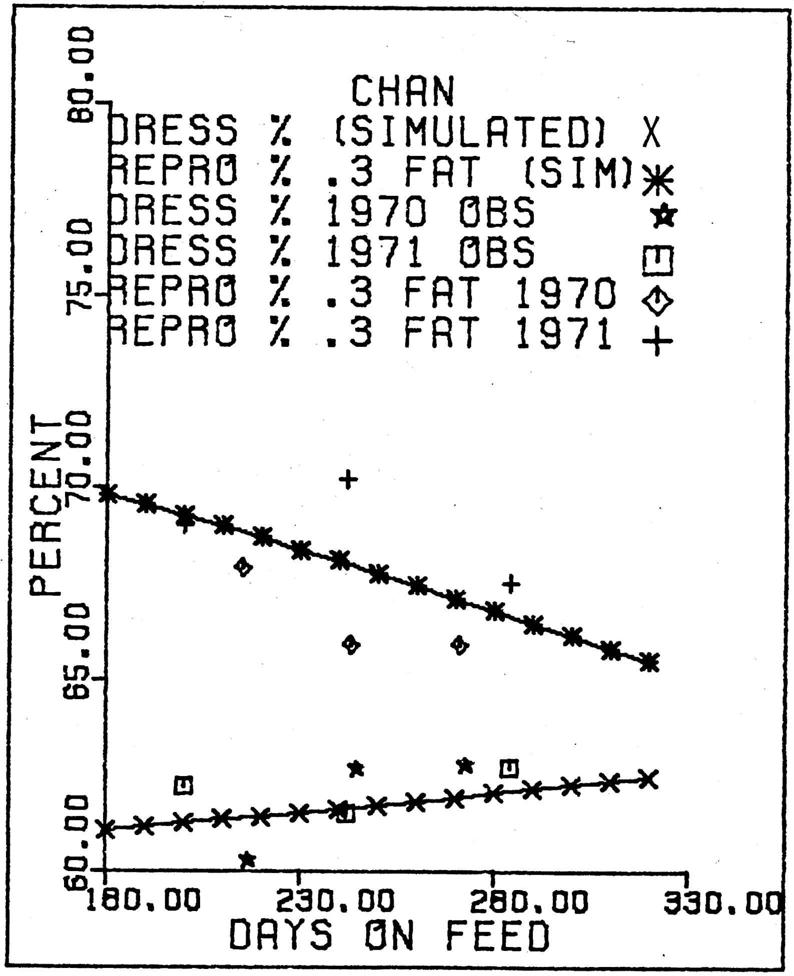

CHHE
LIVE WT (SIMULATED) +
CARC WT (SIMULATED) ×
LIVE WT OBS 1970 ✳
LIVE WT OBS 1971 ★
CARC WT OBS 1970 □
CARC WT OBS 1971 ◇
WEIGHTS
400.00
600.00
800.00
1000.00
1200.00
1400.00
1600.00
160.00
200.00
240.00
280.00
320.00
DAYS ON FEED


CHHE
QG (SIMULATED) X
YG (SIMULATED) ✳
QG OBS 1970 ★
QG OBS 1971 ⊡
YG OBS 1970 ◇
YG OBS 1971 +
GRADES
17.00
13.00
9.00
5.00
00
180.00
230.00
280.00
330.00
DAYS ON FEED


CHHE
DRESS % (SIMULATED) X
REPRO % .3 FAT (SIM) ✳
DRESS % 1970 OBS ★
DRESS % 1971 OBS ⊡
REPRO % .3 FAT 1970 ◇
REPRO % .3 FAT 1971 +
PERCENT
80.00
75.00
70.00
65.00
60.00
180.00
230.00
280.00
330.00
DAYS ON FEED


CHAN
LIVE WT (SIMULATED) +
CARC WT (SIMULATED) ×
LIVE WT OBS 1970 ✳
LIVE WT OBS 1971 ★
CARC WT OBS 1970 □
CARC WT OBS 1971 ◇
WEIGHTS
400.00
600.00
800.00
1000.00
1200.00
1400.00
1600.00
160.00
200.00
240.00
280.00
320.00
DAYS ON FEED


CHAN
QG (SIMULATED) X
YG (SIMULATED) ✳
QG OBS 1970 ★
QG OBS 1971 ⊡
YG OBS 1970 ◇
YG OBS 1971 +
GRADES
18.00
14.00
10.00
6.00
2.00
180.00
230.00
280.00
330.00
DAYS ON FEED


CHAN
DRESS % (SIMULATED) X
REPRO % .3 FAT (SIM) ✳
DRESS % 1970 OBS ★
DRESS % 1971 OBS ⊡
REPRO % .3 FAT 1970 ◇
REPRO % .3 FAT 1971 +
PERCENT
80.00
75.00
70.00
65.00
60.00
180.00
230.00
280.00
330.00
DAYS ON FEED

2

# VITA

Kenneth Ervin Nelson

Candidate for the Degree of

Doctor of Philosophy

Thesis: A SYSTEM ANALYSIS OF INFORMATION AND COMMUNICATION IN BEEF MARKETING

Major Field: Agricultural Economics

Biographical:

Personal Data: Born in Hastings, Nebraska, January 1, 1945, the son of Mr. and Mrs. T.R. Nelson.

Education: Graduated from Clay Center High School, Clay Center, Nebraska, in May, 1963; received Bachelor of Arts degree in Economics from Nebraska Wesleyan University in 1967; received Master of Science degree from Oklahoma State University in 1969; completed requirements for the Doctor of Philosophy degree at Oklahoma State University in May, 1976.

Professional Experience: Graduate Research Assistant, Agricultural Economics Department, Oklahoma State University, 1967-68; Cooperative Agent, Economic Research Service, U. S. Department of Agriculture and Oklahoma State University 1968-71; Agricultural Economist, Economic Research Service, U. S. Department of Agriculture, Stationed at Stillwater, Oklahoma 1971-73 and Urbana, Illinois 1973-76.

Organizations: American Agricultural Economics Association, Southern Agricultural Economics Association.