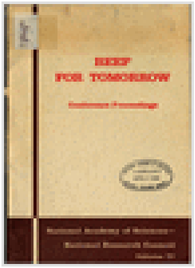

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BEEF FOR TOMORROW

Proceedings of a Conference

Sponsored by the Agricultural Research Institute and Agricultural Board of the National Academy of Sciences— National Research Council

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Foreword

A GREAT DEAL has been said pro and con in recent years about the beef industry in the United States. Industry, government, and the land-grant colleges have often disagreed on various points such as the merits of our present grading system, definition of quality, and many others.

As the demand for beef increases with a rising population, some members in the field decided it was time to bring researchers together from all over the United States for an objective appraisal of the beef available today and that which will be in demand tomorrow.

In order to have a successful conference where representatives of industry, government, and land-grant colleges would be in attendance, it was necessary to find some organization or institution willing to act as an impartial body to clarify and recommend further areas of study once all the material had been presented. In 1957, the Agricultural Research Institute Conference Committee began basic groundwork towards organizing such a conference.

Later, the California Cattleman's Association asked the National Academy of Sciences—National Research Council to establish a committee on beef research. It was decided, however, that a general accumulation of present research was necessary before such a committee could be formulated.

Once again the Conference Committee of the Agricultural Research Institute began a deeper study of the problem and finally it was brought to the attention of the Agricultural Board of the National Academy of Sciences—National Research Council. After it was agreed such a conference was necessary for the further improvement of an agricultural industry, a formal petition was presented to the National Academy of Sciences—National Research Council.

The Academy-Research Council approved the conference with the stipulation that it be held only with the idea of evaluating the results of research as a basis for projecting research needs to meet requirements for beef in a rapidly increasing national population. A planning committee was established to make arrangements for the actual conference.

After careful consideration, the Conference Committee invited speakers from industry, government, and the land-grant colleges to participate in the program. It was the hope of the committee to bring to the attention of the agricultural world some of the most important and controversial problems in the beef industry. No thought was given to solving these problems other than for the committee to recommend, upon completion of the conference, areas in which further research was needed.

It would be impossible to mention the success of this conference without acknowledging the cooperation given by Purdue University and its Extension Service. The hospitality accorded the members and guests of the Agricultural Research Institute-Agricultural Board was both gracious and accommodating.

Grateful acknowledgment is accorded the following firms for their financial support:

American Brahman Breeders Association
Houston, Texas

American Dehydrators Association
Kansas City, Missouri

American Feed Manufacturers Association
Chicago, Illinois

California Cattleman's Association
San Francisco, California

Chas. Pfizer and Company, Inc.
Brooklyn, New York

Eli Lilly and Company
Indianapolis, Indiana

King Ranch Inc.
Kingsville, Texas

Merck and Company, Inc.
Rahway, New Jersey

Santa Gertrudis Breeders International
Kingsville, Texas

Conference Objectives

PRODUCING, processing, and marketing of beef is currently undergoing a rapid structural change. Results of research at state, federal, and industrial laboratories on quantity and quality production of beef have stimulated changes in production practices and have fomented demands for changes in the regulatory grading of beef.

In the selling of beef, research has attempted to measure the changes in the marketing pattern brought about by social and economic forces acting upon the beef industry. These forces will loom larger and larger as our population turns increasingly upward in the decades ahead. Authorities in industry and government have clearly indicated what this means to the producer of beef—he must produce more, more efficiently.

Because of these structural changes it was decided that this beef conference should have three major objectives. These objectives would be: To define the beef we want, to identify the term "quality" in beef, and to describe methods of producing beef more economically.

To determine the beef for the future it was felt necessary to evaluate the quality of our current beef supply, the probable place beef is to have in the American diet of the future, and estimates of quantity and quality required to meet future demands.

Recognized as being one of the most difficult words to define when applied to beef production is the term "quality." Consequently, it was hoped that conference discussions would present background factual information upon which clarifying statements could be made in this, the most contentious area of producing and servicing of beef.

In fulfilling the final objective, program participants were asked to review factors related to efficient beef production as a basis for determining where emphasis might be placed in breeding, feeding, and management research in order that beef would retain a favorable competitive position as a desirable item in the diet of the future.

Since these objectives were discussed by scientists from industry, government, and the Land-Grant-Colleges it was thought advantageous to have an impartial body as sponsor. The National Academy of Sciences-National Research Council is an ideal sponsor for such a task. Therefore, upon the request of the Agricultural Research Institute which is affiliated with the Agricultural Board of the National Academy of Sciences-National Research Council, it was agreed that the Academy-Research Council would evaluate the research plans and accomplishments presented at this conference.

From this conference, the NAS-NRC Conference Committee on Beef hopes a clearer picture will develop of what is ahead for the beef industry and has taken steps to suggest where additional research is needed so that the beef industry can properly orient its programs to meet the demands for the beef of tomorrow.

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THIRD SESSION

How to Produce Beef Economically

M. L. Baker, *presiding*

Preface

THE CONFERENCE on "Beef for Tomorrow" was programmed into three sessions entitled, "The Beef We Want," "How to Identify the Quality of Beef," and "How to Produce Beef Economically."

It was brought out in Session I that per capita consumption of beef has shown a rather steady increase over the past 50-year period. Based on Bureau of Census estimates of population growth, an approximate increase of 44 per cent in total beef production will be required to maintain the present per capita consumption level in the approaching 25-year period. The high position of beef in the American diet is in part traditional, although consumption has been demonstrated to accompany the general standard of living. Consumer preference studies have shown a definite trend towards beef with a high proportion of lean to fat, rather than a high proportion of separable fat as was formerly the case. Only sufficient fat to give added juiciness and flavor to the lean is preferred by the consumer.

Beef from grades commercial and above is about equally nutritious in regards to protein and vitamins. Calorie values, however, increase in relation to the amount of fat when going from the lower to higher grades. Less is known of the nutritional value of beef below the commercial grade. This is the beef that normally enters into the processed beef trade. On the other hand, consumer acceptance of beef is largely based on quality factors of tenderness, juiciness, and flavor of which tenderness is of major significance to the consumer. These quality characteristics may be greatly modified in the cooking process making the final cooked product more or less palatable than the quality classification given the original raw product.

"Quality" with reference to beef carcasses and beef cuts was the special subject of Session II. What is meant by "quality" was admittingly difficult to define and even more difficult to measure, yet it is a term widely used in beef merchandising. Tenderness, juiciness, and flavor are considered the main components of quality but even these are difficult to define objectively. In relating these quality components to U. S. carcass grades of commercial and above, the results of research have shown that U. S. carcass grades are related to quality factors and consumer acceptance. The great variation within grades and the considerable overlap of quality factors between grades, however, result in low prediction values in associating quality of individual carcasses with U. S. Grade. In recognition of the low prediction values of the present U. S. beef grades, the U. S. Department of Agriculture has initiated extensive studies towards evolving an improved grading system based on "cutability" and "quality" factors. Real progress in these studies awaits more accurate and objective methods of determining "cutability" and "quality" in the carcass and live animal.

FIRST SESSION

The Beef We Want

E. R. Kiehl, *presiding*
Roland M. Bethke, *General Chairman*

Beef in the American Diet

B. S. Schweigert
American Meat Institute Foundation

BEEF IS CONSIDERED by many people in this country to be the preferred food in the diet. Undoubtedly, the high satiety value of beef, the "status aspect" of a hostess serving roast beef, steak, etc., as well as the high nutritional value of beef, are major factors in the strong preference shown for this meat.

Per capital beef consumption in the United States has increased in the past few years, as shown in Table 1. It is interesting to note, however, that the Australians and our South American neighbors in Argentina consume two to three times as much beef as we do.

TABLE 1
Per Capita Consumption of Carcass Beef (Pounds)

Period	United States	Australia*	Argentina
1900	66.6		
1920	58.6		165
1940	54.7	144	156
1958	80.5	116**	214***

* Beef and Veal.
** 1955–1956.
*** 1957.

Extensive studies have been carried out to determine the nutrient content of beef muscle cuts and organ meats. These studies show that beef is an important source of high quality protein, minerals, and vitamins in the diet. The energy value of muscle cuts varies with the fat content, particularly with respect to the amount of the external fat, and fat that is present between the muscles that are consumed.

The percentages of the recommended dietary allowances of certain nutrients for adult man that are provided by 100 gram servings of cooked lean beef round and of beef liver are shown in Table 2 (1-4).

TABLE 2
Percentages of Recommended Daily Allowances Provided By a 100 g Serving of Cooked Lean Beef

Nutrient	Beef Round	Beef Liver
Protein	56%	34%
Thiamin	7%	4%
Riboflavin	18%	220%
Niacin	28%	74%
Iron	34%	78%

These two beef items are selected as examples and additional data on vitamin and mineral composition are shown in Table 3. Several conclusions may be drawn from these and other data: 1) a serving of lean beef round provides more than half of the recommended allowance for protein; 2) organ meats (liver) are higher than muscle cuts in B vitamins and minerals (thiamin is an exception to this in that both beef muscle and liver contain about the same amount; 3) liver and other organ meats contain significant amounts of vitamins A and C, while muscle cuts contain only traces of these vitamins.

TABLE 3

Vitamin and Mineral Content of Cooked Lean Beef (mg. per 100 grams)

Nutrient	Beef Round	Beef Liver
Vitamins		
Vitamin A, I.U.	Trace	43,900
Vitamin C	Trace	31
Vitamin B_6	.54	—
Pantothenic Acid	.41	9.4
Folic Acid	.034	.105
Vitamin B_{12}, micrograms	2.2	85
Minerals		
Phosphorus	235	330
Calcium	14.5	30

Important new data developed by Leverton and Odell (1) have provided a sound basis for the estimation of calorie content of cooked meat cuts that contain varying quantities of fat. Much of the older data was obtained from composite samples of fresh meat cuts with approximately ½ inch of external fat included in the sample. It is obvious that knowledge of composition of foods *as eaten* provides more reliable figures on nutrient intakes than composition data based on foods *as purchased* or *available for consumption.* Comparative data adapted from the Leverton and Odell study are shown for the protein and calorie content of beef round and beef rib based on the lean portion, lean plus marble, and lean plus marble plus fat portions, in Table 4.

In the case of beef rib, the calorie intake per unit of protein may vary threefold, depending on the amount of fat

TABLE 4

Protein Calorie Ratio in Beef Round and Rib Cuts

Beef Cut	Percent Protein	Calories per 100 g.	Protein: Calorie Ratio*
Beef Round			
Lean	36.4	223	6.1
Lean + Marble	35.5	238	6.7
Lean + Marble + Fat	31.3	306	9.8
Beef Rib			
Lean	28.6	169	5.9
Lean + Marble	25.5	262	10.2
Lean + Marble + Fat	20.4	391	19.2

* No. of calories per 1 percent protein.

consumed with the lean portion. Less variation is noted for beef round. These figures are extremely valuable to physicians, dietitians, and nutritionists, as well as to those engaged in the livestock and meat industry, in that the calorie intake from beef and other meat cuts can be readily adjusted by the amount of fat consumed. Thus, a serving of cooked lean beef will provide over one-half of the recommended protein intake per day, with a caloric intake of approximately 200 calories. As shown in Table 5, cooked lean beef, pork and lamb muscle cuts are very similar in protein and calorie content. The protein-calorie ratios are remarkably uniform, and indicate that the protein and fat content within the muscle (the major source of calories) is quite similar for muscle cuts from the three animal species represented.

A more detailed evaluation of the amino acid composition of meat protein shows that beef is an excellent source of all of the amino acids required by man. Representative data of four important amino acids are shown in Table 6 for beef round and several other foods of animal and plant origin (2, 5-7). Lysine, methionine, and tryptophan were selected for emphasis since they tend to be most limiting in the human diet, while leucine appears to occur in liberal quantities in most food proteins.

Proteins of foods of animal origin are quite uniform in amino acid composition, while the cereal and legume foods are limiting in lysine and/or methionine and tryptophan. It is important to point out that the data as expressed reflect the completeness of each food protein source. The amount of each amino acid present in an average serving of each food can be calculated from these figures, the protein content, and the weight of the serving.

TABLE 5
Protein and Calorie Values of Cooked Lean Meat Cuts

Meat Cut	Percent Protein	Calories per 100 g.	Protein: Calorie Ratio
Beef Round	36.4	223	6.1
Beef Rib	28.6	169	5.9
Pork Ham (uncured)	38.6	223	5.8
Pork Chop	34.6	250	7.2
Lamb Leg	28.8	175	6.1
Lamb Chop	28.7	197	6.9

TABLE 6
Amino Acid Composition of Beef and Other Foods (Percent of Total Proteins)

Amino Acid	Lysine	Methionine	Tryptophan	Leucine
Beef Round	9.2	2.5	1.2	7.9
Pork Loin	7.8	2.6	1.2	7.3
Lamb Leg	7.7	2.5	1.3	7.2
Milk	7.6	2.2	1.4	9.2
Eggs	7.8	2.7	1.5	9.2
Corn	2.3	2.1	0.6	10.2
Wheat	2.4	1.3	1.4	5.6
Soybeans	5.7	1.4	1.4	7.1

Other studies show that the amino acids in beef and other meats are not destroyed during cooking. Experiments have also been carried out in our laboratories to determine if the amino acids in meats subjected to varying heat treatments are utilized completely by the animal (that is, to determine the digestibility and the ability to support growth of the specific amino acid being studied). Results from a study recently completed are shown in Table 7. It is clear from these findings that the lysine from beef cooked in various ways is completely available for growth of the weanling rat. Only when extensive autoclaving for 16 hours was employed (a procedure far more severe than household or commercial practice) could a reduction in lysine availability be demonstrated. Thus, we may conclude that lysine is well utilized from cooked beef. On the basis of a recent review by Hertz (8) of the amino acid requirements of man, a 100 gram serving of cooked lean beef would provide considerably more lysine than the daily requirement for adult man.

TABLE 7
Percentage of Lysine Available In Cooked Beef Round

Heat Treatment	% Lysine Available
Raw	98
Rare, 200°F.	102
Well done, 200°F.	102
Rare, 300°F.	100
Well done, 300°F.	113
Rare, 400°F.	112
Well done, 400°F.	100
Rare, Electronic	106
Well done, Electronic	108
Autoclaved, 4 Hrs., 250°F.	118
Autoclaved, 16 Hrs., 250°F.	71

While nutrition experiments are often carried out to evaluate single foods as sources of specific nutrients, the supplementary value of foods in a mixed diet is of greater importance in practical nutrition. In a recent study (9) the value of beef as compared with a cereal blend or casein (the principal protein of milk) in supplementing a bread diet was determined with growing rats. As indicated in Table 8, cooked beef was superior to the other test materials in supplementing a bread diet. In this case, 30 per cent of the total protein present was provided by the beef.

TABLE 8

Weight Gains of Rats Fed Various Protein Foods (All diets contain 10% Protein)

Diet	Weight Gain in 6 Weeks (g.)
Bread	19.8
Bread + Cereal Blend	36.7
Bread + Beef	159.8
Bread + Casein	96.7

These studies, therefore, extend our knowledge on the high protein quality of beef when determined by amino acid analysis, availability of amino acids, growth promoting value as a sole source of protein in the diet, or as a supplement to cereal products such as bread.

The high esteem for beef as a food in the American diet is justified not only on the basis of taste and related organoleptic quality factors, but also in the significant contribution made to good nutrition. New knowledge on the nutritive value of meat will be of great assistance to the medical and dietetic professions in providing information to utilize this food to an even greater extent in a variety of diets for patients of all ages.

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Changing Patterns in Beef Utilization and Distribution

H. B. Arthur
Swift and Company

PEOPLE LIKE BEEF and it's good for them. Upon this simple statement, which requires almost no proof, is built a great industry. Marketing is one phase of this industry.

By marketing is meant the commercial transactions between the livestock owner and his customer, his customer's customer, and so on down the line to the ultimate retailer and his sale to the consumer.

These transactions are a part of the free market system we have long been familiar with. Entirely different kinds of knowledge might be needed if we operated under rationing or under a regimented system in which there was a single owner from the live animal to the ultimate consumer.

It is the system of markets we have that has served tolerably well in *integrating* the beef industry over the years. It is through this system of markets, with all of the uncertainties, bargaining, and changes, that consumers have reached out to secure the kind of beef supply which in their opinion best meets their likes and their judgment of what is good for them.

If this reaching out by consumers is to be effective, we have to develop not just a system of *distributive* channels through which the product can flow in an efficient way; we have to provide a system of *communications* which will be sensitive to the wants and preferences of the buyer. This system must enable us to identify the quality of the product which is going to produce the greatest satisfaction, not just at the retail counter, but all the way back to the live animal and even to the breeding-herd.

We have to know how to recognize the steak you or I will prefer, even on the hoof. And if anybody knows how to supply our preference, even at a higher cost, we have a right to get what we want if we are willing to pay the required price.

After we have identified the wants, and then provided a way of specifying the product that will meet those wants, including the live animal, our job is still far from complete. The marketing job involves finding the most efficient and convenient means of providing the entire bridge from the farm to the kitchen. Not just for you and me as individuals, but for this integrated nationwide industry of ours as a whole. In order to do this, we must know how big the market is, what its geographical differences are, what the structure of channels of distribution should be, and whether we are finding the straightest line to market with the least waste motion and the fairest treatment for all the participants, consumers and producers alike.

Consumer Demand and Preference Studies

Marketing research in this area is trying to isolate and describe the attributes of beef about which consumers need to be informed, and to measure the relationship of those attributes to current government grade standards, or other means of identifying the quality attributes in the product.

These researches should be useful (1)

to the consumer, as a means of making known the kind of beef he wants, and (2) to the producer, as a guide to the type of product which is likely to bring him the greatest gross income. Whether or not net income will be maximized remains to be determined.

Demand Education and Advertising Effectiveness Studies

Research on the impact of advertising and promotion has been conducted in an exploratory way by the USDA specifically with respect to lamb (Sacramento and Cleveland studies). No such work has been done on beef. Such research would serve an extremely useful purpose if it could be developed beyond the exploratory stage so that meaningful results emerged. Many producers as well as processors are spending good money for advertising.

Measures of Consumer Market Dimensions

The work of the Institute of Home Economics and the Agricultural Marketing Service in 1955, which attempted to measure food consumption by items, regions, income levels, and by urbanization, typifies the research that has been conducted under this heading. Previous studies of the same type that are partially comparable were conducted earlier at the Bureau of Home Economics and the Bureau of Labor Statistics.

Research of this type can be used to quantify in crude terms the geography of consumer demand, the impact of income distribution on demand, and the relationship of urbanization to demand. These data also carry some inference as to the price-quantity relationships between various retail cuts. Research of this type may conceivably give some guidance to production over long periods of time, but gives little guidance in the short run.

Studies of Marketing Efficiencies, Margins, etc.

For many years, the USDA has engaged in attempts to measure marketing margins for farm products, including beef. Occasionally effort has been made to break the marketing margins down into their component costs by function and by the type of resources employed. Such research, if accurately done, is revealing as to changes in the level of marketing expense. However, it cannot by the very nature of the data make adequate allowance for process and service changes and for the impacts of volume variation. So far as we can judge, such data are descriptive but do little to explain the reasons for what is happening. Perhaps this vagueness is why politicians like them so much.

Price Analysis and Forecasting; Factors Affecting Supply and Price

Price analysis requires market information. We must not overlook the vast amount of market news, supply information, and other forms of market intelligence in our industry. I don't know that this information itself comes under the heading of research. Certainly it takes research to plan it and intelligently appraise its validity.

Therefore, let us say that we have a large volume of market information which is widely used by commercial men as well as researchers and which serves well for many purposes. For some purposes, however, there is much to be desired.

Researchers use these data both for basic analyses and for a great deal of what has traditionally been called "outlook work." The basic studies are well represented by Working's "Demand for Meat," and numerous other analyses of factors associated with supply or price. Pork has received more attention than beef in this respect. In fact, there was a period when we used to say that a graduate student in Agricultural Economics had to "cut his teeth" on a hog-corn analysis before he could qualify for his degree. However, there have always been numerous studies, generally using multiple correlation methods, which attempt to measure the factors affecting prices of cattle and beef.

The basic studies almost automatically lead to an effort to predict the future for supplies or prices. Such studies are obviously of vital importance to the producer, although most of them leave much to be desired since they are likely to employ annual data and to relate to an average of all grades and classes of product. When findings are narrowed to specific areas, to pinpoint particular types of beef or cattle, or to sharpen the focus in respect to shorter time periods, the errors of the forecast multiply and the application of results are likely to be more conjectural than scientific.

Research on Transportation and Distribution Facilities, and Costs

USDA has long had a division conducting research in these fields and much of this research has been productive, both in describing situations that have been highly efficient and in calling attention to areas where performance could be vastly improved. The work has been indirectly of service to producers, and some studies have provided direct help to farmers in improving their shipping and marketing operations.

Efficiency Studies Relating to Processing and Distribution

This is an area in which a good deal of research is done on a private basis. Generally it is unpublished except as trade journals pick up stories about new methods, or as equipment suppliers undertake to demonstrate the contribution which their product can make to better or more efficient operations. Published research in this area is illustrated by the USDA study of the expense structure at the slaughtering level, specifically in Texas.

Since our chief reliance for efficient processing and distribution rests in the competitive market system and the pursuit of profits by meat packers, wholesalers, and the rest, this kind of research is useful to producers if it helps individual processors to do a better job thus enabling them to pay more for the producers' livestock.

Descriptive Studies of Channels of Flow

Over the years, a number of descriptive studies have been made by Knute Bjorka and others measuring the channels of flow of livestock through various marketing institutions from farm to slaughter, and the channels of flow of meat from slaughterer to retailer.

In the last two or three years the USDA has also published studies describing in great detail the channels of flow of beef at the wholesale level (Willard Williams' studies of the San Francisco and Los Angeles metropolitan areas). These are descriptive studies of practices currently prevailing in these markets and are educational particularly from the point of view of national policy. They are also useful in guiding those who do economic analysis in the industry. They provide little direct guidance to producers.

Explorations of New Methods and New Products

One should not overlook substantial experiments and investigations of private firms, not reported as "research," but research nevertheless. This embraces a great deal of the marketing research conducted by private firms. Some of these studies include experiments and surveys relating to new products such as frozen consumer cuts, fabricated specialties such as precooked items, new sausage products, canned foods, and the like. It also embraces a great deal of research in product improvement.

One of the great challenges in the beef industry is the matter of tenderization and this has received an enormous amount of attention. It is too early to draw final conclusions but great progress has been made in the area of beef tenderization. Some methods permit quick aging. Another area in which effort has been concentrated is in the enzyme tenderization field.

One of the great challenges in the beef marketing area is the possibility of meat packer processing, packaging, and labeling that will assure the consumer of just the kind of fresh meat he wants. To the extent that we can succeed in this area, the meat packer will be enabled to pay a better price to the producer who can turn out the raw materials he requires.

Another field that has received a good deal of research is that of operating efficiencies or technology. Mechanized livestock dressing has moved forward as various operations have been studied, and the power and skill of machines have replaced human effort in various operations such as hide removal.

Other kinds of private research include those in the general field of industrial economics where a great deal of work is done in market analysis and plant location, primarily seeking the "shortest road to market."

There is a strong inclination to assume that research is limited to that which appear in formal, technical reports. I suppose that farmers do more research (because there are more of them) than any of the groups I have discussed. They are forever trying something new, comparing it with experience, and then moving on to the next step. This kind of research, which doesn't appear in print, is undoubtedly the greatest factor in the changing patterns and channels in the processing and distribution of meat. Research doesn't have to be dignified by the name "research" in order to be highly effective and useful.

Research done in many cases has been too static. It has consisted of compiling and analyzing past experience, using known factors. Some of these factors form patterns which are useful for the producer to know about and to take into account as he adjusts his production plans.

On the other hand, most of the dynamic changes that occur are a product of research of a very informal sort, but research nevertheless. This research consists of trying something new and measuring it, as carefully as circumstances permit, against the things that will be displaced. This measurement is then tested in the crucible of consumer preferences. Price potentials are compared with expenses and the whole process leads us to adapt ourselves progressively to the fluid changes that occur around us.

We have moved into an era of extremely high labor costs, retailers absorbing wholesaling and many processing functions, super market merchandising, consumer preferences for convenience rather than personal service, and a general emphasis upon mass appeals accompanied by standardized prepackaged, pretrimmed, and prepriced product. Wide-awake, flexible approaches are as necessary in research as in business decisions.

The industry's job is to find a way to determine the qualities which consumers want, and to see that our products provide those qualities in an identifiable way, so that the greatest possible satisfaction will be reached. We must provide efficient means of producing, incorporating, and channeling those qualities so that each of us knows his job and does it at least as effectively as those others who are competing with us.

Against this background, the criteria that enter beef grades—whether they are represented by government, retailer, or packer brands—leave us with a number of questions not fully answered.

1. Are the grade criteria *appropriate* for establishing grades that parallel the degree of excellence in fulfilling wants? (Consider such things as fatness, wastiness, tenderness, tastiness. Do beef grades really parallel the consumers' scale of wants?)

2. How *adequate* are grades for specifying all the essential criteria in which consumers should be interested? There are questions here relating to freshness, selection, age of animal and age of the meat, cutting styles, nomenclature of cuts, etc.

3. How *objective* are grades? The experience with grade discrepancies on regrade tests leaves much to be desired. These remarks are not presented as argu-

ments against grading. They do suggest two things to me. First, the state of the arts as revealed is immature and unsettled. Second, the effective operation of markets could well be impaired if such grading were compulsory, or if its limitations are not fully understood and recognized by all concerned.

In this context, a great deal is left to be desired. We don't know with a high degree of accuracy how to fit our products to what the consumer will most desire because research shows that the consumer often doesn't know what he wants. We must try to relate this research—as one of the studies in Florida has undertaken to do—to the analysis of breeding and feeding practices in relation to consumer satisfactions.

If I were to try to name the major areas where the questionmarks loom largest from a marketing viewpoint, I would certainly include the following questions:

1. What are the attributes consumers really want in beef?

2. How can we identify these attributes and relate them to the cattle we produce so that everything we do from breeding forward contributes to the meeting of those wants?

3. How can we keep ourselves in the forefront in providing all the services involved on a basis of maximum efficiency?

I am convinced that the person who can answer these three questions correctly, and carry out his answers, will be operating a highly profitable business whether he is on a ranch, in a packing plant, or in a retail store.

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Evaluation of Consumer Acceptance Studies on Beef

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There has been a tremendous upsurge of interest in consumer acceptance research in the past few years, and especially since World War II. A good deal of this, no doubt, was stimulated by the passage of the Research and Marketing Act in 1946. The basic stimulus, however, was probably the growing realization that consumers are coming to insist on purchasing what they want instead of what is offered them.

A review of the literature on consumer acceptance research as well as direct observations reveal some interesting facts about changing attitudes toward consumers. Before World War II there seemed to be little concern about these important people, especially in the food industry. Only a scattering of research reports concerning work done during this period are to be found, and seemingly these attracted little attention by those most concerned. It would appear that the "experts" were in the saddle. In the food industry these consisted largely of production, marketing, government, and university people. These experts established quality criteria, standards, and official grades for a variety of foods, including beef. It was assumed, but generally never substantiated, that these criteria, standards, and grades were in line with consumer needs and desires. On the whole, things weren't too bad for the consumers, but certainly something less than perfection was achieved in meeting their actual needs and wants.

The present authors received their first shock about the "sad state of affairs" in the field of food acceptance early in World War II when we began to work with the food research and development group in the Quartermaster Corps. A tremendous effort was being made at that time to produce military rations which were highly nutritious, wholesome, compact, and stable. To the surprise of most of us, when they were served to our men, many had very poor acceptability. Some were thrown away and some were even used as dunnage! The situation became so bad that our fighting men at times went under-nourished in the midst of an abundance of food. The meat items, normally the backbone of the American diet, did not escape criticism and canned meats to this day do not enjoy much repute, although a great deal of progress has since been made to improve consumer acceptance.

Gradually, we have learned a great deal about consumer acceptance, and now a majority of people engaged in food marketing realize that they cannot take it for granted. Further, most realize that no one of us can accurately speak for consumers without first finding out what he wants. Accordingly, we must contact the consumer and thus determine directly his needs, desires, taboos, habits, etc. Only in this way can we safely predict what type and quality foods he will buy and what will regularly satisfy his needs and desires.

Consumer Acceptance Testing

There do not appear to be any universally accepted methods for evaluating consumer acceptance. Many different approaches have been tried, some obviously very imperfect. Except when gross differences in quality are under study, workers generally agree that the test situation should be as normal and natural as possible. Furthermore, the economic factors involved in normal decision-making should be brought into play, if at all possible. Thus, consumer reactions to the appearance factors in beef can best be evaluated in a meat counter or kitchen situation, or at least in an environment simulating one of these locations. Admittedly, such test conditions are difficult and costly to arrange. On the other hand, if this is the only way valid information can be obtained, we will have to accept the difficulties involved. Perhaps short-cut, cheaper methods can be found. However, before accepting such methods, we should be sure they have been validated.

Some valuable information on consumer likes and dislikes can be obtained by less rigorous methods of testing. For example, reactions to gross differences in quality attributes may be obtained by appearance and eating quality tests carried out in stores and fairs, during conducted tours, educational meetings, etc. Such tests can be quite helpful in establishing the lower limits of acceptability, serious quality defects, and others.

Quality Attributes of Beef

Before going to the consumer to determine his reactions to food items, one should have a reasonably good understanding of the quality characteristics of the product most likely to influence his decision to buy and use them. In the case of beef, it seems to us that the following quality attributes are important:

1. Appearance factors (raw meat)
   a. Color, amount, and distribution of fat
   b. Color of lean
   c. Amount of bone
   d. Shape and contour of cut
2. Palatability factors (cooked meat)
   a. Aroma and flavor
   b. Tenderness
   c. Juiciness
3. Convenience
4. Wholesomeness
5. Nutritive value

The first three of these attributes are probably the only ones of which consumers are aware to the point of expecting to exercise some preference. The first two are of prime importance, although convenience is of growing importance as homemakers strive for most freedom from the drudgery of housekeeping.

Objective means for measuring important quality attributes are essential if a precise evaluation of consumer reaction to them is to be obtained. Of the appearance factors, color is perhaps the only attribute that is difficult to measure accurately. Even here, the availability of special instruments to measure tri-stimulus values greatly reduces the problem. All of the palatability factors are difficult to measure accurately, although the shear force measurement of tenderness is reasonably satisfactory when carefully carried out. Properly conducted sensory tests are the only valid methods available for measuring juiciness, odor, and flavor.

Present Status of Consumer Tests on Beef

Having reviewed the need for consumer acceptance tests as well as the methodology involved, let us take a look at the present status of such tests for fresh beef. A number of publications have appeared in recent years and apparently more are on the way. In studying the available literature, one is impressed by the fact that most workers have attempted merely to correlate U.S. grades of beef with consumer reactions. To us, this reflects a serious lack of appreciation of the basic problems involved in determining the important factors controlling consumer acceptance of beef of different characteristics.

Even with the short-comings of these tests, there appears to be evidence that consumers object to an excessive amount of fat. On the other hand, it would appear that they prefer the eating quality of such beef over that with less fat. This is a contradiction which, if really true, will have to be corrected by an educational program with consumers. It also appears clear that there is a serious, adverse reaction to toughness in beef.

Because of the nature of the tests, we are not sure of the degree of consumer reactions to beef quality since, in practically all of the surveys made, the results are confounded due to the fact that two or more variables were generally in operation during the tests. Perhaps a word of explanation about this problem is in order. Differences in acceptance between carcasses of different grades may not only be due to amount and distributions of fat or color of lean, etc., but also may be related to other quality attributes controlled by breed, strain or cross, age at slaughter, hormone treatment, aging treatment, nutrition, disease, and history. In order to sort out these effects, the meat used for consumer acceptance tests should be from animals which are fully comparable, except for the attribute under study. Thus, if we are interested in the relative acceptance of "tender" vs. "tough" beef, the cuts under test should be from animals uniform in all respects except those causing major differences in tenderness (e.g., age at slaughter or aging conditions after slaughter).

Another deficiency noted among the consumer studies conducted so far on beef is the frequent use of paired comparisons. It has been the experience of many in the field of consumer acceptance that the results from such tests are very difficult to interpret. While consumers undoubtedly will express a preference between two such samples, this is not a normal situation, and the results obtained do not accurately express the relative acceptability of the two samples under study. It is generally agreed, therefore, that it is better to judge acceptance by presenting test subjects with one sample at a time. Hedonic values of relative like and dislike attained in this way seem fairly accurately to reflect differences in acceptability.

Still another deficiency noted in the consumer acceptance studies carried on thus far is a lack of data on which to analyze variability, especially that due to chance. The use of replicate, coded samples permit accurate calculation of the repeatability of acceptance results. A minimum of duplicate samples for each variable is of course essential for estimating such errors.

Another poor practice in the conduct of consumer tests is in the use of photographs rather than actual cuts of beef. There is serious doubt whether acceptance results so obtained are valid. Then too, researchers frequently try to establish overall acceptance by using visual tests only. As already indicated, while many consumers object to the amount of fat cover in choice beef, they actually prefer its eating quality.

Needed Research

We believe that there are a number of additional consumer acceptance studies on beef that should be undertaken. The following would seem to be especially worthwhile:

1. Establish acceptability of various cuts of beef from carcasses of different levels of finish (in the absence of differences in other quality attributes).
   a. As an appearance factor
   b. In relation to eating quality
2. Establish acceptability of various levels of tenderness (in the absence of differences in other quality attributes).
   a. As affected by genetic factors
   b. As affected by age at slaughter
   c. As affected by aging time after slaughter
   d. As affected by the cut of beef used
   e. As affected by position of sample within the cut
3. Establish acceptability of color of lean variations (in absence of differences in other quality attributes).
   a. As influenced by age at slaughter
   b. As influenced by post slaughter treatment

In addition, much more needs to be done on methodology. Particular attention needs to be devoted to improving the reproducibility of results by test individuals, by test areas, etc. Also, a greater attempt should be made to introduce the economic factor into the test situation.

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Beef for Family Use

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THE COUNTRY OVER, families buy more beef than any other kind of meat. Only in the South—if findings of the U. S. Department of Agriculture survey of household food consumption made in the spring of 1955 (73) still apply—does beef take second place. Pork outranks beef in quantity consumed in this area.

Of all the meat used by families at home, 41 per cent was beef, according to this survey. Of the beef, 31 per cent was reported as steak, 28 per cent as roasts, and 30 per cent as ground meat. Stewing, dried, and canned beef made up the remaining 11 per cent. In addition, the survey families consumed some beef in products not identified by specific kind of meat. About 12 per cent of the total meat was reported as luncheon meats of various kinds—a broad group that includes frankfurters, Vienna sausage, bologna, canned luncheon meats, and other products likely to contain a mixture of meats. Another 3 per cent consisted of variety meats, such as liver, heart, and tongue.

City and farm families, the survey showed, eat about the same amount of meat per person in all regions except the South, where city families eat more meat than those on farms.

City families buy almost all of the meat they use. Farmers, on the other hand, produce about half of the meat for their tables. In 1955 they reported having produced about 60 per cent of their beef during the previous year. Availability of freezer facilities has contributed to a marked shift from pork to beef in farm production of meat for home use. Satisfactory home storage for beef had previously been lacking, whereas storage of pork has long been possible through curing. As a share of all meat eaten on farms, beef increased from 30 to 42 per cent between 1942 and 1955.

In 1955, beef, veal, pork, and lamb together claimed an average of 25 cents of each food dollar of the survey families. The proportion was a little larger in cities than on farms, and in the North and West than in the South. Differences in the place of meat in the food budget are largely explained by differences in income. Because of lower average incomes, the South as a region used less meat than other regions, but at comparable income levels, families there ate as much or more meat than did families in the North and West.

The larger the income of a family, the more money it spent for meat. The quantity eaten per person by high income groups was not as much greater than others as might have been expected. Instead of buying a great deal more meat the higher income groups used their larger buying power for more expensive kinds and cuts of meat. For example, they bought less pork and more beef, which is generally a little more expensive than pork. They bought more steaks and roasts, about the same amount of ground beef, and less of the cheaper stewing and boiling beef. Thus the expenditures for meats by the higher income groups are higher, both total and per person, due in large part to the higher priced products they buy.

On the average, for each 10 per cent increase in income, city families included in the 1955 survey tended to spend about 2.8 per cent more for beef (10). This income-expenditure ratio for beef was especially high in the South and West, and lowest in the North Central region. The 1955 figures reflect consumer behavior in a year when meat was abundant and low in price in relation to high employment and rising incomes.

The effect of income on consumption of meat by city families as shown by the 1955 study has been compared (10) with that found in two similar surveys—one made in 1948, and one in 1942. The years themselves are not entirely comparable. The greatest difference was the big increase in the general price level and in consumer incomes—first from 1942 to 1948, and then further by 1955. While it is possible partially to correct for the income-price difference by converting all income and expenditure data into constant dollars, other differences are not so easily resolved. 1942 was a war year. In 1948 meat prices were relatively high and meat supplies, especially of beef, small. In 1955 beef supplies were much larger and meat prices lower than in 1948.

The rate of change in amounts purchased from one income class to another was found to be slightly less in 1955 than in 1942 or 1948. The chief difference between 1955 and the earlier periods was the higher level of meat consumption at all income levels in 1955.

What Do Consumers Want in Beef

Most people who buy beef are interested both in a palatable and in an economical product. They want flavorful, tender, juicy meat on the table. They want a high yield of edible meat for their money, with a large proportion of lean in relation to fat. When they want fat they can buy it more cheaply in other forms.

The guide to quality most widely used by consumers seems to be its general appearance, including the amount of fat—both the separable fat and that seen in the marbled lean. A number of studies have been reported since 1952 on consumer buying practices, preferences, or acceptances that were made in several Central and Western States. Some of these studies show that many consumers want beef that is lean with little or no marbling (9, 11, 45, 54, 66). Others want a fatter meat because they associate fatness with juiciness, flavor, and tenderness (16, 46, 64, 75). They recognize, however, that large amounts of separable fat may mean considerable household waste (75).

Consumer choice of meat appears to be influenced by what people are accustomed to buying. In a market test in one city (75) three qualities of beef were sold at the same price but without grade identification. The lowest quality in the test cuts offered was bought most frequently in those stores where the customary practice was to handle beef of low market grade. In general, buyers were satisfied with the cuts they bought and gave as reasons for satisfaction, tenderness and flavor; for dissatisfaction, toughness.

How dependable are judgments of consumers in selecting meat of high cooking and table quality when these judgments are based chiefly on the amount of character of the fat seen on the meat?

Research reports on the influence of fat on palatability of beef cuts are conflicting. *Increased juiciness* with increased fatness has been reported by many workers (3, 8, 21, 30, 33, 43, 76). Dawson and her co-workers have summarized the extensive research sponsored by the U. S. Department of Agriculture on the effect of method of cooking beef or different market grades and produced under different conditions (29), and results indicate that cooking methods that minimize cooking losses may contribute more to juiciness than fatness *per se*.

More pronounced and *more desirable flavor* of the lean meat with progressive fattening has been reported by several investigators (3, 38, 39, 43, 76). But others point out that the character of the fat from different animals varies to such a degree that the flavor of meat may be affected more by the quality rather than by the quantity of fat (29).

Little or no relationship between *fatness and tenderness* of cooked beef has been reported by some investigators (24, 32, 35, 62, 76) but others have found that with increased fat content, meat tends to be more tender (6, 29, 30, 38, 42, 48, 50, 58). Palatability scores seem to be more closely related to intramuscular fat than to separable fat (21, 24, 67).

The seemingly contradictory results of these investigations reflect the fact that the physical and chemical structure of the product we call beef is very heterogenous. This heterogeneity may be found within the same cut and certainly in different cuts from the same carcass as well as in the same cut from different animals within a grade classification. Palatability is influenced by many interrelated factors. These include the breed, feeding management, and age of animal; the period and conditions of aging of raw meat (ripening); the amount and nature of connective tissue, both collagen and elastin; the size of muscle fibers; the fatness, including finish and intramuscular fat; and the method of cooking. The comparative influence on palatability of these many factors, alone and in combination, are not well understood.

Food store operators try to have the trim of cuts, quality, and variety of beef that attract and hold customers. A survey of 82 member companies of the National Association of Food Chains, operating over 9,000 stores located in nearly every part of the country, showed that 80 per cent of these companies use USDA grades to advertise and sell beef. The remaining 20 per cent use their own brands, packer brands, or a combination of these methods for selling beef. About half of those using USDA grades handle more than one grade as a usual practice in their merchandising, and all grades of beef produced find markets in some section of the country. (John A. Logan, February 5, 1959, "A Frank Look at Tomorrow's Beef Business.")

Studies made in a number of locations as to consumer preference for the different grades of beef that appear in present markets show that a substantial percentage of persons will state a preference for steaks graded Commercial to those graded Good, Choice, or Prime, when they judge quality from color photographs or from the appearance of the raw cuts of meat (9, 16, 17, 45, 46, 54, 66, 69). These choices probably are highly influenced by leanness and the relatively low amounts of fat. In consumer tests involving cooking and eating paired graded steaks, on the other hand, higher grades are preferred as a rule over the lower (31, 44, 63, 65). Some consumers state a preference for low amounts of external fat such as often characterizes the Commercial grade of beef but want the degree of marbling associated with Prime grade (79).

Interest of consumers in the fatness or leanness of meat is probably of complex origin. Experience holds that some degree of marbling is essential to tenderness, juiciness, and flavor. But as mentioned earlier, homemakers are concerned about the reduced amount of lean that comes from each pound of meat as amounts of separable fat and marbling increase, and about the high per-pound cost of fat when it is bought as part of beef. In addition, health reasons are given by some for their current interest in diets higher in protein and lower in fat that once were acceptable.

Some Recent Research on Methods of Cooking Beef

Regardless of the market grade or the degree of fatness of meat, the method of cooking greatly affects the acceptability of the product that comes to the table.

In recent years several state agricultural experiment stations and universities undertook an exploratory series of meat investigations sponsored by the U. S. Department of Agriculture, which were designed to broaden our base of knowledge about household preparation methods for some of the lower market grades of beef. Paired cuts of beef from carcasses of different market grades were cooked both by commonly used dry methods—roasting and boiling—and by moist methods—stewing or braising on top of the range, in an oven, and in the pressure cooker. The cuts were from steers and cows of various ages, some grass-fed and some finished with dry-lot feeding. The raw meat differed in fat content and other components that generally are considered to affect the palatability and nutritive value of cooked meat. While the cuts chiefly represented carcasses corresponding to Good, Standard, or Commercial market grades, some meat of Prime or Choice grades was also included. Results obtained at the various locations have been or are being published by the respective investigators or institutions—Cover of the Texas Agricultural Experiment Station (26, 27), Fenton of Cornell University (32), Griswold of the University of Chicago (34), Harrison of Kansas State College (36), Hood of the University of Georgia (41), Lowe of Iowa State University (48), and Paul of Michigan State University (59). The results have been collated by Dawson and co-workers in a U. S. Department of Agriculture publication now in press (29).

Unquestionably, method of cooking can contribute a great deal to the eating quality of beef. We know that cooking develops flavor, especially when the meat is browned in the fry-pan, in the oven, or under the broiler. The flavors developed by the conventional dry cooking methods of broiling or roasting have come to be highly prized. These flavors have become associated with steaks and roasts of rib and loin cuts—cuts that comprise only a small proportion of the beef from each carcass. Other cuts have usually been considered not tender enough to give acceptable products when subjected to dry cooking methods. Cuts from the shoulder or round, for example, have ordinarily been prepared by moist cooking methods.

The use of moist cooking methods to tenderize beef, especially cuts from carcasses of low market grade, has been recommended on the premise that these cuts contain large percentages of connective tissue (40, 50, 56, 57), and that by converting the collagen to gelatin by the application of heat in the presence of water, a tender product will result (47). The rate of conversion of collagen to gelatin is believed to be influenced by temperature and time of cooking, size of pieces of meat, acidity of the cooking solution, and denseness or kind of collagen. The relationships between collagen content and tenderness differ with the muscle (20, 28), and it has been pointed out that the nature of the connective tissue (the proportions of collagen and elastin) rather than its quantity may be the determining factor of tenderness (55).

Tenderness in beef may not increase consistently with increased cooking time (29). In cuts cooked to the rare stage, the connective tissue is altered only slightly or not at all, and the muscle fiber proteins may be only slightly coagulated. In cuts cooked to a more well done stage, the effect of cooking on tenderizing beef depends on a balance between the softening of connective tissues and the firming of muscle proteins (48).

End-point temperatures

The end-point temperature to which meat is cooked is an important consideration in achieving palatability. Generally, meats cooked to relatively low internal temperatures are more tender, juicy, and flavorful than those cooked to high internal temperatures. The USDA-sponsored research has shown that broiled or roasted cuts of loin, rib, and round were generally more tender, juicy, and flavorful when cooked to an end-point temperature of 160° F. (medium) rather than to 176° F. or 194° F. (well done). It also has shown that braised meat cooked to the lower end-point temperature is preferable. In paired cuts of round from steer beef, the meat cooked to the lower internal temperature tended to be the juicier, and about equally tender and flavorful (20, 29, 48). Increasing the internal temperature to which a roast or steak is cooked (well done vs. rare) tends to decrease the yield because of shrinkage, especially that due to losses through evaporation (47, 51, 60).

Oven temperatures of 300° to 325° F. usually are recommended for dry cooking of beef, but still lower temperatures, e.g., 250° F., have been suggested (1, 18, 68). Griswold (34) reported that round of beef roasted at 250° F. scored high in flavor and was more tender but less juicy than that roasted at 300° F. Roasting beef at an oven temperature of 300° F. to 350° F. results in less weight loss than roasting either at a high temperature (47) or at a temperature so low that the cooking time is greatly prolonged (49).

Dry versus moist cooking methods

Paired cuts of round of beef, cooked to the same end-point temperature, generally scored higher in tenderness, juiciness, and flavor when prepared by dry than by moist methods (15, 19, 29, 41, 59). And when lower end-point temperatures were used for oven roasts than for braised cuts, palatability generally was better for those cuts cooked by dry than by moist methods (14, 26, 29, 59).

The method used for braising seems to have less influence on palatability of beef than the internal temperature to which the meat is cooked (13). No differences in palatability scores were noted in braised beef round *(semitendinosus muscle)* whether cooked in the oven or on the range, even though the latter required a longer time to reach the internal temperature of 176° F. (41). However, pressure-braised beef cooked to the internal temperature of 176° F. was less juicy and flavorful than oven-braised beef but more tender (29). Pressure braising beef to an internal temperature of 216° F. resulted in a more palatable product but greater weight losses than oven braising to 209° F. (29, 32, 34).

Yield of meat cooked by roasting or braising varies with the thickness of the cut and conditions of cooking time and temperature. Roasting at 300° F. gave a little higher yield, 3 percentage points, than braising at 300° F., with either 1½-inch or 3-inch thick cuts. Thin cuts of beef cooked at higher temperatures for a short time give better yield; the thinner the cut the higher should be the temperature and the faster the cooking (59). Under other cooking conditions slightly higher yields were obtained with braised than with roasted cuts (29), probably because of higher moisture content.

Nutritive value also must be considered in evaluating cooking procedures. Beef makes its special contributions to nutrition chiefly through the high-quality protein, iron, and B-vitamins it provides. To whatever extent these nutrients are water soluble or affected by heat, the factors that affect nutritive value are cooking time and temperature, size and shape of cuts, and amount of water used in cooking. In the USDA-sponsored studies (29), retention of the B-vitamins in the lean meat was found to be higher when dry methods rather than moist methods were used (27, 41), but a considerable proportion of thiamine, riboflavin, niacin, and pantothenic acid occurred in the drippings (2, 22, 23, 53). The difference due to method of cooking would be small if all of the drippings were utilized. Thick cuts generally retained slightly more of the B-vitamins studied than did the thin cuts (27, 29). Thiamine was more affected by both braising and roasting than were the other nutrients (27, 39).

It has been suggested that a short cooking time even at a high temperature favors thiamine retention in beef. Higher thiamine retentions have been reported in fried steaks than in broiled or braised steaks (72), in rare than in well done roasts (25), and in broiled steaks than in oven roasts (27). However, in roasts, thiamine retention has been reported to be higher when the meat was cooked a longer time in a 300° F. oven than when cooked a shorter time in a 450° F. oven (22, 52). This result was found also for retention of pantothenic acid, niacin, and riboflavin (22).

Since much beef is purchased by *market grade,* I shall mention some results of the USDA-sponsored studies that relate to grade. When braised, cuts of beef of Good and Commercial grades were almost as satisfactory in eating quality as those from carcasses of Prime or Choice grade. When roasted, beef graded Good and Commercial generally scored lower in tenderness than that of Prime or Choice grade, but the scores received by the meat of lower grades indicated very acceptable products—average or above in flavor, juiciness, and tenderness. Thus meat of very satisfactory eating quality can be obtained from animals less well-fattened than those achieving the Prime grade (29, 34, 48). In general, yields of the cooked edible portion from beef cuts of Prime and Choice grades were higher than from lower grades of beef (29, 32, 34, 48). Yield could not be consistently associated with fat content, however, (29) because of wide variations in the amount and the location of fat found within each grade classification.

Economy in use of meat

Since a large share of the family's food money goes for meat, many homemakers must stress choosing wisely and shopping carefully as well as cooking properly. They often compare relative economy on the basis of the cost of a serving of lean meat, inasmuch as meats as purchased generally include parts that cannot be eaten, such as bones and gristle, and include more or less fat, part of which may be discarded in the kitchen or at the table. A given serving of lean of beef from chuck roast provides about the same amounts of nutrients, for instance, and is likely to be quite a bit less expensive than that from a rib roast. But inexpensive cuts may be no bargain if they contain such large amounts of bone, fat, and gristle that there is relatively little lean meat present.

Homemakers often take advantage of different techniques for tenderizing meat in efforts to use the lower priced and so-called less tender cuts of meat. Mechanical techniques include grinding, cubing, slicing, and pounding to break up the muscle and connective tissue. Grinding is the most widely used. Other procedures vary in effectiveness. For instance, Griswold (34) found that pounding increased tenderness of beef, but scoring did not.

Household use of commercial enzyme-containing preparations for softening connective tissue and muscle protein has become popular. The satisfaction from the use of a tenderizer depends greatly on the concentration used, the uniformity with which it is distributed throughout the muscle, and on the temperature of the meat (37, 47, 58, 70, 77). While the application of enzymes can increase the tenderness of meat, it can have a deleterious effect on juiciness and flavor unless it is well controlled (29, 58).

The preoccupation of today's busy homemakers in saving time as well as money has accented interest in cuts of meat that are ready for cooking without much preparation and cuts that can be cooked quickly. Thin tender cuts, ground meat, and frozen precooked products have become increasingly popular. Research has given some information about factors that affect the eating quality of the frozen precooked meat products and the problems encountered in producing high quality items. Roast beef, Swiss steak, hamburger, and meat loaf have been the main beef items featured in precooked "television" dinners (71, 74). The most successful frozen cooked meat dishes are those prepared with a sauce or gravy which gives the meat considerable protection from oxidation and moisture loss during frozen storage. Other cooked meats —roasts, loaves, patties, broiled steaks— have been frozen with only moderate success. One unsolved problem is how to avoid the "warmed over" flavor of precooked meat, particularly of roasts and steaks. Another need is for better home methods of reheating meat. Some hospitals find the use of the electronic oven advantageous for reheating foods (4, 78).

The time required for cooking meat is considerably less when the electronic oven rather than conventional methods is used, but the shrinkage in meat is much greater (5, 7, 12, 61), and the cooked meat is less juicy (7). Unless the meat is pre-browned by other means, the flavor is less well-developed. When roasts are cooked to the rare stage by microwaves, distinct areas of well done, medium, and rare appear from outside to inside (5, 7).

Some Concluding Remarks

Beef is a very popular meat with American families. If relatively inexpensive and of good table quality, more would probably be eaten, especially by families in low-income brackets.

The kind of beef that tomorrow's families will prefer would seem to be a lean product that will be tender, flavorful, and juicy whether cooked by dry or by moist methods. Perhaps more of the beef now on the market can be cooked by dry methods than the public commonly realizes. Falling into this category is much of the beef marketed at relatively young age and with less finish than the Prime grade calls for—perhaps even less finish than is represented by the Choice grade.

The beef of tomorrow that will come from animals produced under conditions that might result in tough products if handled by usual methods should be specially tenderized under controlled commercial conditions so that it can readily be made into juicy, tender, flavorful products when it reaches the Nation's kitchens.

It is unlikely that visual inspection by the household buyer can ever be as good a guide to potential table quality as the judgment of the meat expert. He can be knowledgeable both about the appearance of high-quality beef and about the effect of different treatments to which beef may be subjected during production, processing, and in channels of distribution.

The beef of tomorrow should be fully labelled as to probable tenderness and to suitability for different cooking methods. Information on age of animal and other facts that may prove to be significant for cooking and eating quality of meat might be indicated.

Research has given us much information to help the homemaker use fresh and frozen raw meats in ways that make for palatable, nutritious, economical products. But much of the research has been with experimental beef animals of known history and often on only one muscle, cut as the rib or loin. Results so obtained may not always be applicable to all of the many different qualities of beef found on the market, nor to the many cuts or forms in which the meat from any carcass may appear.

Many problems relating to the home preparation of frozen prepared meat-containing products remain to be solved—how best to reheat them and conditions under which meat cooked to rare, medium, or well done stages can be frozen and reheated.

There also are problems in planning nutritionally balanced meals using the highly processed and ready-to-use foods now available. And before newer preservation techniques such as dehydrofreezing, dehydrocanning, or treating with antibiotics or irradiation come into wide use, the influence of these treatments on the palatability and nutritive value of beef should be thoroughly investigated.

The more services that are added to food while in market channels, and the more processing to which foods are subjected between the site of production and the site of consumption, the greater are both the opportunities and the responsibilities of industry for maintaining or improving the qualities of concern to consumers. This applies also to the production of the "Beef for Tomorrow."

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Discussion

Session I
The Beef We Want

GEORGE SCARSETH: Is there a parallelism between the problem of consumer acceptance in marketing in the meat industry and in the automobile industry?

DR. G. F. STEWART: I think it is pretty obvious that there are parallelisms because we are dealing with the same person. I think there is something to be said on both sides about it. It is very difficult to get information you want. There is something sacred about telling people what you are going to do and not going to do, as those who didn't vote for Truman will remember. You don't always tell people what you are going to do, although you may give them answers to questions.

I think there is also a very grave danger in the desire to give people what they ought to have. You sense this in a good many places where people decide this is really what people want but not what they say they want. I think this was perhaps exemplified by the lack of interest on the part of the American automobile manufacturers to give people a compact car. But we just decided in spite of all of the evidence that they got that we really needed a compact car. Of course, this is all conjecture because I am not connected with any research along these lines.

R. E. RUST: To what extent do we know how a consumer develops specific tastes or wants? Is it something instinctive, or is it something cultivated and developed? If it is the latter, is there a possibility we might supply this consumer demand with a development of cultivated tastes according to the type of product we can offer them, or most economically produce?

DR. STEWART: I think there is no doubt that tastes can be changed. This is, I think, even a tougher problem than establishing what the current tastes are and how to meet them. I think it is one that you have to face, particularly as we enter into the area of consumer convenience foods, because obviously here you have to make certain kinds of compromises to prepare these products.

I know of very little work along this line, but I think it is something that ought to be encouraged, particularly from the basic standpoint of psychology and sociology and so on. It is so evident in this field that we are undergoing changes in tastes. We see some of these convenience items which we technologists were sure were no good, but some how or other consumers are eating them. I think today this has been largely a trial and error proposition and those lucky enough to succeed are in business.

DR. STIEBELING: I think we start out liking what we are used to, and we learn to like other things very largely because of what people who occupy prestige positions in relation to us like. We also change our minds about things because we find there are other considerations than palatability that are important to us. There are many of us who sacrifice certain attributes of palatability because of time saving or convenience or cost factors. Acceptability of a new product depends upon whether it can serve a variety of values that people want from a product. Palatability, convenience, cost, all of these things are important.

H. H. COLE: I am wondering to what extent the housewife does at the present time select the meat. We are talking about the housewife being reached through this consumer reaction. Does she select the butcher or the meat?

DR. STIEBELING: Perhaps that differs in different parts of the country. Where I am at the moment, the meat is all cut, and you go in and look at it. Men are doing a good deal of the food shopping these days. Men are also helping to select the food that comes to the table.

DR. STEWART: I think the degree of selection is very small because stores these days don't usually bring in more than one kind of meat and if it is in a supermarket, they have very detailed ideas about the kind of meat they will let come into the store. The consumer has probably no selection of meat except between cuts that are already there. I think this is dangerous because somebody else is deciding what they want. I would like to see at least an opportunity for the consumer to decide what kind of meat she wants and to express that decision into the market channel.

T. C. BYERLY: Many of us eat in restaurants. What kind of beef are we served by choice? Soldiers eat beef. What kind of beef are they provided and why?

DR. STEWART: I presume there are some choices available. I think they are relatively restricted. Certainly in the Army they are restricted, except on leave time. I am not speaking as though the Army didn't do a good job in preparing beef. I think they have done a pretty fair job.

I presume you have choices in the stores you go to. Sometimes there are very few alternatives that you can live with. The same is true with restaurants. There are limitations in time, distance, and dollars, and so sometimes we make unhappy decisions. We aren't going to stop eating meat, but I expect we are not necessarily satisfied with what we are doing, and if we had the opportunity to make those decisions they might be quite different than those who are forced to make them.

DR. STIEBELING: Even when you have an opportunity to go to different stores that handle different grades of meat there are very few criteria by which you can decide whether it is going to be a good or poor piece of meat. When I was talking about further labeling, I didn't mean only a grade mark. I think a label can do a good deal more than just be a grade mark which has only taken certain characteristics into consideration. Unless you are provided with more information than now, you have to depend on either the integrity of the store to which you go or by whatever visual inspection you can make. The labeling, to my mind, isn't sufficient.

GERALD ENGLEMAN: Dr. Stewart seemed to imply at one point that meat is pre-selected, and this is a rather poor method. Suppose this meat were not pre-selected and the entire array were put in a package, from utility up to prime, rather indiscriminantly. How would the demand for beef be answered?

DR. STEWART: I think in the poultry field we feel that standardization has been a big factor in the increased consumption of this commodity. I am coming back in support of the chain stores who are taking a beating here. It seems to me this is what they are attempting to do. They are trying to standardize with all of the devices they have before them. This is the reason they pre-select because they assume that consumers will buy more beef from their counters if they do. I agree that the real problem of merchandising any product is standardization.

DR. ARTHUR: We learned a lot of things, some of those in a painful way, on this choice matter. We can get into all kinds of troubles with limitations of choice in the free market. A few years back when Swift and Company was offering some very excellent roasts in frozen form that had been molded into a nice square shape, we could prove without a question this sliced more economically and was highly acceptable, but the consumer wanted a standing rib roast with a rib in it. This block of beef roast is not now on the market. The homemaker had her choice. She showed us what it was, without any question.

F. E. DEATHERAGE: Appliance people feel that we haven't done a very good job of teaching the consumer how to handle frozen meat from the standpoint of kitchen cookery. Maybe this has some concern for the frozen ribless rib roast.

DR. STIEBELING: I am not aware of any particular problems in food preparation of frozen meat, excepting that you must be aware of the time factor. The literature seems to be a bit controversial on whether things are more tender if they are cooked after thawing or before thawing. I don't believe this is as much of a problem as the matter of handling foods properly prior to coming into the kitchen.

DR. ARTHUR: We would all agree there is to be a considerable job of consumer education. This is an area that represents a definitely continuing challenge. There is a question of how far one should go towards educating the consumer.

R. S. TEMPLE: From a geneticist's point of view, do we at present have clear-cut goals and targets at which to aim in producing the beef for tomorrow, or is it still in the research stage? Or, is this a problem of using the beef of today and merchandising it in a different light than we are at the present?

DR. SCHWEIGERT: I think a long range goal for heredity, inheritance, and genetics studies is to be able to select an animal with improved quality attributes and grading for characteristics. We should endeavor to minimize certain characteristics that may not show themselves on the table. In the meantime, we've got some very fine beef we are producing, and we can do a better job of improving present attributes.

DR. ARTHUR: The only reason cattle growers raise cattle as they do today is because people like beef and it is good for them. This is a good base from which to start any efforts of improvement.

An Evaluation of Consumer Acceptance Studies of Beef With Reference to Paper of Stewart & Mrak

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Consumer acceptance research must be evaluated in terms of the market context of the institutions, ideas, and problems existing concurrently. It cannot be viewed as solely a laboratory science expanded from the laboratory panel into a consumer panel, although acceptance researchers do have an experimental approach.

Contributions of consumer acceptance research in beef:

1. Called to the attention of producers the consumer dislike of wastiness in retail cuts—retailers already knew this.

2. Helped to develop the concept of lean, tender, tasty beef as the "beef for tomorrow." This concept was heresy four short years ago but is now solidly entrenched in the thinking of meats and animal researchers and of many industry leaders.

3. Have demonstrated

a. the absence of the traditionally assumed excellent relation between grades (and/or finish) and acceptability.

b. the presence already of much beef of excellent eating quality in the Good grade.

These demonstrations have helped to break a set pattern of thought which impeded satisfaction of consumers preferences by merchandisers, packers, producers, graders, and educators.

These demonstrations have promoted for investigation a whole series of questions which were not even asked seriously four years ago. Questions recently posed by Stewart and Mrak are good examples of this type.

4. Have studied the effect of individual variables to a considerably greater extent than Steward and Mrak realize *(See appendix for a bibliography on various subjects)*. However, the exploratory work on individual variables can be done most economically by laboratory scientists. Acceptance research is too cumbersome, expensive, and imprecise in comparison. For example, the relative accuracy of a new grading scheme and the present system might well be evaluated by a consumer panel, *after* clues have been discovered by technologists which show promise of superior grading.

5. Have indicated that variations in consumer eating preferences are not a major problem in the market-place. Four years ago it was generally assumed that quality variations (as indicated by grade) were associated with groups of consumers of different basic preferences as to qualities. The assumed problem was to determine how well the market mechanism matched different qualities with different preference groups. How wrong we were!

In any appraisal of contributions of a research effort, there is danger that the effects of concurrent events will be confused. Too much may have been claimed as contributions of preference research.

What can acceptance research be expected to accomplish in the future?

Such a question cannot be answered with accuracy, of course. It appears that the main tasks will be the rather prosaic ones of testing the impact of various factors, such as enzymes, upon acceptability and the accuracy of new sorting systems. Such research should be preceded generally by laboratory tests. It appears that the controversial era of beef acceptance research is past, although research always has some possibility of surprising results.

A more exciting—and perhaps profitable—phase of research may be in developing a better understanding of the "product image" of various beef cuts.

What improvements are needed in the methodology of acceptance research?

Stewart and Mrak's criticism of failure to isolate variables is not well taken. This "failure" was not due to ignorance of scientific method but rather to interest in more general problems. In point of fact, four years ago, we took products as given and were forced by our own results to recognize that "product design" was a more pressing problem than variations in eating or visual preferences of consumers. Our approach has often involved study of more specific variables since then, although the most important problem has been the general one of acceptability as related to grades, because of the crucial importance of grades in our marketing system.

Proper isolation of variables is likely to be aided much more by statistical techniques and much less by purely physical separation of the type implied by Stewart and Mrak. Single variations of one factor alone are often much more difficult and expensive to obtain and/or identify than might appear at first glance.

For example, a study of the effect of age at slaughter, all other variables constant, appears to be a relatively simple and useful experiment to the non-initiated. However, the problems of obtaining a reasonable number of cattle from the same sire which at slaughter are entirely alike in marbling, size, and shape of loin eye, etc., are astronomical. If one argues that somewhat different marbling, size, and shape of loin eye is characteristic of different age cattle, then the researcher must either use all the variations in those characteristics which accompany cattle of different ages or he must delimit the particular nature of those characteristics which he will allow. There are arguments for any of these approaches—the only point of this discussion is to question just what is meant by isolation of explanatory variables in a biological product with much partially concurrent variation of variables.

It is to be hoped that acceptance researchers may have some beneficial effect upon the methodology of livestock and meats researchers. With a few shining exceptions, these men have been statistically naive. Small sample studies with materials of as great a biological variation as meats must inevitably lead to conflicting results. These researchers need to become much more sophisticated in their understanding of the meaning of data and of its adequacy.

Really new developments in the methodology of acceptance research are likely to come from the psychologists and sociologists rather than from other disciplines. This likelihood will be higher to the degree that beef promotion and advertising become more important.

Partial Bibliography of Recent Consumer Acceptance Research

While more research is always "needed" in some sense in most areas, it seems relevant to note research already accomplished in areas listed as "needed" by Stewart and Mrak.

1. Establish acceptability of various cuts of beef from carcasses of different levels of finish (in the absence of differences in other quality attributes).

a. As an appearance factor
Major publications:

(1) V. James Rhodes, Elmer R. Kiehl, and D. E. Brady. 1955. *Visual Preferences for Grades of Retail Beef Cuts.* Missouri Res. Bul. 583.

(2) George W. Campbell. 1955. *Consumer Acceptance of Beef,* Arizona Rep. 145.

(3) C. Van Syckle, and O. L. Brough. 1958. *Customer Acceptance of Fat Characteristics of Beef,* Washington Agr. Exp. Sta. Tech. Bul. 27.

(4) R. E. Branson. *The Consumer Market for Beef.* Texas Agr. Exp. Sta. Bul. 856.

(5) F. G. Lasley et al. 1955. *Consumer Preference for Beef in Relation to Finish.* Mo. Res. Bul. 580.

b. In relation to eating quality
Major publications:

(1) V. James Rhodes, Elmer R. Kiehl, D. E. Brady, and H. D. Naumann. 1958. *Predicting Consumer Acceptance of Beef Loin Steaks.* Missouri Res. Bul. 651.

(2) Elmer R. Kiehl, V. James Rhodes, D. E. Brady, and H. D. Naumann. 1958. *St. Louis Consumers' Eating Preferences for Loin Steaks.* Missouri Res. Bul. 652.

(3) V. James Rhodes, et al. 1958. *The Effect of Continued Testing Upon Consumer Evaluation of Beef Loin Steaks.* Missouri Res. Bul. 676.

(4) V. James Rhodes, et al. 1958. *A New Approach to Measuring Consumer Acceptability of Beef.* Missouri Res. Bul. 677.

(5) G. T. King, and O. D. Butler. "Methodology and Results of Consumer Preference Studies of Steaks and Roasts from Cattle of Known History in Texas." *Proc. Recip. Meat Conf.* 9:72-74.

2. Establish acceptability of various levels of tenderness (in the absence of differences in other quality attributes).

a. As affected by genetic factors
Work has been underway for more than two years at the Florida and Texas Agricultural Experiment Stations.

b. As affected by age at slaughter
Work is reported to be underway at Oklahoma State University.

c. As affected by aging time after slaughter
Harry Sullivan. 1958. "Aging of Beef and Consumer Acceptance," M.S. thesis, University of Missouri.

d. As affected by the cut of beef used

(1) V. James Rhodes, et al. 1958. *A New Approach to Measuring Consumer Acceptability of Beef.* Missouri Res. Bul. 677.

Those of us who have been working full time in this area for several years would be the first to insist that problems remain unsolved in each of the areas reviewed above. However, those who attack those problems need to be aware of the foundation already laid.

Committee Recommendations

If efforts to discover what people want are to be reasonably successful, the design of the projects must be much broader than those undertaken to date, the methodology must be more thoroughly thought through before beginning work, and the work must be better controlled during the research period.

At the present time the demand for processed and other convenienced beef products, hamburger and sausage, has been increasing. More research is needed with respect to nutritional and physical quality of beef used in ground beef, sausage, and other processed beef in relationship to quality of the end product. In addition, some attention should be given to the effects of the changing beef requirements of the meat industry.

Because agreement is lacking among research workers on the definition of "quality" and the relative importance of the component factors that determine "quality" it is recommended that research be accelerated to ascertain the components of "quality" in beef, to develop methods for its measurements in the laboratory and market place, and to determine its importance in consumer acceptance.

Cows and Catalysts

Earl L. Butz
Dean of Agriculture, Purdue University

A CATALYST is defined as a substance which accelerates a reaction but is itself unaffected by the reaction. Many kinds of catalysts are used constantly in chemical manufacturing processes to speed up desirable reactions.

If some catalyst could be compounded which would markedly increase the total effective demand for beef, and at the same time reduce production costs, the cattle industry would be in the "Promised Land."

Fortunately, some such catalysts are available, and are working in the interest of the beef industry. They're not spectacular, but they're nonetheless real. Two of these catalysts operate largely independently of beef producers, and two others are at least partly under the direction of beef producers.

Total Demand for Beef Will Rise

The total effective demand for beef in the years ahead will depend on two factors: (1) size of the population and (2) changes in the amount of beef consumed per capita.

The latter factor in turn is dependent upon three things: (1) the amount of increase which may be expected in per capita real income (taking into account the relatively low income elasticity for food), (2) the impact on per capita consumption of an aggressive promotional and merchandising campaign, and (3) the impact on per capital consumption from lower relative selling prices and improved quality in the retail counter as a result of a stepped-up research program in the whole beef industry.

The first two "catalysts" listed above operate largely independently of anything the beef industry can do. The second two are largely under control of the leaders in the beef industry.

Our exploding population means a substantial increase in our consumption potential, even assuming for the moment a static per capita consumption. Our population now surpasses 177 million. It's growing by nearly 3 million per year. A recent Census Bureau projection estimates that by 1975, just 16 years from now, the population of the United States is likely to exceed 240 million. Extend this figure 4 more years, to a time 20 years from now, and the prospect is for better than 255 million people, or up nearly 80 million from present levels. A population increase of that magnitude is greater than our population growth during the entire nineteenth century. A 78 million increase in population represents a 44 per cent increase from the present base. Therefore, assuming no change in per capita consumption of beef, we could expect a 44 per cent increase in the total outlet for beef in the next 20 years.

Let's look now at the second "catalyst" —the rising purchasing power of our people. In the last 20 years the per capita real income of our people (after taxes and inflation) has increased by some 50 per cent. Reliable predictions are that it will increase by another 50 per cent in the next 20 years. Many economists think it won't take that long to go up 50 per cent.

While we don't increase our food consumption proportionately as income increases, we do eat some better. We improve the quality of our diet. We do this by shifting to a protein diet and other more expensive protective foods.

It's common knowledge that beef is a relatively desirable item in our national diet. It has sometimes been called a "luxury meat."

If our per capita real incomes go up by 50 per cent in the next couple of decades, we can be almost certain that the demand for meats, including beef, will rise some, although not by a like amount. And it's probable that the effective demand for beef, as a result of this income rise, will go up a little more than that for other competing meats.

If we can assume that the income elasticity for beef is 0.20, and it's my feeling that this assumption is on the conservative side, then we conclude that a 50 per cent increase in per capita income would result in a 10 per cent increase in the relative amount that would be spent for beef and beef products. This of course is at the retail level. It is likely, however, that as incomes rise, consumers will purchase more services with their food. Therefore, not all of this increase in expenditures for beef would be reflected back to producers. Hence, just to be conservative, if we cut the estimated income elasticity from 0.20 back to 0.10, this would then give us an estimated 5 per cent increase in the amount of money spent for beef and beef products (at the farm level) resulting from a 50 per cent increase in real income per capita.

Promotional Possibilities Are Often Overrated

We turn now to the third "catalyst," promotion. Some enthusiastic supporters of a greatly stepped-up promotional campaign for beef consumption expect results which it probably would be difficult to attain. We should be relentless in our efforts to acquaint the consuming public with the advantages of a high protein diet based upon a growing animal agriculture. Our efforts should be to expand the consumption of all meats. If we dissipate our resources in attempting to persuade consumers that they should eat more beef—perhaps at the expense of pork or lamb or poultry—about all we accomplish is to induce the pork, lamb, and poultry industries to spend an equivalent amount of money in "offset promotion," and the whole industry ends up about where it started except with a big promotional bill on its hands.

This is clearly an area that calls for a well-coordinated effort by all of animal agriculture.

There's Great Promise in Research

Research—the fourth "catalyst"—is under our control. It offers real promise on both the production and the marketing side. Research on the production side can be cost-reducing, and research on the marketing side can be consumption-expanding. Indeed, reduction in production costs themselves can be consumption-expanding, if such cost reductions are at least partly translated into lower selling prices in the retail counter.

We have stepped up our efficiency of beef production in recent years, but not enough. Over the past 30 years, evening out cyclical fluctuations in cattle marketings, growing cattle numbers have just about kept pace with our growing population. Each has increased about 43 per cent in the last 30 years. However, if beef marketing were geared to beef numbers alone, consumers would be getting no more beef per capita now than they did 30 years ago. But the production of beef per head has also increased by about 44 per cent, so that consumers now eat substantially more beef per capita than three decades ago. Our people in 1959 are eating about 80 pounds of beef per capita, contrasted with 55 pounds per capita in 1935-39. This is an increase of 44 per cent from 1935-39, and an increase of 22 per cent from 1947-49. This per capita consumption figure is down from the 85 pounds consumed in 1956 and 1957, because of reduced marketings in

1959. However, again making allowance for cyclical variations, the increase in the last 3 decades has been approximately 44 per cent. Since this is based on approximately the same number of cattle on farms per capita as 30 years earlier, the entire increase in consumption may be attributed to increased beef output per animal, which in turn is based largely on research in the beef industry.

However, before we rest on our research laurels in the beef industry, we must take a look at our cousins in the poultry industry. Per capita consumption of chicken meat in this country has more than doubled since 1935-39, being 219 per cent of the earlier figure in 1959. A similar figure for turkey meat is 268 per cent.

American consumers have not flocked to increased poultry and turkey consumption in such record proportions because they suddenly preferred drumsticks over T-bones. They did it because poultry and turkey meat have been placed in the retail counters of America at such attractive prices that Mrs. Housewife just couldn't resist picking up an extra package or two. And those attractive prices were made possible because the modern poultry industry is based almost entirely on recent research. Today's poultry industry would have been impossible 20 years ago, without the research applications that have gone into it since the war. Research in the poultry industry has advanced on the multiple fronts of genetics, physiology, nutrition, and management. No sector of the industry has been left unexamined, from the feed bag to the dressing plant. Costs have been cut everywhere. Efficiency has been stepped up wherever possible. Even the time-honored breeds yielded before the more efficient production records of hybrid strains. An aggressive program of research enabled the poultry industry to build a great new market in this country where only a small one existed before.

Your competition is not resting. Although per capita consumption of pork has not increased as much as per capita consumption of beef, in recent years science has been moving rapidly into the hog lot. The stage has now been set there for revolutionary changes in production and marketing. Thirty years ago it took 5.1 pounds of feed to produce a pound of gain for all hog producers in the United States. In 1950-54 this was reduced to 4.5 pounds, or an improvement of 12 per cent. The advances since 1954 have been marked. We now know how to make a pound of gain for 3.2 pounds of feed, or 37 per cent better than 3 decades ago. Good producers are doing this consistently. Some really good ones achieve a feed conversion ratio of 3.0.

The work in litter testing and certification is moving forward rapidly. There is some evidence that we are on the verge of a major breakthrough in pigs per litter, as we learn more about pre-natal lethal factors in brood sows. The race for cost-reducing efficiency in pork production is currently being propelled with high-octane fuel.

We need to step up our total research program in the U.S. beef industry. If we are going to meet the anticipated more than 50 per cent increase in effective demand for beef in the next 20 years, we'll probably do about half of this with increased cattle numbers and about half with increased production per animal. It now appears that cattle numbers on farms January 1, 1960 will probably be around 102-103 million head. They may pass 105 million head before they start down again. This will compare with the previous peak of 96.8 million head in 1956. The cattle cycle will continue in the foreseeable future, with ups and downs in numbers about as in the past. However, each peak will be higher than the previous peak, and each trough higher than the previous trough. In 20 years we'll need at least 125 million head of cattle in this country to feed our growing population, assuming that we can in the same time increase our beef output per animal by one-fourth.

This is the job cut out for research.

We must not let current agricultural

surpluses, nor the prospect of increased cyclical marketings of beef two or three years hence, dissuade us from our long-time campaign to achieve better living for all of us through research.

The application of science to American agriculture forms the very cornerstone of the high standard of life that all of our people enjoy. American agriculture is now feeding our growing population on science and research. This enables us to release such a large share of our population and our production resources to produce non-food items and services that the American standard of living has become the envy of the world.

Research is the expandable term in the beef equation for tomorrow.

The people will be here by the millions, their incomes will be high, and their appetite for beef will be whetted.

What a fertile reactor into which to pour a generous quantity of our most effective catalyst—Research.

SECOND SESSION

How to Identify the Quality of Beef

C. Peairs Wilson, *presiding*

Factors Indicative of Quality in Beef and Their Measurements

A. M. Pearson
Michigan State University

THE WORD QUALITY has many connotations and each of us probably has a different conception of quality in beef. In speaking of quality in beef, I am referring to that combination of physical, structural, and chemical characteristics which result in a maximum desirability from the standpoint of appearance and eatability. Thus, beef of the highest quality is attractive to the eye and produces a maximum of satiety upon consumption. Such a combination of traits will not only contribute to impulse buying at the meat counter but to continued consumption of beef.

Factors Contributing to the Appearance of Beef

Three attributes of meat would seem to contribute towards the desirability of its appearance: (1) color of lean, (2) color of fat, and (3) firmness of the cut.

Color of Lean

Color of lean is seemingly the most important factor from the appearance standpoint. The effect of discoloration or off-color upon the saleability of beef is well recognized by the meat retailer. Most of the color problems with beef are not directly related to production, but are associated with handling at the retail level. A discussion of the handling problems is not feasible, but suffice it to say, a number of compounds, such as nicotinate, ascorbate, and carbon monoxide, are available for color stabilization. However, approval for usage is necessarily controlled by Federal laws.

A problem of more importance is that of dark-cutter beef, or beef which fails to brighten on cutting and exposure to air. Hall, Latschar, and Mackintosh (1) investigated the characteristics of dark cutting beef and established the fact that the brightness or darkness was pH dependent. At pH 5.6 or below, the color was normally bright, and at 5.7 commenced to become shady or dull, while at 6.5 or above was dark. The oxygen uptake capacity of the dark muscles was greater than for the bright muscles, which indicated the failure to brighten was a direct consequence of the higher pH. Analysis showed the muscle glycogen reserves were partially depleted at death making less glycogen available for breakdown to lactic acid, which is directly responsible for the ultimate pH of the tissues. Proper handling prior to slaughter can materially reduce the incidence of this problem (2).

Work with pork reported by Wilson *et al.* (3) indicated a marked breed variation in color of lean. Differences were especially marked in the darker colored muscles. The major differences in color appeared to be related to variation in myoglobin content of the dark muscles between breeds. Whether variation in myoglobin content occurs between breeds or lines of cattle is not known, but studies are needed to ascertain if myoglobin content may be a factor in color of beef.

Color Measurement. Color is difficult to measure since it is composed of three independent variables: hue, chroma, and value. Nickerson (4) has written an excellent review on the subject of color.

As mentioned earlier, myoglobin content can be used as an indication of color, but is not an accurate measure (5). Winkler (6) developed a photoelectric color comparator, which has seen limited usage in meat studies. The Hunter Color and Color Difference Meter (7) has been widely used in meat studies and operates as a tristimulus colorimeter that measures color directly on three scales, brightness, redness, and yellowness. Disk colorimetry was developed by the USDA (5) and makes use of varying the proportion of red, yellow, black, and white. The percentage of these colors can then be converted to Munsell renotations of hue, value, and chroma. A number of workers (8, 9) have used the spectrophotometer for color measurements, while color paddles have been used in most work on the dark-cutter beef (1).

Unfortunately, none of the methods for measuring color is easily described in terms which can be readily understood. However, it would appear that either the Hunter Color and Color Difference Meter or the Munsell Spinning Disks are the best methods currently available. A simple, rapid method is still needed which can be used to express meat color in a direct meaningful manner.

Color of Fat

USDA grade specifications for color of fat have been deleted, but many graders and most retailers discriminate against cattle with yellow fat. The basis for the objection is that cattle with yellow fat "lack in quality" or are of "inferior breeding.' To my knowledge, there is no basis for such discrimination. Consumer studies in Washington (10) and Texas (11) have indicated that yellow fat *per se* is not objectionable to the consumer.

Color of fat can be influenced by breeding and feeding. It is well established that Jerseys and Guernseys (12) tend to store their vitamin A reserves in the form of carotene, which imparts the yellow color to fat. Grass-fed cattle also tend to store carotene, and thus, have yellow fat. Therefore, the discrimination against yellow-fat seems to be largely a result of the association with certain dairy breeds or with feeding on grass.

In final analysis, color of fat would appear to be of little importance from the consumer standpoint. Any advantage in color of fat from cattle having similar breeding and finish would tend to favor yellow fat, because of the greater potential vitamin A potency (13).

Measurement of Fat Color. Determination of color of fat can best be accomplished by extracting the fat and measuring the concentration of carotene per unit of fat by either a colorimeter or spectrophotometer (14). Although attempts have been made to develop visual standards for fat color, application has been difficult.

Firmness of Cuts

Soft watery cuts are unattractive and move slowly at the retail outlets. Because measurement of firmness is difficult, studies have necessarily been limited. The factors responsible for softness are not well-known in beef, although extensive studies have been conducted with pork (15). Results of the studies on pork would lead one to believe the major causes of softness are related to diet. However, according to Maynard (12), cattle tend to deposit their fat in a characteristic manner for the species regardless of diet. This has been borne out by studies at the Iowa station (16, 17) showing that firmness of fat and lean was not altered by the addition of high levels of oils to a basal ration. Age appears to have a definite effect upon firmness, with calves and veal being soft and watery while older cattle are more firm. Recent work by Swift and Berman (18) would indicate that firmness varies from muscle to muscle in the same carcass and tends to follow the same pattern between carcasses.

Measurement of Firmness. Subjective visual ratings appear to be the most reliable means of measuring firmness. This would seem to generally be adequate, since only major differences appear to be important. Recent studies by U.S.D.A. workers (18) indicate that water retention of muscles may possibly be used as an index to firmness, but this has not been definitely established.

Factors Contributing to Eatibility of Beef

From the standpoint of the greatest amount of satisfaction upon consumption, the consumer appears to desire a maximum of tenderness combined with his ideal for juiciness, aroma, flavor, and texture. It is obvious that all may not desire the same combination of factors since preferences vary from person to person.

Tenderness

Consumer surveys have indicated that tenderness is the most important single characteristic desired from the palatability standpoint. Recognition of tenderness in the beef carcass without subjective or objective testing is much more difficult. Many different factors have been suggested as possible indicators of tenderness including such items as conformation, maturity, finish, marbling, and histological structure. Conformation does not appear to be related to tenderness according to recent studies (19).

Maturity. It has been generally accepted that older animals are not so tender as young animals. Work at the Iowa Station (20) indicated that age was related to tenderness, while more recently work at California (21, 22) has shown that cattle finished at 18 months were more tender than those finished at 30 months. This was true for both a large scale household type panel and for a trained taste panel. Thus, maturity of beef at the time of slaughter appears to be an important factor in aiding tenderness.

Determination of maturity is a much more difficult task. Maturity in the carcass is generally ascertained by subjective judgment as to the appearance of the bone and cartilage. It is apparent that this may not be an indication of age *per se.* In fact, McCay, Crowell, and Maynard (23) have shown with rats that when growth was slow, the rats grew longer and the epiphysis did not ossify until they reached a more advanced age. Although Winchester and others (24, 25) found delayed growth did not effect the tenderness of cattle, they did not make studies upon the nature of the bone and cartilage at slaughter.

It is evident that bone appearance or maturity alone is not responsible for tenderness since some 3 to 5 per cent of all cutter and canner cows are as tender as young beef. Thus, work is needed to ascertain if a relationship exists between hardness of bone and tenderness. Measurement of hardness of bone is difficult. Breaking strength has been used but is not a true measure of hardness (26). Rockwell numbers cannot be used for measuring bone hardness, as the sponginess and resiliency of bone makes such determinations meaningless. Measurement of bone hardness by total ash determination per unit of weight appears to be the most feasible method.

Finish. The amount and distribution of fat covering has been emphasized in the past. The trade has required a completely and uniformly covered carcass. The reasoning behind such requirements has been that the fat prevents the carcass from drying out and allows for aging and shipping. It has also been claimed that the thicker covered carcasses are more tender, if other things are equal. It has been reported by several workers (27, 28, 29) that as a stepwise decrease occurs in grade, the average tenderness score is lowered. However, there is generally considerable over-lap between grades, and differences between adjacent grades are usually not greatly different. Whether this effect is due to fat *per se* or due to some other associated factor is not known.

Measurement of finish can be accomplished by specific gravity determinations on the entire carcass or for any particular cut. A number of workers have indicated the reliability (30, 31, 32) of specific gravity as an indicator of finish. Linear fat measurements can be used to measure exterior fat thickness, but variation from site to site may minimize its value. Furthermore, linear measurements do not account for either intra or inter-muscular fat deposits. Actually, the most accurate way of measuring fatness is by grinding and chemical analysis or by physical separation. However, both chemical analysis and physical separation are time consuming, tedious, and expensive. Selection of a method for determining fatness would therefore depend upon the nature of the study being conducted and the availability of facilities, funds, and manpower.

Marbling. The amount and distribution of intramuscular fat, commonly called marbling, has been quite generally accepted as an indicator of tenderness by the trade. The basis for stressing marbling is unquestionably the result of earlier experiments (20, 34) which showed higher finished cattle to be more tender. Furthermore, there should be a mechanical advantage to marbling, if the fat and its supporting connective tissue are more tender than lean. However, Ramsbottom, Strandine, and Koonz (33) found extreme variation existed in tenderness readings from external fat samples taken from different sites. Although no feasible method of measuring the tenderness of marbling is available today it is conceivable that the resistance offered by marbling could differ from location to location and from animal to animal.

Although Hostetler, Foster, and Hankins (34) obtained evidence that marbling was not an important factor in tenderness over 20 years ago, marbling has continued to be stressed by trade practices as important. The earlier work was further collaborated by Ramsbottom, Strandine, and Koonz (33) who in 1945 stated, "The data show that there was no relationship between the amount of fat within the muscle and the shear of the raw or cooked muscle."

Cover, Butler, and Cartwright (35) studied the effect of marbling (ether extract) upon tenderness, and found a disappointingly low relationship for a factor receiving such homage. The correlation of coefficients are summarized in Table 1. Palmer *et al.* (36) obtained similar relationships between marbling and tenderness of loin steaks which has since been further substantiated by Wellington and Stouffer (37). Thus, results would indicate some factor other than marbling is responsible for tenderness variation.

TABLE 1
Relationship between Ether Extract and Tenderness

	Tenderness Score	Shear Force
Loin		
Broiled	.34	−.33
Braised	.30	−.34
Bottom Round		
Broiled	.50	−.35
Braised	.54	−.52

Measurement of marbling can be accomplished by ether extraction of the ground muscle, which is probably the accepted method. Orme *et al.* (38) were able to obtain a good estimate of marbling by specific gravity determinations, which is a fairly simple, non-destructive, but painstaking method. Visual estimation of marbling deposits has been made with good accuracy, but the method is too subjective for worker to worker comparisons. Recently, Blumer and Fleming (39) have proposed the use of a colony counter as a visual means of determining the amount and distribution of marbling. Interestingly enough, they found considerable variation in marbling from side to side and location to location within the same muscle.

Histological Structure. As the science of biochemistry has come into its own, little emphasis has been placed upon histological structure as it is related to tenderness. Most of the work has come from the laboratory of John Hammond (40) at Cambridge or from the American Meat Institute where Wang (41) has conducted some excellent studies.

Joubert (42) at Cambridge has recently shown that there was no increase in the number of muscle fibers after birth, with muscular growth during post-natal life occurring as a hypertrophy of individual fibers. This is in agreement with earlier statements of Hammond (40). Joubert (42) studied the effect of breeds of cattle upon muscle fiber diameter and found that Friesan and Friesan crossbred steers had significantly thicker muscle fibers than the pure- or crossbred Dairy Shorthorn steers. Table 2 gives a summary of mean fiber diameters for the different breeds and crosses. The effect of fiber diameter upon tenderness is not clear-cut, although with beef a low relationship between fiber diameter and tenderness has been verified by a number of workers (43, 44). Thus, fiber diameter is obviously not directly responsible for tenderness variation, although other structural differences may be primarily responsible for tenderness.

TABLE 2
Muscle Fiber Diameter of Different Breeds and Crosses

	Muscle fiber diameter (u.)
Dairy Shorthorn	
X Dairy Shorthorn	44.00
X Hereford	45.75
X Angus	46.50
Mean—Dairy Shorthorn Crosses	45.36
Friesian	
X Friesian	49.50
X Hereford	47.50
X Angus	49.25
Mean—Friesian Crosses	48.63

The amount and character of connective tissue has been extensively studied. Ramsbottom, Strandine, and Koonz (33) studied samples of white and yellow connective tissue both before and after cooking. Both types of raw connective tissue had very high shear readings, while after cooking considerably less force was required to shear the white connective tissue than the yellow. However, data available indicates that connective tissue is not the major contributor to tenderness as Wierbicki *et al.* (45) have been unable to relate hydroxyproline content, which is a good index for amount of collagen, to tenderness.

Recently Pearson, Spooner, and Orme (46) at the Michigan Station investigated the distance between the A-Z bands as a possible measure of thickness of the sarcolemma, which could possibly be related to tenderness. Results showed no relationship between tenderness and the distance between the A-Z bands. However, the technique was such that the work should be repeated. Muscle fiber extensibility has been shown to be significantly related to tenderness in studies by Wang *et al.* (41), with "r" values ranging from —.43 to —.65.

New tools are available for histological research today, which could be used for investigating the structure of muscle as related to tenderness. They include such items as the electron microscope for detailed study, and the use of carbowax and freeze drying as a means of preventing tissue distortion. New methods of lighting such as phase contrast and the use of polarized light offer new possibilities, especially when coupled with special staining techniques. In light of these new tools, a completely different approach should be made on histological studies.

Effect of Rigor Mortis on Tenderness. Since most meat in this country goes through rigor mortis prior to consumption, changes occurring and their effect on tenderness are of interest. It has been established that beef (47, 48) is quite tender at slaughter, becomes less tender as rigor occurs and then becomes more tender as aging is extended (Table 3).

TABLE 3
Effect of Storage After Slaughter on Shear Values of Steaks

Hours after Slaughter	Semitendinosus	Biceps Femoris
0	12.26	10.95
5	17.02	15.15
12	19.10	14.85
24	18.89	14.73
48–53	17.14	12.35
144–149	11.66	9.86

Two theories of rigor have been advanced and an excellent review has been written by Bate-Smith (49). He concluded that rigor mortis is due to the disappearance of ATP and can occur regardless of pH. Szent-Györgyi (50) concluded that myosin A, Actin, ATP, K, Ca, and Mg ions are essential components of the muscle system. In resting muscle, myosin A was believed to be present as a stable complex with a complement of K, Ca, Mg, and ATP which is uncombined with actin. In relaxed living muscle, a stimulus or nerve impulse dislodges the combined ion, and the actin then combines with myosin A and ATP. In regeneration or the resting phase, the myosin A-K-ATP complex is again formed with the loss of some ATP. In death the ATP is used up and the K diffuses out and is combined with acids for buffering. The myosin A and actin combine to form actomyosin, which in the absence of ATP is extended and confers rigidity to the dead muscle.

Bate-Smith (49) went a step further and on the basis of evidence postulated that an additional cross-linkage occurs between the muscle filaments, which is probably of the hydrogen bridge type. Further studies of this nature are needed to clarify what is happening in rigor and to perhaps solve the basic reason for the changes in the properties of the meat proteins during rigor. Wierbicki (51) and others have worked on the ionic shifts as responsible for changes in the amount of hydration and possibly tenderness. Although there is a relation between hydration and tenderness, it does not appear to be responsible for tenderness *per se.*

Measurement of Tenderness. Although consumer acceptance provides the ultimate test for measuring tenderness or any other desired attribute of meat, the use of small taste panels is involved and poses many problems, such as the method of presentation, score cards, and selection of panel members. Although taste panels are not strictly objective and results may vary, their usage is still believed to be a useful adjunct in measuring tenderness. Lowe (52) suggested the chew count method, which we have satisfactorily adopted to measuring tenderness in our laboratory. More recently, Cover (53) has described a method of scoring tenderness on the basis of softness (sensations from tongue and cheek and ease with which the teeth sink into meat on first bite), friability (crumbliness of muscle fibers) and tenderness of connective tissue (rated as no connective tissue, some is felt or heard during chewing but disappears, or some is left after chewing and must be gulped or discarded). This method appears to be a logical way of scoring for tenderness, and should help to explain the variation observed. Both the chew count and the method of Cover appear to offer distinct advantages in research over the more common subjective methods of scoring. Wierbicki and others (54, 55) have found water binding capacity is related to tenderness and have developed a method for measurement of water retention. However, the effect of water binding capacity on tenderness appears to be an associative phenomena rather than a direct causative effect (56).

Most researchers have looked towards objective methods of measuring tenderness. Schultz (57) has written an excellent review on the mechanical methods for measuring tenderness, which range from artificial dentures attached to a strain gauge to penetration devices. Briefly, the methods can be divided into shear devices, penetration devices, and food grinder methods. The shear methods most commonly used are the Warner-Bratzler shear and the Kramer shear press. The Warner-Bratzler shear is correlated with panel scores for tenderness to the extent of approximately .70 in numerous studies. The Kramer shear press, which has been used primarily for measuring tenderness in vegetables, shows some promise for meats work. Probably, the most interesting device is the Recording Strain-Gauge Tenderometer, which was developed by Proctor, Davison, and Brody (58) at MIT and simulates the chewing mechanism of the human.

The food grinder has been used as a tenderometer and by wiring the grinder in series with an A.C. ammeter, it is possible to plot power consumption in watts as a function of time to represent total energy expended in grinding the sample. This method was developed by Miyada and Tappel (59), but more recently, Emerson and Palmer (60) reported the Warner-Bratzler shear gave a better relationship to panel scores than the food grinder.

As a parting shot on tenderness, I should like to question the validity of our present emphasis upon tenderness in view of enzyme treated steaks, enzyme injections in the live animal, and the possible use of ultrasonics for tenderization.

Juiciness

Relationship to Marbling. Cover, Butler, and Cartwright (35), found that marbling (ether extract) and juiciness scores were related. However, the "r" values were only .51 for broiled loin steak, .36 for braised loin steak, .38 for broiled bottom round, and .25 for braised bottom round. These relationships, although low, were considerably higher than the correlation coefficients for marbling and tenderness, which indicates marbling is more closely related to juiciness than to tenderness.

Effects of Moisture Content. Neither moisture content nor press fluid have been found to be closely related to juiciness.

Effects of Age. The effects of age and degree of fatness on juiciness is presented in Table 4 (20). There appeared to be a slight advantage in both quality and quantity of juiciness as the animals became older, but the changes with age were more regular for quality. Quantity of juiciness seemed to be influenced more by the amount of finish, as the feeder cattle were always rated lower than the finished animals of the same age. This is in agreement with other work indicating that marbling is related to juiciness but the relationship is not high (35, 36, 37).

TABLE 4
Effects of Age and Finish Upon Juiciness

	Quality of Juiciness	Quantity of Juiciness
Calves—feeders	11.13	5.68
Calves—fattened	11.37	7.37
Yearlings—feeders	11.57	5.63
Yearlings—fattened	11.92	8.04
2-yr. old—feeders	12.44	6.33
2-yr. old—fattened	13.11	8.04

Methods of Measuring Juiciness. Although press fluid and total moisture would both be logically believed to be related to juiciness, such has not been the case. There appears to be some evidence that waterbinding capacity may be related to juiciness, but as yet the evidence is not adequate. At present the only legitimate way of scoring for juiciness appears to be by subjective panel ratings.

Texture

Little is known about the influence of texture upon eatability, although it is generally accepted that texture is closely allied with tenderness. Even though the size of the muscle fibers as determined histologically is associated with tenderness to a limited extent (43, 44), no attempt has been made to relate visual texture ratings with the microscopically determined texture to my knowledge. Consequently, we cannot say that texture as felt upon eating meat is associated with its microscopic appearance, although they would logically be expected to be related. However, Kropf and Graf (61) have recently shown that visual ratings for texture were related to mechanical shear readings with an "r" value of —.54. If such a relationship exists between texture and eatability, logically it can be asked whether such an effect is due to a direct causative effect of texture or whether the association is indirect. Consequently, studies on texture and its effect upon the eatability of meat are definitely needed.

Aroma and Flavor

For the purposes of this discussion, aroma and flavor are being grouped together since Crocker (62) reported that flavor of cooked beef consisted more of odor than of taste. This was verified by Kramlich and Pearson (63) who found that the flavor of cooked beef could not be detected when the taster held his nostrils, but on release of the nostrils a flood of flavor filled the mouth. Consequently, flavor as used in this discussion shall include aroma.

Chemically, flavor of meat is complicated and until recently had been attributed to the nitrogenous extractives, such as creating creatinine, the various purines, and pyrimidines. However, recent work (64, 65) has shown a number of compounds appear to be possible contributors to meat flavor. Kramlich (65) found, using gas chromatography, that the volatiles expelled during cooking beef gave six distinct peaks which were tentatively identified as carbon dioxide, methyl mercaptan, acetaldehyde, methyl sulfide, acetone and water. It is obvious that all of these compounds may not be contributors to flavor, although it is possible that a combination may be responsible for beef flavor.

Measurement of Flavor. In the past, studies on flavor have necessarily been limited to subjective panel ratings. Even today we must lean heavily upon such techniques, as instruments do not record taste sensations but merely can be used for identification of such compounds. However, during recent years several of the newer techniques for identification of compounds have been applied to flavor problems.

Both paper chromatography (67) and gas chromatography (64, 65) have been applied to studying beef flavor, although the major amount of effort has been expended in studying irradiation-induced flavors in meat. Mass spectroscopy (65) has also been used in attacking the same problems. In addition, chemical approaches have been made to measurement of flavor contributing components by quantitative methods of determining single components such as methyl mercaptan (68), carbonyls (69), and hydrogen sulfide (70).

Final identification and establishment of the importance of the various flavor components will unquestionably be the result of chemical methods of identification of their importance by trained taste panels. This will be an interesting field to watch, and one that could well result in tremendous expansion of meat substitutes unless producers, processors, and researchers combine to make meat more economical than possible substitutes.

Another point of interest is that of flavor enzymes. Recent work with vegetables has shown that the addition of certain natural enzymes will materially enhance flavor (71). As yet no work has been done with flavor enzymes in meat, but it appears probable that certain naturally occurring enzymes would greatly accelerate and improve the development of beef flavor.

Summary

This discussion has been an attempt to point out some of the basic problems in evaluating quality of beef in light of our present knowledge. Coupled with the problems, possible research tools for studying them have been suggested. It is realized that objective tools are not always at hand for measuring quality in beef, but subjective methods can often be used effectively. The methods mentioned would appear to be useful for measurement of quality, but there are other methods available and unquestionably new methods will be developed that will supercede many of those mentioned.

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Beef Grades and Standards—Past and Present

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THE ORIGIN of beef grading probably dates back to the time when man first started trading in this commodity. Certainly, in appraising the relative merits of beef, the buyer or seller instinctively applied some of the principles of grading. Grading is merely the process of dividing a commodity into segments or groups which have similar characteristics. Obviously, to perform a useful service in the marketing process, grading must be based on those factors that are important to buyers and sellers and which affect the utility of the product.

The early markets in this country were highly localized and a distinct vocabulary or terminology evolved to describe the grading or segregation of cattle and beef at each market. However, with the growth of large urban centers and the development of improved transportation, refrigeration, and communication facilities, large competitive markets developed. This created the need for standardization of grades and terminology in order that prices between markets could be equitably compared. National standards for grades of cattle and carcass beef were first proposed by the U. S. Department of Agriculture in 1916 as a prerequisite for the operation of a national market news service. These original standards were patterned after the only published standards existing at that time—those proposed by the Agricultural Experiment Station of the University of Illinois between 1902 and 1910. These standards for carcass beef were further refined and finally promulgated as the official standards of the U. S. Department of Agriculture on June 3, 1926. In 1923, the Department began the grading of beef for two government agencies—the U. S. Shipping Board and the Veterans Administration.

The Federal grade stamping of beef, as we know it today, started in 1927. The program was started as a result of the action of a producer organization known as the Better Beef Association. That organization consisted of approximately 250 cattle breeders and feeders from all parts of the country and was formed for the primary purpose of sponsoring a meat grading service. It was the contention of that organization that if a system were developed for labeling the different qualities of beef so that consumers would have a reliable guide to identify the quality they desired, it would encourage the consumption of beef and indirectly stimulate the production of better beef cattle. The Secretary of Agriculture assured the Better Beef Association that the Department would provide the grading and stamping of beef on an experimental basis for one year. The Federal grading of beef actually began on May 2, 1927, and the records also indicate that packer brand identification of carcass beef began in August of that same year. During the experimental year, only Choice and Prime grades were graded and this was provided at no cost to the packer. At the end of the experimental period, it was decided to continue grading on a permanent basis and to charge a fee to cover the cost of the service for those requesting grading. Except for city ordinances in Seattle, Washington; Ogden, Utah; and Miami, Florida requiring Federal grading of beef sold in these cities and for two periods of compulsory grading during emergency price control programs, meat grading has continued on the same voluntary self-supporting basis.

The growth of the service was rather slow in the beginning and was apparently definitely stimulated by the two periods of compulsory grading. In 1940 only about eight per cent of the beef produced was federally graded. After the compulsory grading period of 1942 to 1947, this leveled off at approximately 25 per cent. After the compulsory grading period of 1951 to 1953, the volume of federally graded beef leveled at about 50 per cent of the total beef production. The prevailing pattern has always been, and still remains, that the large volume of beef graded is in the higher grades—Prime, Choice, and Good.

There are many explanations for this growth of the grading service. The influence of compulsory grading has been mentioned. Many have attributed its growth directly to the demands of the consumers for graded meats. This, in our opinion, is not the case. The demand of the consumer has been very indirect. It has long been recognized that consumers are not well informed on Federal grades. However, they apparently tend to purchase meat and become repeat customers at stores that handle the quality of meat that suits their particular needs. Therefore, the retailer's use of graded meat is not based alone on the request for graded beef. Many retailers use federally graded beef to simplify procurement to eliminate the necessity of personal inspection and, thereby reduce a marketing cost, and to assure uniformity in quality. Small independent meat packers without widely recognized brand names have utilized grading as a means of competing with the recognized brands of larger packers in the national market.

The grade standards for beef are the tools that make the grading service possible and the effectiveness with which consumer demand can be reflected back through the marketing channel to the producer is directly dependent upon the adequacy of these tools. The original grade standards were based upon the best information available at that time. However, they were largely a result of trade experience and opinion. The grade standards have undergone four major revisions since they were adopted. These changes have been primarily for one of the following reasons: (1) to reflect the results of research with respect to the importance of various grade factors, (2) to clarify the intent of the standards or otherwise to improve the ease or uniformity of their interpretation, and (3) to re-define the grade where the range has been effectively demonstrated to be either too wide or too narrow in scope to be practical and workable.

I would like to comment briefly on the limitations of the present grade standards and the grading program as we see them and to point out some of our efforts for improvement. You are all, no doubt, aware of the fact that criticism of the grading program and the grade standards has been frequent and there is some indication that this has been increasing in recent years. While there may be many reasons why this situation exists, I would like to mention one point which we feel is most important and that is the increasing extent to which grading has been used in merchandising beef in recent years. This is, of course, strictly a volume situation where the considerable growth not only results in more opportunities for controversy but makes the operation one of greater concern to the industry.

Most of the complaints regarding grading naturally originate with packers. Producers also criticize grading. In both instances, the volume of complaints is usually influenced by the supply and price situation. The subjective nature of the grade standards and the necessity of relying on human judgment in their application are the two aspects of the grading program most criticized and which influence the degree of uniformity that can be attained. However, in our opinion, the major limitation of the grade standards is not their subjective nature. It is the need for more factual information relating to (1) the identification and relative importance of the factors that influence quality in beef and, (2) the factors that influence the yield of salable meat from the carcass.

In evaluating the present grade standards and areas for improvement, it is essential to remember that grades are predicated on two considerations: (1) the evaluation of the characteristics of the flesh that are believed to be associated with the palatability of the beef and, (2) the evaluation of conformation or the proportion of the various cuts within the carcass and the ratio of meat to bone.

You will note that I did not include finish or fatness as a grade factor. This was intentional because the quantity of surface fat on a beef carcass is a rather inefficient indicator of beef quality and therefore, in our opinion, should not be a factor in the grading of beef. Quality of beef is measured primarily by marbling, firmness, color, and texture of lean in relation to the indications of maturity of the carcass. It is quite obvious, however, that the quantity of fat that is trimmed in making retail cuts is a very important value determining factor.

We have been keenly aware of the need for more information on the factors affecting the eating quality of beef. Several years ago, the Livestock Division effected a contract with the American Meat Institute Foundation in an effort primarily to evaluate the relationship between various physical, chemical, and histological characteristics of beef and its eating quality. A Department manuscript on this project has been prepared and is now being edited for early publication.

During the course of this study a very significant statement was made by the project leader to the effect that the graders' estimate of palatability was almost as accurate as that which was based on a laboratory analysis of the characteristics of the beef. Such a statement is both reassuring and discouraging. It may indicate that the present standards evaluate fairly efficiently the same characteristics of the flesh that the laboratory is able to measure. On the other hand, it also indicates the complexity of the problem and the difficulty of developing an objective technique for evaluating quality. There is still a great need for additional basic research information relative to the factors that affect palatability in beef.

Our present grade standards provide for full consideration of those factors that are believed to influence palatability. However, since they do not provide for consideration to quantity of outside fat, the only differences that they reflect in yields of salable meat are those that are related to conformation or those that occur incidentally between grades. That is, no effort is now made to differentiate between carcasses of a given grade on the basis of their salable meat even though it is quite obvious that such differences must be quite large. Unfortunately, yield of salable meat and quality of carcass are factors that are far from being perfectly correlated. Therefore, even if our present standards were formulated on a basis which accurately predicted both of these value-determining considerations, their combination into a single grade as provided in our present standards, would in many cases result in a compromise between these two factors that would be representative of neither. Such a compromise grade would be far less meaningful than would a separate grade identification for each of these value-determining factors. In the same general area, there are many who feel that conformation should play a more prominent role in determining the final grade. However, we believe this problem should be approached in an objective manner. If conformation is to be used, it should be used because of its relationship to the total yield of red meat in the carcass and because of its influence on the proportion of preferred cuts to the less desirable ones.

Factors Influencing Yield

Our technicians have been concerned recently with a study of the factors that influence the yield of trimmed cuts from a carcass. In 1956 we completed the collection of data on a study of 459 beef carcasses including all weights and grades from Prime through Canner. This study involved more than 100,000 measurements and observations.

From our studies, it appears that beef carcasses may yield from 40 per cent to 70 per cent of their carcass *weight* in trimmed retail cuts from the round, full loin, rib, and square cut chuck. These four major cuts represent about 85 per cent of the retail *value* of the carcass. Our studies indicated that variations in "cutability" are influenced primarily by the conformation and fatness of the carcass. Unfortunately, perhaps, conformation and finish tend to have opposite effects on the retail yield of these cuts. Superior conformation increases "cutability" while the addition of finish decreases it. Within a particular grade, the finish of a carcass has considerably greater influence on "cutability" than does its conformation.

We were quite hopeful that it would be possible to measure conformation and finish objectively by simple techniques that could be used in a grading program similar to those used in the carcass grading of pork. However, while several measurements were highly correlated with "cutability" these particular combinations of measurements were difficult to make and were not substantially more accurate than our subjective evaluation of conformation and finish.

During the past year we have tested one possible method of identifying cut-out differences in the beef grading system. It has been referred to as a "dual grading" system. Essentially this is a system in which separate identification is given to the "cutability" factor within each of the quality grades. For example, carcasses with Choice quality were further classified into three different groups representing high, intermediate, and low yields. In practical application, these might be identified as Choice No. 1, Choice No. 2, and Choice No. 3, or with some similar term for use in trade by the packer and retailer.

Such a system may appear to add complexity to the grading system but would it provide an improved market identification? Some indications to the answer of this question were obtained in recent testing of this system through selecting some 245 carcasses representing Prime, Choice, Good, and Standard grades. Within each of these grades, carcasses were selected to represent three different ranges in "cutability" of major retail cuts. In this test, the differences in yield of major retail cuts and the differences in sales value per hundred pounds between the high and low yielding groups within the respective grades are found in Table 1.

TABLE 1
Differences in Yield and Sales Value

	Average difference in "cutability" between high and low yielding groups	Average difference in retail sales value per hundred pounds between high and low yielding groups
Prime	7.6 per cent	$6.29
Choice	5.4 "	5.07
Good	5.1 "	4.25
Standard	4.6 "	4.49

Note that these were differences between the averages of the high and the low groups within grades. Differences between individuals within grades were even more pronounced. Between individuals, differences in value of over $10 per hundred pounds, or over $60 per carcass, were not uncommon.

Another method of applying the "dual grading" system is presently being tested. This involves the estimation of cutability independent of the quality grade. In this respect, the approach is similar to that being utilized by some packers in the purchase of slaughter hogs on the basis of their yield of lean cuts. Preliminary results with this technique indicate that carcasses can be segregated with acceptable precision under this system.

Our data emphasize the fact that there is considerable variation in the "cutability" within each of the grades and that it is highly important to identify this factor in our marketing system. There are greater differences in value, attributable solely to the differences in "cutability," within each of the grades than normally exist between adjacent quality grades.

The results of our study also emphasize the fact that "meat-type" cattle do now exist even though little direct selection effort has been aimed toward identifying cattle that combine thickness of muscling, high quality meat, and a minimum of excess fat. Our studies also indicate that "cutability" can be predicted with reasonable accuracy in the carcass, but considerable work is yet to be done in relating these carcass characteristics to the live animal. The problem is little different from that existing in the swine industry 10 years ago. At that time, few believed that it was possible to predict the yield of cuts in a live hog. Today it is an accepted factor of live hog marketing. A similar approach in beef appears logical.

There is at the present time some interest in revising the existing grade standards by lowering the quality lines of the higher grades. This is advocated by some as a means of reducing excess fat on beef. If this is the objective, it is a very indirect method which does nothing to provide identification for carcasses of the same quality but which vary in fatness and muscularity. This may be a misinterpretation of the problem. Beef is receiving unparalleled acceptance by American consumers. There is little indication of dissatisfaction with the quality of beef being produced; there is considerable evidence that consumers are becoming increasingly averse to excess fat on beef. The beef producer can and, no doubt, will meet the challenge to produce high quality muscular cattle that are not overfat. However, it is the job of grade standards and a grading program to furnish the necessary market identification for reflecting trade preferences back through the marketing channel to the producer. Rather limited progress in improving the present grade standards appears possible through the mere juggling of grade lines. Permanent improvements will undoubtedly be the product of good research designed to furnish additional factual information that can be used to provide a more precise market identification of the beef carcass.

Relationships Between Beef Quality, Grades, and Standards

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PERHAPS no single term used in connection with food has as many shades of meaning as the word "quality." Its use to describe beef is certainly no exception. "High quality" to the beef producer implies characteristics that are entirely different than those expected by the beef processor, and, in turn, are somewhat different than the properties expected by the ultimate consumer. Thus, even in the meats field, no *single* set of quality standards apply universally to beef.

For this discussion, quality may be defined as the summation of the distinctive traits or special features that determine the ultimate acceptability of the product to the consumer. Even this somewhat limiting definition immediately raises questions and problems—what consumer, what cut or kind of beef, what method of cookery? Quite obviously, any attempt to evaluate the relationships between quality and grade, or quality as it relates to more definitive characteristics of beef, must consider quality *factors* for specific cuts of meat, prepared by known, carefully controlled procedures.

Quality Factors of Fresh Beef

For the consumer, tenderness is perhaps the quality factor of greatest importance. Unfortunately for the researcher, this important quality factor is not really a single characteristic. Recent investigations (3, 10) have suggested that at least two or three properties are involved in the sensation of tenderness. These are the initial resistance or tenderness of the cooked meat tissue, the amount of residue remaining after mastication of a bite of meat, and the "friability" or nature of the residue. The relative importance of these characteristics in an overall tenderness evaluation depends upon the cut or type of meat, method of cookery, and many other factors that cannot be discussed here.

Juiciness, like tenderness, is not truly a single taste sensation. The original sensation of juicines may be due primarily to the moistness or amount of fluid in the cooked meat, while the sensation of sustained juiciness probably depends upon stimulation of salivary action by fat and other physiological effects.

We know so little about meat flavor, the third important beef quality factor, that it is difficult to suggest precise techniques for its evaluation. For taste testing, flavor usually is separated into "quality" and "intensity." Several research teams are now attempting to separate and identify the constituents in meat that are responsible for meat flavor. When this has been accomplished, it should be possible to measure beef flavor much more objectively and to evaluate the factors which influence it.

Relationship of Grade to Beef Quality Factors and Other Properties of Beef

For purposes of this discussion, the term "grade" will be used generally to mean U. S. Government grade. There are, of course, many other standards and specifications for beef, but most of the research reported in the scientific literature on quality-grade relationships has been based on U. S. Government grades.

Tenderness

There are numerous reports on the relationship between tenderness of beef and grade. Unfortunately, the data are conflicting and it is almost impossible to arrive at positive and definite conclusions. Black *et al.* (2) found that differences in tenderness of 9-11 rib roasts from 3-year old steers were not consistent with respect to grade ("good" and "medium"). Roasts from steers fed grain on grass were more tender than those from steers finished on grass alone. Wanderstock and Miller (9) found that rib roasts from fed steers were somewhat more tender than those from steers finished on pasture alone. Carcasses from the fed steers were one or two grades higher than those from pasture finished steers. Wierbicki *et al.* (11) reported that for bulls and steers tenderness was highly correlated with carcass grade, but that when bulls and steers were considered separately, the relationship was not as close. Hiner (7) has reported a correlation coefficient of 0.20 between carcass grade and tenderness. Texas workers (4) have recently reported that panel scores for loin steaks broiled well-done were significantly correlated with carcass grade of Santa Gertrudis steers. The authors emphasize, however, that "carcass grade was not homogenous for tenderness and that tender meat was not confined to carcasses of the higher grades."

Alsmeyer *et al.* (1) found a highly significant correlation between taste panel scores of loin steaks cooked "medium" and carcass grade of steers sired by Brahman and Shorthorn bulls. Again, the authors emphasize that the relationship was not close, and that breed of sire and specific sire within breed were better indices of tenderness than was carcass grade. Our own studies at the American Meat Institute Foundation (5) have shown that the *Longissimus dorsi* of rib steaks (broiled medium rare) from Prime grade carcasses was significantly more tender than that from Good or Commercial grade carcasses (Table 1). However, variations in tenderness within grade were very great; for unaged rib, the observed ranges in panel tenderness scores were as follows: Commercial—2.2 to 6.2; Good—2.7 to 8.5; Prime—3.7 to 8.6 (scores on scale of 1 to 10).

TABLE 1
Tenderness Scores for Broiled Ribeye

Commercial	5.6 ⎤
Light Good	5.8 ⎥
Heavy Good	6.2 ⎦
Light Prime	7.0 ⎤
Heavy Prime	7.2 ⎦

(Differences between means not enclosed in brackets are statistically significant)

From these data, it can be safely concluded that there is a definite and significant relationship between carcass grade and tenderness of the cooked *Longissimus dorsi* muscle. However, the great variability in tenderness within grade indicates that selection for tenderness on the basis of grade alone would be unsatisfactory in many cases.

Juiciness

Results of investigations that have attempted to determine whether or not there is any relationship between carcass grade and juiciness of cooked beef are even less definite than those attempting to establish grade-tenderness relationships. The data of Wanderstock and Miller (9) suggest that both quality and quantity of juice were less in rib roasts from carcasses of lower grade. Results presented by Black *et al.* (2) do not indicate any significant relationship between grade and quality or quantity of juice. Hiner (7) has reported a correlation coefficient of 0.34 for carcass grade and jucinesss of cooked meat. Data obtained in our laboratories on broiled rib steaks from carcasses of different grades and weights showed only that the cooked meat from light-weight Good grade carcasses was significantly less juicy that that from heavy Good, Commercial, and Prime grade carcasses.

It appears from these results that juiciness of cooked meat, at least from the loin and rib, cannot be predicted on the basis of present U. S. carcass grade. However, it should be emphasized that, in general, the meat from higher grades tends to be more juicy because of its higher intramuscular fat level.

Flavor

The data of some investigators (2, 9) suggest that flavor of cooked lean meat (steaks or roasts) is related to carcass grade. However, careful evaluation of results suggests that flavor differences may well be more dependent upon type of feed than on carcass grade. Usually, investigators have found that beef from animals fed or finished on grain has a better flavor than that from animals finished on pasture. Hiner (7) found that the correlation coefficient between lean flavor and carcass grade was 0.25. Our own data (5) show that flavor of broiled rib steaks was related significantly to both grade and weight (Table 2).

TABLE 2
Lean Flavor Scores for Broiled Ribeye

Light Good	6.8
Commercial	6.9
Heavy Good	7.2
Heavy Prime	7.4
Light Prime	7.7

(Differences in means not enclosed in brackets are statistically significant)

Chemical, Physical, and Histological Properties of Beef as Related to Carcass Grade and Beef Quality Factors

The information presented above indicates rather clearly that carcass grades as now used do not reflect adequately the palatability characteristics of beef. Dr. A. M. Pearson suggested a number of objective techniques that have been reported to be of some value in evaluating beef quality. It is of interest to see how some of these properties are related to carcass grade as well as beef quality characteristics. Most of the data on this subject as presented here was obtained in our laboratories and was supported in part by contract with the Agricultural Marketing Service, USDA (6).

Intramuscular fat and marbling

It is significant, but perhaps not surprising, that the intramuscular fat content and subjective marbling rating of raw ribeye is closely correlated with carcass grade and weight (Table 3).

TABLE 3
Intramuscular Fat, Marbling, and Juiciness Scores of Ribeye from Carcasses of Different Grades and Weight

	Fat %	Marbling Rating	Juiciness Score	Tenderness Score
Light Good	3.1	3.7	6.2	5.8
Heavy Good	4.6	2.8	6.8	6.2
Commercial	6.3	2.3	6.9	5.6
Light Prime	8.1	2.0	7.0	7.0
Heavy Prime	8.7	1.9	7.2	7.2

(Differences in means not enclosed in brackets are statistically significant)

It is interesting to note that the various carcass grades and weights rank in the same order for juiciness score as for intramuscular fat and marbling. The tenderness score for Commercial grade ranks out of order, though not significantly. These data suggest strongly that intramuscular fat is associated with juiciness and tenderness of broiled ribeye. In fact, our data show highly significant linear correlation coefficients between intramuscular fat and both juiciness and tenderness of unaged ribeye. For juciness-intramuscular fat, the relationship is actually curvilinear (Figure 1), and a curvilinear correlation coefficient would be somewhat higher.

These data suggest that tenderness and juiciness of broiled ribeye may well be related to carcass grade to the degree that intramuscular fat and/or marbling is used as a quality index in the grading system.

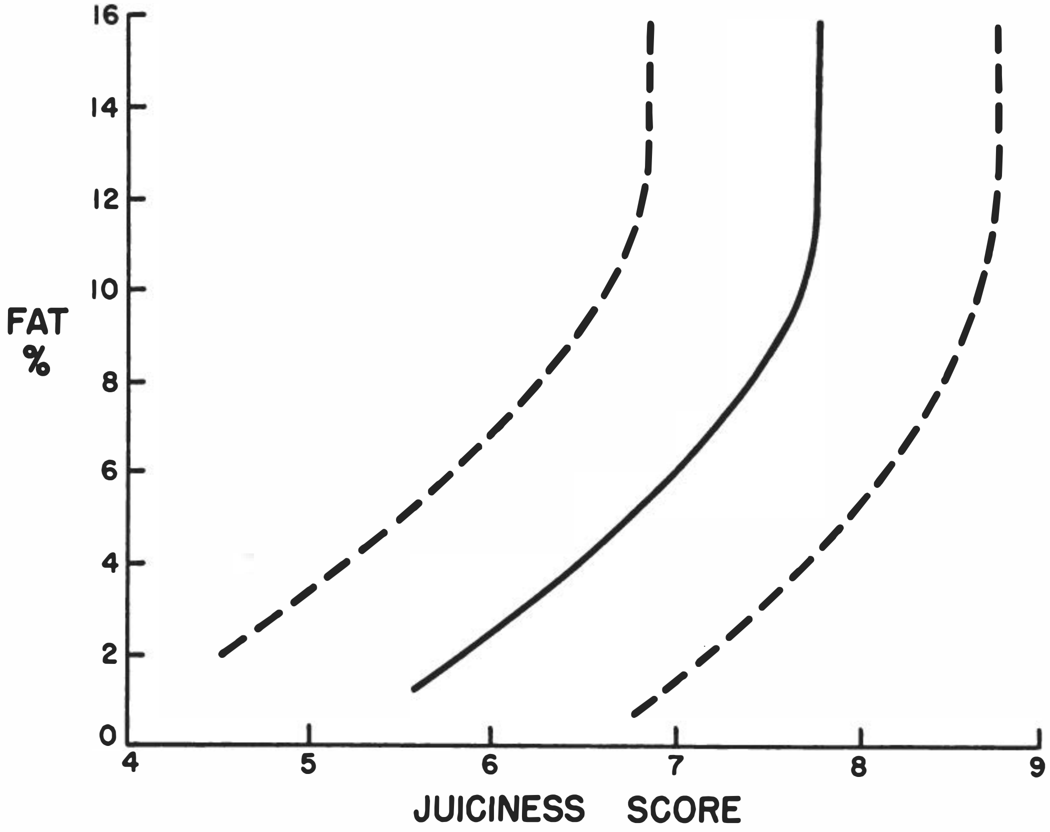

Figure 1. Relationship Between Intramuscular Fat and Panel Score for Juiciness. (Broken lines show confidence limits with 95% probability.)

Other Chemical Components

The amounts of non-protein nitrogen, amino nitrogen, soluble protein, creatine, creatinine, ammonia, urea, and extractable pigment were not significantly different in raw or cooked ribeye from carcasses of different grades and weight.

Physical Characteristics

Some physical determinations as shear strength, press fluid, electrical conductance, and penetrometer reading have been used in studies on meat as possible objective means for evaluation of quality factors. In our studies, the values obtained by these physical measurements were not consistently related to carcass grade or weight (except for shear values as shown in Table 4).

TABLE 4
Shear Values for Broiled Ribeye from Carcasses of Different Grades and Weights

	Shear Value	Tenderness Score
Heavy Prime	8.1	7.2
Light Prime	9.2	7.0
Heavy Good	10.1	6.2
Commercial	11.1	5.6
Light Good	11.6	5.8

(Differences in means not enclosed in brackets are statistically significant)

It can be noted here that there appeared to be fairly good agreement between tenderness score and shear values on cooked meat. This relationship was highly significant for unaged meat, but much less so for aged meat.

Histological Characteristics

Muscle fibre diameter was slightly greater in Commercial grade *Longissimus dorsi* than in the same muscle from Good or Prime grade carcasses. This agrees with results reported by Hiner *et al.* (8) who found that muscle fibre diameter increased with increasing animal age. Other structural properties of beef muscle—muscle bundle size, elastin fibre diameter, and the presence of liposomes (intracellular fat)—were not consistently related to carcass grade or weight. Histochemical determinations for collagen and elastin likewise failed to show any consistent relationships between collagen or elastin and carcass grade and weight. These histological and histochemical properties did not show any consistent significant relationships to tenderness, juiciness, or flavor of cooked meat.

Carcass Grade as Related to Consumer Acceptability of Beef

This discussion would be incomplete without some reference to consumer preference studies as related to grade. Dr. Mrak has given an excellent evaluation of these studies, and it is perhaps sufficient to state that these investigations for the most part tend to confirm conclusions that may be drawn from the more carefully controlled technical research reported here. It would appear that U. S. carcass grade *is* related to beef quality factors and to consumer acceptance, but it must be emphasized that this relationship is not close, particularly in the lower grades. Unfortunately, our present knowledge on properties of beef that influence tenderness, juiciness, and flavor is inadequate. We are not able at this time to suggest positive, objective techniques for the rapid, accurate evaluation of quality in carcass beef.

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The Economic Impact of Identified Beef in the Marketplace

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I SHALL INTERPRET the term "identified beef" to mean a uniform, repeatable product which can be found and identified in the market either in the carcass or the consumer cut. It may wear a brand or grade label which denotes quality, and which may be either proprietary or official. Or, it may be unlabeled and yet readily identifiable in the trade by its own obvious characteristics. It may be bought and sold on specifications stated in terms of age, weight, and finish, and with or without any brand or grade designation.

Its essential repeatability must rest, first, on being widely and readily available and, second, on the fact that, other than for obvious weight and finish differences, the total supply of block beef is highly uniform in all other major characteristics. In the form of consumer cuts it need not be identifiable by any brand or grade mark. The reasons are that consumers have shown little understanding or interest in grades, but depend instead on the reliability of the distributor from whom they buy. Such additional identification as has any meaning to most consumers is that which is perfectly obvious on the face of the cut meat in the retail case. What we now know, or probably ever will learn, of consumer preferences is in terms of product characteristics *per se,* not in brand or grade labels. Mrs. Homemaker selects meat that appeals to her in the cut, and then if it appeals equally to her family at the table, she goes back for more.

Thus, the "identity" that is desired and which I assume to be implied in the topic assigned to me is, *first* and most important, the production of a block beef supply from which the undesirable types have been eliminated and which has the uniformity and repeatability that contributes effectively to trading on a specification basis. Then, *second,* how the specifications are worded is of minor importance, as long as they contribute to the selection of meaningful categories by age, weight, and finish.

The Competitive Market for Food

Food, as one category of economic goods and one item in consumer expenditures, long has been regarded primarily as a necessity. However, the changing pattern of American life, the rising level of consumer real incomes, and the changing budgetary distribution of consumer spending, makes this concept less true today than ever before. Food is not bought by American consumers merely to fill their stomachs. It is purchased against a rising understanding of the more subtle nutritional factors, against an increasing desire to eat well, and against an ability and a willingness to spend for what we refer to broadly as "quality."

Moreover, food in this sense has come to compete strongly with a broad spectrum of other demands on consumer spending—for housing, household conveniences, automobiles, personal care, recreation, and the like. To the degree that food becomes more a combination of quality and quantity, or a combination of food and food services, it becomes a competitor with other forms of spending.

The point must be carried still another step. Food competes not only with other demands on spending, but food also competes with food. The abundance and diversity evident on the shelves of any supermarket reflect the remarkable degree to which consumers have alternatives before them, and potentials for substitution of product for product.

This competitive battle deserves more recognition than typically it has been given. It reveals, for example, the degree to which agriculture has become a large number of competitive sub-groups of producers, with each group trying to build the largest possible demand for its own product. This is illustrated by the fact that the family who had chicken for dinner did not have beef. Why was chicken selected? The answer is important not only to poultrymen but to every other group whose product was bypassed when chicken was chosen. More than anything else, it is the competitive drive of poultrymen to foster the selection of chicken, versus swine producers to foster the selection of ham, versus cattlemen to foster the selection of beef—and all similar competitive drives—that explain the highly dynamic production and marketing developments in today's food industry.

And let's add one more point to this sequence. How successful each product-group of producers may be—cattlemen, for example—hinges not alone on their own efforts, but also on the marketing organizations that process and distribute their product. As never before, competitive success comes from production and marketing teams working together to move a product that has been carefully tailored to its market potentials.

In an economy that is increasingly and inescapably market-oriented, this interdependence of producer and distributor interests has a number of meanings. One meaning which has been difficult for many producers to accept is that if and when there is a difference in view between producers and distributors about what the characteristics of a product should be, it is the distributor's view that usually prevails in successful marketing. Take today's supermarket operator, for example. His business is to sell food in successful competition with many other similar merchants all within convenient driving distance of the customer who typically shops with the family automobile.

In an important sense he does not care what products he sells. He "rents" his shelf space to the merchandise which will earn him the most money. But in order to meet his objectives, he clearly has to have products which will satisfy his customers and bring them back repeatedly to his store. Thus, he writes specifications for products which his experience has taught him will be successful. When he has found a product that is successful in attracting and holding customers, he wants to get it again. He wants it in his store at all times. He wants suppliers who will furnish it in desired quantity, at prescribed times of delivery, and in strict compliance with specifications.

One of the strictest features of his specifications is for product uniformity. The customer who was satisfied yesterday must also be satisfied today, and he wants the product there for her tomorrow with equal assurance that she will be satisfied then. There is, in fact, no other feature more important than uniformity in any product that has been successful under the conditions of impersonal selling in today's self-service food store.

The Changed Character of the Beef Supply

Twenty-five years ago our beef supply was much more seasonal than it is today. Neither the retailer nor his customer are happy with a superabundance of supply at one season of the year and dearth at a later time. Thus, the even flow of slaughter cattle from present day feed lots has contributed both to the stability of the beef market and to total consumer beef purchases.

Likewise, a quarter of a century ago, we had a beef supply far more variable in quality. Many slaughter animals were carried to three or more years of age and went to the packer directly off grass.

More of the beef supply was cow beef, and cows as low as the Utility grade entered considerably into the supply of block beef. More of the beef came from dairy animals and from a very ordinary class of cattle euphemistically called dual-purpose, but really not much good for either or any purpose.

These facts meant that yesterday's beef supply was far below the quality and uniformity that is in the market today. In the last couple of decades the aged steer has practically disappeared from our slaughter cattle. The dual-purpose animals are largely gone. Dairy cattle have dropped far below the proportion which they formerly contributed to the beef supply. Beef herds have improved amazingly in conformation, rate of gain, and early maturity. Exclusive of culled breeding stock, the age bracket of slaughter cattle has been greatly compressed from both ends—and now centers on steers and heifers in a narrow age bracket of 18 to 24 months.

This type of animal lends itself to quick and efficient feed-lot finishing, and has been an indispensable factor in the rise of fed beef from barely 25 per cent of the beef supply 30 years ago to over 50 per cent of the supply at present. Thirty years ago between 35 and 40 per cent of the slaughter steers received at the Chicago market were directly off grass. The proportion of such animals is now negligible, not only at Chicago but at the River Markets and other packing centers as well. And considering that most of the cow and bull beef now ends up in the expanding market for hamburger, frankfurters, and other sausages, we have in consequence a supply of block beef having *behind it* a quality of beef flood lines at an amazingly high level compared with the past—and having *within it* a uniformity of conformation, age, and finish that is unlike anything we have ever had before.

All of these factors lie behind the remarkable success which beef has been enjoying in the highly competitive market for food. That 80 pounds of beef per person per year could sell at today's prices, in competition with abundant and cheaper pork and poultry is nothing less than amazing against our historical experience. This could not have happened with the lower quality and more variable beef supply of the past.

Beef has enjoyed the benefits of intense merchandising efforts by today's food retailers. This is because beef is the preferred meat by most consumers, and the largest single item in dollar volume in the food store. The general experience of retailers is that they cannot have a successful store without a good meat department, and they cannot have a successful meat department without good beef. This has led retailers to work diligently to develop beef specifications that would give them a product highly acceptable in their own region. Practically without exception, they have been able to get the type of carcass they want, in abundant and dependable supply. But this could not have been done without the changes that have occurred in our beef cattle, in the feeding industry, and in the character of the slaughter animals that produce our present supply of block beef.

New Concept of Acceptable Quality

Recently, while analyzing the development of the cattle feeding industry over the last 30 years, I was intrigued to find that there have been three distinct waves of different grades of cattle marketed from feed lots. The first of these was a sharp expansion in the proportion of the Prime grade. In 1930 at Chicago 13.7 per cent of the steers sold out of first hands were classed as Prime. The proportion increased to 36.0 in 1945—and since has decreased again, to about 10 per cent. The second wave was the rise of the Choice Grade.

In 1930 this was 42 per cent of the slaughter steers at Chicago, and has slowly crept up to about 60 per cent at present. The third and most recent wave has been a rise in the Good grade. These were

16.8 per cent of the slaughter steer supply at Chicago when first reported separately in 1951, and have since increased to a little over 25 per cent. Similar trends have been evident at Sioux City and Omaha, the other two markets for which we have a number of years of this type of market report. Good-grade steers now exceed one-third of the slaughter supply at Omaha. It is my belief that these trends have meaning of major significance to the cattle industry.

Repeated studies of consumer preference in beef indicate that consumers want two characteristics in the meat which historically have been at opposite ends of the range of beef grades. The first of these is tenderness—which we have long associated with highly finished beef. The other is leanness which historically has not been found to the desired degree in association with tenderness.

Now we have evidence that acceptable beef from the point of view of tenderness is coming to market with lesser finish than has been true, or has been thought possible, in the past. The market for Prime beef if diminishing even in the high class hotel and restaurant trade, where price has not typically been a primary consideration. The use of Prime is diminishing because beef finished at a lower level has been found increasingly acceptable. Now the increasing proportion of cattle moving to slaughter in the Good grade indicates that distributors are experiencing a growing degree of consumer acceptance at something less than Choice finish.

Bear in mind that no distributor writes specifications or accepts products to which his customers object. If he did he would shortly be out of business in today's ever more intense competition between one food store and another. If more distributors are accepting the Good grade, it is because their customers have liked it and have come back for more.

Customers are increasingly accepting beef with lesser finish—from Prime down to Choice, to low-Choice, and now down into the Good grade—because of changes that have taken place in the quality of blood lines in our beef herds and because of new characteristics and uniformity in the cattle that are producing the block beef supply. The new characteristic of age—meaning uniform youthfulness in the slaughter cattle—is gaining supremacy over the historic characteristic of finish—meaning fat—in the production of an acceptable consumer product. This new product is combining the two most desired characteristics, tenderness *and* leanness, in a degree never before possible.

Of course, we are talking about a trend, not about an ultimate goal completely attained. But no longer is it necessary, as in the past, to put an uneconomic total of fat in and on the meat in order to make it tender and tasty. Youth in the slaughter cattle is providing the tenderness in wholly new degree—and the number of consumers to whom taste difference between young beef and aged beef has any importance is negligible.

It is interesting to note that the Prime steers offered on the Chicago market in the last couple years have an average live weight of just short of 1,250 pounds. The Choice steers average 1,150; the Good steers, 1,050. Since these grades average only slightly different in age, the weight difference is primarily 100 pounds more tallow from grade to grade. The market is beginning to discriminate against what is regarded by consumers as unnecessary increments of fat beyond the amount that makes acceptable eating quality by *their* standards.

This discrimination is reflected in the narrowing price differentials across all the grades of fed beef. Some people, no doubt, will still prefer Prime for some time to come. Others will persist in a demand for Choice. And the evidence is that an increasing number are accepting Good—and not especially for price difference, because the price difference is becoming less.

Specification Beef

Perhaps some of these comments may seem remote from "the economics of identified beef." I submit that they are not, because the trends discussed have contributed so fundamentally to the production of a block beef supply highly uniform and readily identifiable. It is a beef supply remarkably adaptable to the specifications of distributors. Moreover, it was moving rapidly in the direction of serving precisely the kind of specifications now in use, long before the specifications were developed.

This does not mean that breeders and producers anticipated the specifications. Rather, they were striving to upgrade the quality of their herds, to improve conformation, to achieve efficiency of gain and early maturity as factors long recognized to be significant in successful cattle production. These are the circumstances back of the calves and yearlings with which the feeding industry has had notable success in producing specification carcasses. And of course, again we are talking about trends, not about goals ultimately achieved.

Today's beef has had its acceptance and success in the competitive market for food because, whether or not it is the ultimate in desirable characteristics, it is notably acceptable to the consumer. Retailers' specifications call, obviously, for an identifiable product. That product has been available to deliver against the specifications. These specifications have had an impact on packers, and in turn on feeders, and in turn on ranchers—stimulating each one to produce in increasing quantity the calves, the fed animals, and the carcasses which will provide a specified consumer product.

Government Grading

Government-grading was a war-induced marketing tool. Of course, it had an earlier beginning but was not used for any major part of the beef supply until it became compulsory under OPA regulations. On the so-called voluntary basis it has been widely used only since the war. It came into voluntary use mostly because it proved to be a convenient component of the purchase specifications written by mass retailers. It cannot be regarded, however, as primarily responsible for the uniform beef supply of today and for the marked success of beef in the consumer market, as some people have claimed was the case. This is because our uniform beef supply—our identifiable, specification beef—came out of the long-developing improvements in our beef stock already discussed. This beef supply began when the first shorthorn bull was put on the first longhorn cow, and the process of improvement has been going on ever since.

Government grading has contributed to the beef we have because, under the compulsory wartime regulations, it set up one system of identity standards across the whole industry. This contributed to what packers are now calling "only one kind of cattle." But it was no more than a further stimulus to the improvements in breeding and feeding that already had been long under way.

Government grading probably also was a stimulus to specification buying. But this system of buying would have come anyway, as an almost necessary tool in present-day retail procurement. Practically the total retail supply is now procured on specification, with any requirement as to Government grade being only one among several specifications.

My carefully considered belief is that Government grading is probably today at its peak of use and influence, and that from this point it is more likely to diminish than to increase. It has been a useful tool in beef merchandising, but seems likely to be less so in the future.

I know several retailers, including some large chain operators, who have been shifting down in the grade range of the beef they are merchandising. They began to do this in the price competition between retailers. They concluded that the acceptance differential among their customers for Good versus Choice was less than the then prevailing price differential for the two grades. They concluded further that with most retailers pushing the

Choice grade, and with the four or five cents price difference that prevailed until recently between Good and Choice, they would shift to Good and take the price advantage. A yet small but significant fraction of retailers have been quite successful with this change, because the factors we have already discussed—mainly the ascendancy of youthfulness over finish—have been working with them.

I believe that more retailers in the future will make a similar change, and as they do so they will tend to shift away from the use of Government grades. They will shift down in the grade range because their customers will find that something less than the Choice grade, as it now stands, will be entirely acceptable from an eating standpoint. And, if a retailer does not merchandise U. S. Choice, he probably will not promote his beef by any Government grade designation—because he is not at all likely to find it to his advantage to merchandise the grade-names "U.S. Good" or "U.S. Standard." Rather, he will probably be putting his own reputation behind the beef, and then look to his packer and wholesaler suppliers to provide him with what he needs and to stand behind the acceptability of what they deliver.

In this setting, Government grades will have diminishing significance. Thus, it seems to me that they will be less used in the future, for these reasons:

1. Government grades have been more useful to retailers than to other segments of the cattle and beef industry,

2. An insignificant fraction of consumers know anything about grades and seem to care less,

3. The increasing acceptance of less-finished beef indicates the obviously greater efficiency of putting on less fat as long as the end product has equal acceptability,

4. The fact that any grade designation below Choice will be far less desirable as a merchandising tool.

It may well be that a Government grade stamp will persist in purchasing specifications beyond its use in merchandising. But the whole beef industry is moving so rapidly toward "specification orientation" both in product and organization—towards still increasing uniformity from calf to fed animal to carcass—that the result will be diminishing significance for Government grading even in purchasing specifications.

As this whole commentary has attempted to emphasize, the fundamental development of today's young, lean, *and* tender supply of block beef is something bigger and more potent than anyone's grade stamp, including the Government's. It began in the cattle-producing industry, and that is where it will be carried forward.

Discussion

Session II

How to Identify Quality of Beef

E. J. WARWICK: I would like to ask Dr. Doty the approximate place on his scales of tenderness where beef became objectionable to the average consumer, and then whether he would be willing to hazard a guess as to the per cent of prime, good, and commercial cattle beef, that would fall in that unacceptable range?

DR. DOTY: Actually, the data which I showed were made with a so-called expert panel and not with a consumer panel. I cannot relate that to acceptability. I think acceptability is important, but I think there are other factors that should carry more weight than they do. If I had to guess, I would say anything scoring above 6 on that 10 point scale would be considered acceptable by a great many people.

H. H. STONAKER: Assuming that we are going to go ahead with grading, and that we will continue to make improvements in the grading scheme leads to this matter of increased ability to predict cutability. First, how much of this correlation is just a matter of fatness or finish to the animal? Second, along the same lines, there was some indication that we can predict the lean bone ratio by means of conformation. I wonder if perhaps we could go into that with some detail as to the background with what we need for conformation in relation to bone ratio?

DR. PIERCE: With respect to your first question relating to cutability, I think our original data indicated that on the basis of present grades, fatness influenced cutability about four times as much as conformation. In other words, for a third of a grade change in conformation it took four-thirds of a grade change in the finish normally associated with these thirds of grade to affect the same change in cutability.

Your second question relating to the relationship of conformation to ratio of lean to bone is one that we have only recently got into. I don't feel that we have very qualitative analysis at this point. Conformation, of course, has two influences. One is as it relates to proportion of various cuts from the carcass, and the other is as it relates to yield of salable meat. We found a rather wide ratio of bone to lean meat. We found the lower and canner grades, as I recall, one part bone to 2.38 portions of lean. This is a low. A high was encountered somewhere up in the good grade, with one part bone to something over six parts lean. This is not strictly lean. This is salable meat with the normal amount of fat left on a cut as it moves through the retail market, but with all of the bone removed.

I think that our emphasis on conformation throughout the years has influenced or has tended to emphasize thickness of muscling, which would be reflected in differences of ratio of lean to bone. When you expect differences in proportion of cuts from a carcass, you are essentially expecting differential development. I think it is possible to make some progress in this direction, but certainly it is not as easy as it was in the past.

V. H. BRANDENBURG: It seems to me that there is a thought that grading is not uniform geographically; that in Colorado, a man can receive a choice grade on cattle, where he may not be able to receive a choice grade in Sioux City, Omaha, or Chicago. I think that is a general feeling among cattle producers. I wonder if Dr. Pierce could explain why the thinking is along that line, or if that is true.

DR. PIERCE: This seems to be tied in a little bit with pride of ownership. I can't recall discussing grading with a member of the trade when someone didn't influence me that this was the toughest grading in the country. Apparently it is a matter of where you sit. I am sure we would be the first to tell you that we recognize that there are errors in grading. We have no reason to believe that there would be an unusual geographic distribution. We have a fairly intensive system of supervising grading, and I think it keeps errors down to about the minimum that can be expected under this kind of a system.

WISE BURROUGHS: I would like to ask Dr. Pierce about the various indexes for determining within a grade those carcasses which are least wasty versus those that are the most wasty. Is thickness of fat over the loin one of the better indexes that you get so far as the better cut (out) value, say within the choice grade or good grade, or is it more complicated than that?

DR. PIERCE: Correlation of thickness of fat over rib area with cut out in our data is something like 0.4. We have correlations, as I indicated earlier, that had gone up to 0.921. However, it isn't this simple. We have some fairy usable indexes, but most of them involve several measurements; they are cumbersome to make, and we have found that considering the entire disposition of fat over the carcass inside and out, we can do a pretty reasonable job of predicting this.

MR. RALPH BIERMAN: I would like to ask Dr. Pierce what would happen at Sioux City, Omaha, Chicago, Phoenix, Cincinnati, and so forth, if the graders were transferred over the weekend and had to grade beef without any further instruction?

DR. PIERCE: I think if you transferred all graders over night, I would not be the one to tell you we wouldn't run into some new problems. I think new problems would be primarily that of subjecting graders to a different type cattle from that normally seen. This would probably cause some temporary problems. However, I would like to emphasize that insofar as maintaining uniformity is concerned, we have a corps of national supervisors who are constantly traveling. They are not limited to any one geographic location. I think they are trying to do about all that is humanly possible to get an accurate and uniform interpretation. Certainly the situation that you bring up would create some problems, because a man who is accustomed to grading 1,250-pound cattle, thrown into Texas where they may be marketing 700-pound steers of a likely different type would find himself confounded with new problems. This, as I see it, is in no way an indication you cannot obtain a reasonable uniformity through a national system of supervision, which is what we are trying to do.

Committee Recommendations

Quality standards are important in the pricing, merchandising, and market communication between rancher, farmer, feeder, buyer, processor, distributor, and consumer. U. S. government grades and propietary brands are presently being used to reflect the application of these standards and are useful means of identifying beef of different qualities for merchandising. However, variations within such grades or brands is very great.

Future beef merchandising will include quality control in the production of beef. Quality control includes control of breeding, nutrition, and management of beef cattle, pre-slaughter treatment of slaughter animals, and post-slaughter treatment of beef.

Standards should be improved through research to develop more accurate, more practical, and more objective tests for cutability, tenderness, flavor, and juiciness which preferably may be applied to raw meat, and to identification of these factors in live animals.

Marketing Beef on the Hoof

Joe B. Finley
Callaghan Ranch, Encinal, Texas

PRACTICALLY SPEAKING, there is no such thing as discussion among people who have livestock to sell as to the manner in how it is to be done. Almost every individual has already decided how he will accomplish this. There is much talk about how much the animals brought. Braggingly when the sale was good; disgustingly when it was bad. Generally every delivery nets a different price even though the animals come from the same group with all conditions the same. It is very difficult to secure uniform feeders in numbers except from the reputation brand herds. Marketing beef on the hoof has more variations in handling than almost any practice you can imagine. The product is not consistent enough to accomplish the best marketing. Still, every animal regardless of its age, flesh condition, color, shape, or size has value and will produce a nourishing meat product.

I shall use "range areas" to mean all sections of the U.S.A. from which stockers and feeders are sold. Fattening cattle in the feed lot has some mechanical aspects. For example, averages for daily consumption, daily gains, feed conversion, and cost of gain can be detailed with reasonable accuracy if the weights, ages, weighing conditions, and flesh conditions are known. Occasionally you will be taken for a big surprise. Fortunately though, it is not always unpleasant. Gains can be surprisingly favorable as well as disappointing. Development of beef on the range, as you know, is uncertain depending on the vagaries of the elements. Drought is almost as bad as poor management. The combination of the two cannot be made to produce desired results. Custom feed lots are set up on a production line basis. The latest modern feed mill has turned to automation. It is so accurate in the mixing process that a shortage of 5 pounds of one ingredient in a batch of 1,000 pounds will stop the operation. As long as the various feed ingredients are maintained in the flow pattern the finished mixed feed will be delivered to the mechanical feed wagon without delay. This operation requires no more than casual supervision. Buzzers and/or lights may advise of impending shortage and/or tanks or bins nearing capacity.

Grain-fed beef seems to have hit a popular chord with the American Public. I, for one, subscribe to that. Until 1952, I could not realize how unpopular grass beef could become. We did have ample warning that the aged steer fattened on grass was not selling with the ease that he formerly enjoyed. The average western rancher from the great range states does not know what good meat is. I readily admit I was not fully aware of what I had been missing through the years until we arranged to eat from the choice animals finished in the feedlots. You can get the same results by patronizing and encouraging a butcher who consistently handles the better grades of beef. It is convincing now, after a few years' experience in the California feed lots, that unless our taste buds for good red beef change, we can look forward confidently to increased per capita beef consumption as we learn to produce consistently more of the popular beef and less of the unpopular quality that has to get into the trade.

It would be ideal if tough and unsavory pieces of beef could be cut back and destroyed before ever getting into the trade—a method similar to culling vegetable produce. Most all beef production goes into consumption at some price, as even the tough unsavory pieces are nourishing food. Very small quantities of beef are wasted. Quality meat will promote consumption. Quality beef in quantity will move into consumption with the least disruption in price. We are hopeful that the abundance of forage and grains, together with the capacity of our farmers to produce more, will not overload the market during this present cattle inventory cycle.

You scientists are giving us both pleasure and pain by helping to grow more feed per acre and more beef for less feed. The advantage to the industry, if we can make the adjustment, will be that the consumer will learn to use and require more meat in his diet. With pork and poultry selling so much cheaper, beef has never had such notable competition. It takes time, patience, and experience to make a fine cut of beef; quality products are always more expensive to produce and enjoy. We could exist, I am sure, on chicken and pork, but who among us wants to sleep on a straw mattress or use or consume any product that does not warrant some pride in its ownership or use. This nation has the outlet for quality in all products and beef most certainly is no exception.

We are now making beef animals at near 1,000 pounds average per animal in less than 20 months of age. Formerly, it took as long as 36 months to produce grass-fattened beef whose quality was not attractive.

The beef cow herd in our United States had expanded to 25,584,000 head by January 1, 1959, from 15,919,000 head 10 years prior. Numbers will be up again in the January 1, 1960 estimates.

In the last two years calves have not been slaughtered in their usual numbers, resulting in a greater percentage of the annual calf crop being pushed to make beef and their average dressed carcass weighing more. I am sure we have less of what are classified as heavy carcasses in the trade. Also, with less of the light carcasses, the middle weights are up by large relative percentages. I hope this means we are moving toward more consistent quality in beef. We need that badly. Beef carcasses weighing more than 700 pounds are usually sold to the Armed Forces or are used for breaking purposes. These weights are not in popular demand. It is estimated that 1,500,000,000 more pounds of meats will be produced in 1959. This means that beef production is gaining faster than the increase in population. More pounds of beef per capita are being made available. This is causing some concern among all operators who have given it some thought.

Beef Importation

I am not certain what prices will stop the excessive importation of meat products. It is not important to this group when this will transpire, but let it be known that this is causing a very severe headache to the producer at this time.

Many thousands of tons of beef have been imported from areas not accustomed to selling on our shores. The beef producers of America should be complimented in not heretofore seriously objecting to this importation—a competition that has lowered the prices of their product from the level at which they would have sold.

It is estimated by good authority that this competition has kept prices down through what I call the remunerative period of the present cycle by an estimated $5.00 per cwt. I have been unable to determine at what price level this importation will be shut off, but it is my own estimate that 15 cents for the commercial cow will do the job.

The tight money policy of the Federal Reserve Bank has contributed immeasurably in recent weeks to a lowering of prices in the range side of our industry. Beef producers in the Central United States have been advised that liquidation of their fattened cattle must be well advanced before replacements from the range areas will be financed. The result of this, combined with some increase in finished beef, has brought about a loss in net returns to the range and feed lot producers alike averaging between $25.00 to $40.00 per head below the average 3 to 4 months ago.

Considering this foregoing statement I am fearful that we are now in the declining price side of the present cattle cycle. Other more competent authorities than I contend that the remunerative period will last into late 1960. In either event, this will be the shortest remunerative period in a cattle inventory cycle ever experienced.

With forage and grain production for 1959 now assured, meat production will be even greater per capita for 1960 than 1959. To keep our business normal the Beef Councils over the country are making every effort available to them to increase consumption of beef. We can assist by feeding well and making our product as consistent as possible. There is no better food for man than beef.

Buying and Selling Methods

Buying and selling between the producer and processor of beef is made in many different ways. The great public markets were conceived originally to afford a great gathering of all classes of livestock at central points to which all comers could go to select their needs. It was expected that the great packers would be able to slaughter all animals suitable for beef that were not taken as stockers and feeders. This is no longer true. What has actually happened is that these markets have served a very useful purpose. But, from the producer standpoint, he has many times gone away unhappy. He was rubbed wrong—he went home grumbling that something was lacking. The public market did not do a good enough job. Lack of public relation understanding helped competition to spring up through local packing plants and country selling. The public market owners were adamant in stating that cattle producers could not afford to sell except through their facilities. The security the public yard owners felt was not shared by the producer. The producer, however, liked the few sales he did make direct to stocker and feeder buyers and to local packers in his area. Maybe good roads, motor transportation, and wonderful communications helped to bring the change. Whatever it was, we now have auction sales and country buying that are handling an increasing volume of the sales. Volume on the public markets has decreased to the point where country buying by the commission merchants serving the public markets is needed in order to keep their offices open.

Do not feel that the commission merchants have lost out entirely. They have been dependable and useful friends for many years to the cattle industry. They will meet their problems and I am certain that the industry will have need for their services in the merchandising of livestock.

Local packing plants have increased enormously and seem to get all the kill they need as they increase their volume at prices that keep the animals from the market centers. The auction markets have an attraction for the producer. An auction sale is available locally. Animals in small numbers can be delivered readily in a trailer or pick-up. The many miles to the public market make it impossible for the small operator to transport small numbers economically. It is notable that most of the small operators go to see their cattle sell and, having time on their hands are afforded an opportunity for diversion. In addition, I suppose there are other psychological factors that are unfavorable for the public markets.

Buyers will, and do, go any place cattle are accumulated in numbers. The auctions handle sizeable volume in numbers. The public stockyards could not handle the volume if all cattle sold each week were forced into their markets. Stockers and feeders make up the big volume at the auction markets, but packers are available to take all beef offered.

Trucks now handle the volume of livestock on the shorter hauls. The railroads that were so important to the large public market do not serve the local markets successfully. No longer are many cattle driven to the railroads. It is easy to see that once livestock are on the truck why unload onto slower transportation, except for long hauls.

Taking California as an example, it would seem that packers will be adjusting their kill to the supplies within truck delivery distances. It is almost certain the big public markets, as we have known them, will continue to lose ground except for favored spots that will afford large volume delivered by highway transportation.

We still depend on about three of the public markets to influence general price levels in the California and western trade areas, and we determine volume of supplies for day and week by that reported for the twelve principal markets. This is a service supplied by the Department of Agriculture gathering market reports from various markets, including some auctions and also some country sales. Beef prices are quoted regularly for some markets—Chicago and New York being more regularly reported.

There are those who expect Los Angeles to become a beef market similar to New York, with the bulk of the meats for the Los Angeles market being shipped into the area and little local kill. In this I do not concur since California is a great agricultural state. Of course, in any event, much meat will be moved into the Los Angeles area—there is not enough roughage in California to feed all the beef.

This cattle inventory cycle previously referred to has not been determined definitely by any means. Advantages in prices did not appear until July, 1957, so you will see the recovery period which I have called the remunerative period of the cycle covers not much more than 24 months to now. Fat cattle sold since August, 1959, have been losing the feeder money in many instances and more recent sales in September and October show less favorable results.

I am convinced, however, that commercial breeders can take their production to finished beef with less risk than is now done with one or more changes in ownership, before the beef is finished for slaughter. Workable only though, as, and if the commercial feed operation takes hold in the Midwest.

The large commercial feed lot may never replace the small feeder who does his own work, feeding his own farm-raised feed. There seems to be an efficiency in the commercial feed operation that is not truly defined as yet. The advantages of favorable climate coupled with mechanization, plus higher feed costs against the disadvantage of less favorable climates with lower feed costs add up to the uncertainty. I do not have the experience nor do I know any operator who can answer this comparison. There are commercial feed lots in the Midwest that seem to no more than compete with the lots serving the West Coast.

Merchandising beef on the hoof takes in every classification of cattle sales. Every cattle sale beginning with the first as stocker or feeder is one step closer to beef on the hook. The registered cattle breeder produces the bulls for our commercial herds. His culls go into meats as they cease to be breeders. The commercial breeder furnishes the animals that make up the bulk of meats that sell into the popular grades. Prepared meats and hamburger are certainly in constant demand, but they are not ordinarily produced from the grades of meats that get preferential feeding through the feed lots. We are concerned here with all meats, certainly, but the Beef for Tomorrow must be the delight on every table it is served.

The beef that goes into most hamburger and the prepared meats is at this time a consistent product, and is taken from boned meats of animals which are not considered the most important sales in any production operation. These cull cattle from the breeding herds generally go to the closest market or auction and their sale is ultimately to the packers.

The stockers and feeders from the commercial herds are the important sales for every range area. Since the advent of the *supported prices on basic farm products,* stocker and feeder animals are produced in greater numbers in many states that previously produced very few stockers and feeders. These animals may go to the West Coast or any feeding area across the nation as far east as New York state. The New England states surely feed livestock, but they do not come into any scope. We, from the western areas, do not know they exist.

The Beef of Tomorrow will come from the commercial breeding herds from all over the nation. Maybe this beef will be defined here at this conference. If so, it might still be years before the animal will be generally known. This is an important meeting—competent breeders will take new appraisals of their problems if they have not already done so.

Big commercial feed lots may be put up in all areas where there is ample roughage to go with grain. Many range states will be producing more grain fattened animals. Transition is in the making—those that make no mistakes in making adaptions to the trend will be termed intelligent operators. Others will earn less favorable comment, not because they were not making an effort, but because they were not fortunate with their appraisal. I do not see anything but trial and error for some time to come, unless the answers may develop more quickly than I anticipate from meetings of this sort.

Beef transported some distance is less in demand than the locally dressed carcasses. When this difference is solved, live cattle will move only that distance that takes them to where they can be fattened the cheapest to the popular meat grade. I could use the words "choice grade of meat" rather than popular, but in deference to my colleagues and to the estimates you may make or have made here at this conference, I shall prefer the term "popular" to define what the Beef of Tomorrow will be. After all, commercial operators like ourselves who wish to handle numbers are very anxious to have answers in order to make their operations better. With greater production a certainty, and greater production needed each year to meet population increases we need to determine definitely how the beef product must be finished. We need to know it soon. May I repeat—production of beef will surge ahead of consumption needs in the near future.

Better Beef Provides Challenge

This is America at its best—no holds barred in developing a better product so that our meat consumer will give more working time towards obtaining it for his table.

Grading done by the Department of Agriculture should and will eventually place the term "choice" on the type meat that by volume meets popular consumer preference in all respects. This will be the Beef of Tomorrow.

Three Steps to Good Merchandising of Beef on the Hoof

1. Well owned is half sold. This is the old proverb changed to fit our occasion "well bought is half sold."
2. Develop the customers needed for your particular size of business.
3. Plan with all responsible persons available to you and plan with your customers what to produce and when to have it on the market.

These steps have been learned through experience. They have given our family a better than average result financially and it has also given us much satisfaction in our association with the good people who have been our customers throughout the years.

Step 1. Well owned means much in this instance. The necessity of owning well may awaken you at night. You should look well into every step of your purchasing, breeding, and production procedures and do it often.

I suggest for the actual selling of your beef on the hoof that you should continue to do as you have always done—attempt changes only after you understand what you are doing, regardless of what others may tell you. Do not try to guess the highs in any market year. It can hardly be done and will create trouble for that operator who supposes he can do so.

You should develop a formula to guide you in your purchasing. It is not enough to say that you bought cattle on the day of purchase in line with the market of that particular day. Plan by use of your formula the price you can pay in order to sell your produce in a market months ahead. You cannot buy prudently without anticipating what price will be needed to get your money back. The most dependable advice you can have is your own hard-headed experience and the mistakes of others. Don't be led too fast by the seeming success of others.

If you produce your own stockers and feeders you will strive to grow them so their cost will give you satisfactory results in low price periods. If you purchase all or a part of your animals your formulas will still be the basis for your decision.

You can't afford to be a high pressure salesman. It is wiser to base your business on live and let live prices. High pressure salesmen generally lose the perspective of producing or purchasing wisely.

Accurate bookeeping today is a must. We have long passed the era that we can survive without adequate records for comparisons and estimates. Agricultural advisors and publications can assist with formulas if you need them.

The above tells you then that you must set price goals that you consider possible lows for the period in which your animals will sell. Then apply your formula in reverse—so to speak—by which method you will determine what you can or cannot pay for stockers and feeders that are to sell in that projected market price range.

The answers you get from your formulas will also give you some basis for deciding the extent of your operation. And you can, with these answers, balance your operation with some "sense of proportion" that will expose your operation only to the risk that you feel will be prudent.

There is one more important caution that I find many operators do not contemplate. Never plot a purchase or production program planning that certain amounts of profits will return. Plan only that your capital will return with some margin of error against the low side. I assure you that profits will be the reward on the average. You may decide, as we have had to do often since grain comes to the commercial feeder at a protective price, that competition is going to be rough, but we do have to do a certain volume of business to hold our organization intact. We ranchers and livestock farmers make our living from efficient operations; we have no control over prices nor the elements.

It is an exceptional rancher or farmer who makes much more money annually than that required to provide his family with a reasonable living. He, though, who lives with the same farm or ranch over a long period of years—operating it efficiently, will develop into a substantial citizen. The proverb that "a rolling stone gathers no moss" must have been invented to suit an agricultural society.

You may ask what this last statement has to do with merchandising beef on the hoof. You have to be on the field to play the game, which means that its value to you will be beneficial if it causes you to get your feet firmly on the ground.

Step 2. Develop a customer or customers for the kind of beef animals you can best handle or which fit into your buyers merchandising programs. Merchandising in all fields is best accomplished where confidence has been established between buyer and seller. This can be done through your commission man on the public markets as well as through direct contacts. Unfortunately, for the commission merchant more sales are being made outside public stockyards each year. The commission man is working diligently in the country and we should not discount his value.

It is fallacy to feel that you must get the last dollar available for your livestock. It is wiser to be considerate of your buyer so that you do not have to find a new customer for each sale. The time wasted looking for new customers can be utilized for valuable planning—worth much more to you than the extra money you may get.

Step 3. Seek advice from every source available to you—your banker, commission man, your buyers and good trade literature. Never has there been so much information available to the cattleman as comes to him now. Much of it is basic in our operation—thanks to all who have made it available. Finally, however, your decision must be your own and, since a program once set up takes time to accomplish, it is practical to stay by it to the end. In fact, that is about all you can do.

Explain to your buyer what your feeding program will be. Employ advice on feed formulas if necessary. Show him by example that you do produce a good beef carcass for the grade of your animal. Let him know when your animals will be ready to slaughter—maybe he will drop by to see your cattle and together you may plan when the animals will be ready. Very few cattlemen or feeders know much about their beef in the carcass and miss the quality on the hoof, notable unless the cattle are very close to one grade.

If you are fortunate to deal with a high class packer, you will find that selling your beef on grade and yield will net the best averages. To do this you must feed well and know something about beef or have confidence in your packer.

There are very few packing plants who do not order their buyers to purchase only certain types of animals for each day's kill. Sometimes the kill will be bought ahead on certain types, particularly if the plant is buying to fill a contract or if the management anticipates a rising trend in the market. You will be benefited by staying with a consistent program of selling. Sell by contract ahead of the time your cattle are ready or sell for fair prices the day your animals are ready.

You should realize that your packer customer has a three department team that practically runs his operation. The manager (if not the owner), the beef sales department, and the livestock buyers. The beef sales department wields the big stick. They tell the story of why or why not the beef is moving or not moving and at what price. So learn, if possible, all you can about the ability of the sales department where you sell. They are not all good and I have known companies that did not deserve to do business with clean cut operators because of the inability or the uncooperative attitude of the head beef salesman.

This head beef salesman, together with management and the cattle buying department, determine purchase price and the cattle buyer is so limited by this decision.

If you can pick your choice, avoid packers who are erratic in their purchases or those who may have volume ideas rather than a good consistent business. No more beef can be put into the coolers from the killing floor than goes out through the sales door. A packer who allows his coolers to become over-loaded too often should be avoided.

Since there are relatively few packers and many producers, keep your buyer constantly advised so that your animals will be placed in the kill without delay. No plan is automatic. You have to ride herd on your operation. Sometimes you can wait several days if the market is high or rising. On the low market, however, it is doubly important to move livestock as they are ready. Delay means money out of your pockets where the cost of gain is higher than the sales price.

The customer who will take your cattle without delay as they are finished for slaughter should be cultivated when prices are high and cattle hard for him to buy. See that he gets your cattle in the high priced, shortage periods but tie him to you by so doing since you will need him much more in the low periods, and he can easily repay you for your previous consideration without cost to him or his plant.

Beef on the hoof is nothing more to you than the merchandise, relatively speaking, found on your neighborhood grocer's shelf. Some different kind of a store, I grant, but still just your stock in trade. Your inventory turnover is as important to you to sell prudently as it is for the grocer.

Do not allow yourself to fall in love with your beautiful cattle. Love your family, respect your home but sell your production as it is ready.

I would almost guarantee if you can master these "Three Steps to Merchandising Beef on the Hoof," that you will be in the business when others are having more troubles than you. I believe these steps will keep your operation adaptable to the changes in the industry.

THIRD SESSION

How to Produce Beef Economically

M. L. Baker, *presiding*

Type and Quality in the Live Beef Animal and in the Carcass

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DISCUSSION of this topic is justified by the belief that marketing of slaughter cattle on foot will continue to be the trading system of choice for most packers and producers. The accuracy of evaluation of characteristics contributing to variations in value obviously improves as the beef progresses toward the consumer's plate. Dressing percentage is not important when the carcass weight is known. Carcass weight is not important when the weight of the component trimmed wholesale cuts is known, and value at retail is finally established rather definitely when retail cuts are processed, weighed, packaged, and priced.

"Quality" is a very ambiguous word. To showmen it may refer to style and symmetry, haircoat, length, thickness, luster, or color markings, and even excellence of fitting including dehorning, hoof trimming, clipping, and grooming. Meats men estimate "quality" by the appraisal of factors thought to be related to the eating desirability of the beef, but consumers just decide on the basis of the tenderness, juiciness, and flavor of the cooked meat. Accuracy of appraisal decreases at each processing point along the chain from the dinner plate to the live animal.

Efficient movement of about 14 billion pounds of perishable beef to U. S. consumers annually has fostered a sense of urgency and an attitude of "the less handling and processing the better" all along the line from the slaughterer to the retailer." Low margins make high volume necessary for processing profit. If consumers were really hungry and beef had a monopoly on the protein food market, buyers would not be very discriminatory in their beef purchases. The abundance of protein foods and the general prosperity and strong buying power, however, make most Americans very critical shoppers. In fact, beef purchasing habits might be as good as automobile purchases in stratifying people according to income and position. For the foreseeable future, we must conclude that people will be willing to pay more for preferred cuts of beef than for less preferred cuts, and that preferred cuts approaching ideal tenderness, juiciness, and flavor will bring top prices if properly identified and offered for sale.

Therefore, cattle that yield a higher proportion of preferred cuts combined with excellent "quality" beef from the viewpoint of discriminating, informed, and prosperous consumers will certainly be more valuable than average cattle.

We just need to identify such cattle and allow free play of economic forces. That is a large order. Researchers have been attempting to develop better identification methods for many years. Progress has been slow.

Lush (9) made 17 measurements on 185 steers during dry lot feeding to record the changes in conformation during intensive fattening. The data were treated statistically and many ratios were calculated, but no reference to carcass characteristics was made. Lush (10) added 56 steers to the original 185 and related measurements to rate of gain, dressing per cent, and "value" of dressed carcass. The "value" was the appraised price per pound for the dressed carcass set by packer beef men. Though Lush's data were detailed and were analyzed statistically in a classical manner, comparison to an appraised carcass characteristic reduced the usefulness of the results.

Black et al (1) refined the techniques of Lush, and applied 9 live measurements to 50 record of performance steers of beef, dual-purpose, and dairy breeding. The steers were produced under standardized conditions and slaughtered at a uniform weight of 900 pounds. Live measurements were correlated with gain, dressing percentage, percentage of fat in the carcass, percentage of total edible meat, and slaughter grade. Their results confirmed observations of Lush (10) that steers shorter in height, shorter legged, and shallower bodied were higher in efficiency of feed utilization, had more fat, more edible meat, and less bone in the carcass than the taller, longer legged, deeper bodied animals. "Edible meat" apparently included all the fat as well as the lean meat, which reduces the present application of their results. Black et al (1) found visual observation to be superior to the measurements used, because "measurements cannot show exactly the symmetry and proportions that should exist in a good beef-type animal." No other data were given on meat yields.

Hankins and Howe (7) standardized cutting procedures for beef carcasses, and developed a valuable sampling method for estimating the lean, fat, and bone in carcasses without complete physical separation. Naumann (12) presented the method of Hankins and Howe with slight modifications, and the procedure was adopted by the Reciprocal Meat Conference.

Cook et al (4) reported on the relationship of 5 live measurements on 157 Milking Shorthorn steers produced under standard conditions at Beltsville, Maryland, with slaughter grade, carcass grade, and dressing percentage. Their data gave 12 out of 15 significant correlation coefficients but the relationships were not high enough to be of predictive value, as the highest was .51. The correlation between slaughter grade and carcass grade, however, was .69.

White and Green (16) related measurements of live steers to weights of wholesale cuts. Fifty beef-type steers were used weighing from 800-1,440 pounds and grading medium to choice. Thirty-six linear measurements were made with detailed statistical treatment of the data, including multiple correlation coefficients. Their high correlations included live weight in the formula, which is obviously related to the weight of wholesale cuts, and contributed greatly to the multiple correlation coefficients because of the wide spread in weight of the cattle.

Green (6) related the data taken on the 50 steers reported by White and Green (1952) with combined weights of preferred cuts including round, trimmed loin, and rib (I), and the latter combined with the "cross cut" (II). He emphasized the importance of shoulder width and width through the thighs as indicators of carcass muscling. Depth of chest was not a good indicator of dressing percentage or preferred cut weights. Compactness was not associated with higher yields of preferred cuts.

Width of shoulders and hooks and depth of twist were more highly correlated with the yield of preferred cuts than other linear measurements.

Yao et al (19) related 8 meat production characters with 19 body measurements on

101 beef Shorthorn steers and 62 Milking Shorthorn steers raised at Beltsville. All of the width and circumference measurements were positively correlated with slaughter grade, carcass grade, and dressing percentage. All of the height and length measurements were negatively correlated with slaughter grade. No carcass cut-out values were reported.

Woodward et al (17) reported relationships between preslaughter evaluations of beef cattle. Their data were taken on 635 steers produced at Miles City, Montana between 1941 and 1951. The correlation between slaughter grade and carcass grade was .54, with much lower coefficients for area of eye muscle (.16), thickness (.22), dressing percentage (.19), length of body (.15), and length of leg (.03) compared to slaughter grade.

Thickness of fat was related higher (r = .43) with carcass grade than was area of eye muscle (r = .08). They stated that "since the ultimate value of the carcass is enhanced more by a large eye muscle than by excess external fat, it is possible that thickness of external fat received too strong a consideration in the grading."

The relationships between body measurements and area of eye muscle, thickness of fat, and dressing percentage were less than .50, but "length of leg" in the carcass was rather closely related to length of body alive (r = .77). No cut-out data were taken.

Kidwell (8) reported on the relationship of beef conformation and carcass quality in beef calves. Actually the 64 steers used were exhibited at the 1954 Nevada Junior Livestock Show, and ranged in age from 10 to 16 months. The correlation of slaughter grade with carcass grade was .60. Body measurements were correlated with slaughter grade, carcass grade, and dressing percentage, but no cut-out data were reported.

Butler (2) reported the results of the Texas Agricultural Experiment Station beef carcass cut-out tests for the previous six years. The most important conclusion reached was that animals of the same fatness may vary considerably in conformation without affecting the percentage of wholesale cuts materially. The main factor influencing the percentage yield of wholesale cuts is the fatness of the carcass. Bones and muscles tend to develop proportionately, but fat is deposited unevenly over the body.

Tallis et al (15) of the Ohio Agricultural Experiment Station related body measurements to beef type and certain carcass measurements. Their basic criterion of carcass "meatiness" was the "edible portion," as developed by Professor L. E. Kunkle and his group. On a side of beef, this consists of boneless cuts trimmed to 3/8 inch fat cover or less along with the boneless lean trim. This is an exacting test.

Ten live measurements were made, circumference of heart girth, navel, and forearm, width of chest and hooks, depth of chest and twist, height of withers and hooks, and length of body. Repeatability of measurements as taken by two investigators on the same steers was good except for circumference of forearm and depth of twist.

They found that animals with a high ratio of weight to height (low-set) and with a high ratio of weight to length (compact) tended to have larger ribeyes, but a smaller edible portion percentage. They explained that the ratios were apparently positively correlated with carcass fat, and thus negatively related to edible portion, since the latter is highly influenced by the amount of fat trim.

Several workers are presently engaged in developing objective measures of muscling and lean-fat-bone variations in live animals by application of ultrasonics and specific gravity measurement. Stouffer seems to be developing ultrasonic measurements to usable accuracy in estimating area of ribeye of live cattle and swine. Pearson (14) and the group at Michigan State University are making progress in the use of an air chamber for determination of specific gravity by air displacement. Their appraisal of the application of this technique is envisioned as follows:

"The specific gravity obtained by air displacement is a means by which leanness of animals can be measured directly. Current methods of determining body composition arrive at leanness via a direct measure of fat.

"If this method can be adapted to measure leanness of whole droves of animals, it can be used to more accurately determine the worth of market animals. Also, when using individuals, this method can be applicable as an aid in the selection of animals for breeding programs."

Fat slaughter cattle that look very similar alive are likely to show marked variation in carcass muscling. This is of major concern to the beef industry. Fulk (5) reported the loin eye and fat cover measurements for 384 cattle shown at the International. His data are shown in Table 1.

The variability shown by such selected cattle is great, and should be of concern to beef producers.

Some of our major packers are attempting to improve the ability of their cattle buyers to select steers and heifers with superior muscling within the various grades. J. N. Jones of Swift & Company, and Fred Haigler of Armour and Company reported on their programs at the American Hereford Association research meeting March 19 and 20, 1959. Mr. C. A. Rheinberger of the Beef Department,

TABLE 1
Loin Eye and Fat Cover Measurements
(Average of 384 cattle that were shown in the International Carcass and Carlot Contests)

	Live Weight	Loin Eye Sq. In.	Fat Cover Inches	Per Thousand Loin	Per Thousand Fat
Junior Yearlings (Avg. 21 months) (75% Prime—25% Choice)	1,150	12.2	1.4	10.5	1.2
Summer Yearlings (Avg. 17 months) (60% Prime—35% Choice—5% Good)	1,000	11.0	1.0	11.0	1.0
Senior Calves (Avg. 13 months) (35% Prime—45% Choice—20% Good)	875	10.1	0.7	11.5	0.8
384 Steers	1,000			11.0	1.0

VARIATIONS

Smallest Loin Eye	7.65 sq. in.	1,035 pound steer
Largest Loin Eye	16.2 sq. in.	1,250 pound steer
Smallest Loin Eye per 1,000 pounds	7.8 sq. in.	1,145 pound steer
Largest Loin Eye per 1,000 pounds	14.9 sq. in.	840 pound steer
Most Fat Cover on a Prime Steer	2.33 in. on a	1,192 pound steer
Least Fat Cover on a Prime Steer	.47 in. on a	900 pound steer

Cattle Buying Division, Swift & Company, Chicago, recently stated that they had not recorded statistical data, and were unable to report facts at this time. "The problem of excessive waste material on cattle is still with us, however, and we are constantly reminding buyers in our day to day operations that it is necessary to discount fat, rindy, wasty cattle."

Though we all admit to being rank amateurs, staff members at Texas A. and M. are attempting to learn to estimate carcass traits of live animals more accurately. Table 2 indicates the accuracy of estimates at present as shown by the data on a recent group of experimental steers.

Substantial progress has been made by swine breeders in improving the yield of lean cuts on slaughter hogs. The lean cuts of pork are anatomically quite comparable to the preferred cuts of beef. The answer to higher percentage yields of lean cuts in hogs is the combination of superior muscling and reduced external fat. The same prescription will work for beef cattle, though extremes of weight, age, and other factors complicate the problem.

Evidences of superior muscling in hogs may apply to cattle, such as turn of top, shoulder muscling, wide set front and hind legs, and well developed "hams." Cattle with extremely good or extremely poor muscling can be identified, but those clustering more closely around the average are difficult to rank.

Progeny testing with direct selection for the most important production and carcass traits seems to be one pathway to progress. Artificial insemination can spread the influence of a few top sires tremendously.

Some of the "quality" factors traditionally checked on slaughter cattle are refinements of head, hide and bone, and fineness and luster of the haircoat. Small heads and thin hides increase dressing percentage. Refined bones may actually be related to inferior muscling (11, 13, 18). It is inconsistent to select for heavy boned breeding cattle and light boned slaughter cattle.

Cartwright et al (3) measured the hair density and diameter on slaughter steers and compared to the tenderness of the

TABLE 2
Correlation of Live Estimates with Actual Measurements

	Dressing %	Carcass Grade	Ribeye Area	Sum Loin + Rib + Round & Rump	Ribeye Area/cwt. Chilled Carcass
No. Steers	41	41	41	41	48
Estimator					
A	.64	.51	.51	−.04	.35
B	.74	.40	.27	.17	.45
C	.68	.49	.43	.13	.47
D	.62	.31	.37	−.21	.34
E	.43	−.21	.27	−.83	
Measurement Range	54–63.8%	Std.-to Good	7.3–10.5 sq. in.	46.1–51.6%	1.4–2.3 sq. in.

Required for significance: 0.1 = .39
0.5 = .30

beef. No significant relationship was shown.

So far no short cuts to feedlot tests have been found to establish gaining ability of cattle.

Tables 3 and 4 present data on two small demonstration groups of fat slaughter steers weighing about 1,000 pounds. These cattle were selected from groups of about 20 steers of each breed and used to demonstrate the variability in value of such cattle.

It is interesting to note that the steer in each group with the least fat had the most tender meat. This could easily have been coincidental, but does point out that tenderness is not highly correlated with fatness.

It is also interesting that the price spread between choice and prime was not enough to offset the higher cut-out percentage of the low choice steer No. 1 in the Angus group, so the carcass value per cwt. actually figured higher for the low choice than for the prime.

We must conclude that slaughter steers of approximately the same live weight and grade vary significantly in value on the basis of their retail yield of various cuts. The increased value is related closely to superior muscling and reduced outside fat covering. No objective measures have been developed to characterize and rank live steers accurately, but the extremes can be identified visually. Ultrasonic measurement of muscling and specific gravity estimation by air displacement show some promise, but their application to selection of breeding animals seems more likely than to slaughter animals, because trading on a carcass basis probably would be simpler.

Production of slaughter cattle with superior cut-out and beef desirability is a logical goal for beef cattle producers, and progress will tend to stabilize the majestic position of beef in the American diet.

TABLE 3
Demonstration Hereford Steers About 1,000 Pounds

Animal No.	Carcass Grade USDA	Ribeye Area Sq. In.	Area Ribeye/ cwt. Chld. Carc. Sq. In.	Fat Covering over Ribeye Inches	% Loin + Rib + Rnd. Retail	Total Value cwt. Carc.	Shear Force lbs. (24 hr. chill)
1	Av. Ch.	14.83	2.15	.77	37.34	$46.50	9.38
2	Av. Ch.	13.26	2.01	.97	36.51	46.34	10.69
3	H. Ch.	11.41	1.68	1.55	30.11	41.30	12.63

TABLE 4
Demonstration Angus Steers About 1,000 Pounds

Animal No.	Carcass Grade USDA	Ribeye Area Sq. In.	Area Ribeye/ cwt. Chld. Carc. Sq. In.	Fat Covering over Ribeye Inches	% Loin + Rib + Rnd. Retail	Total Value cwt. Carc.	Shear Force lbs. (24 hr. chill)
1	L. Ch.	11.78	1.81	.80	36.36	$45.29	6.37
2	L. Pr.	10.45	1.48	1.53	31.16	44.53	8.56
3	Pr.	9.80	1.46	1.30	32.50	45.08	7.69
4	L. Ch.	9.69	1.55	1.10	33.07	42.55	8.13

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Genetic Aspects of Production Efficiency in Beef Cattle

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MAXIMUM improvement of production efficiency of beef cattle through breeding depends upon (1) a knowledge of the types, relative importance, and inter-relationships of hereditary variation present in available stocks, and (2) utilization of this knowledge to make matings or design breeding systems to most fully exploit hereditary variations. Although much remains to be learned, research during the past 30 years and particularly during the past 15 years, has set the stage for substantial genetic improvement in most characters influencing economy of production and consumer desirability of product.

Table 1 summarizes material accumulated to date on heritability of several important traits influencing efficiency of production and carcass quality. Estimates as given here are heritability in the narrow sense and, for the most part, include only additive gene effects. Characters with medium to high heritability are those for which individual selection within a population should be at least moderately effective and for which the production of high performing crossbreds or linecrosses will depend, to a large extent at least, upon crossing of productive parent stocks. Improvement in characters of low heritability, if capable of genetic improvement, will depend upon judicious crossing and perhaps selection for crossing ability rather than on selection for performance as such.

Speaking generally, it appears that all the traits studied to date relating to growth, efficiency of gain, conformation scores, and carcass characteristics have heritabilities high enough that selection should be effective. Only a few estimates of heritability of factors related to reproductive rate are available but they are uniformly low and, taken together with the more voluminous literature on genetic aspects of reproductive efficiency in dairy cattle, lead to the belief that selection is not likely to be effective. Presumably automatic selection (i.e., infertile breeding stock leaves a lower than average num-

TABLE 1
Heritability Estimates for Beef Cattle Characters[1]

Character	No. of Estimates	Ave. of Estimates
Calving interval	3	8
Birth weight	15	41
Weaning weight	29	29
Cow maternal ability	2	40
Post weaning feed-lot gain	19[2]	47
Efficiency of feed-lot gain	8[2]	40
Final feedlot weight	9	69
Post weaning pasture gain	9[2]	34
Cancer eye susceptibility	2	32
Live animal scores		
Weaning	18	27
18 mon. off grass	7	27
Slaughter	7	44
Carcass traits		
Dressing percent	2	71
Carcass grade	6	32
Rib eye area	3	69
Tenderness	5	58

[1] Most pertinent references are given in Warwick (45). Additional references include Blackwell *et al.* (2), Shelby *et al.* (38), Kincaid and Carter (27), Carter and Kincaid (7, 8), Brown (13), Cartwright *et al.* (9, 10), Gaines *et al.* (20), Wagnon and Rollins (44) Dinkel (17), Alsmeyer *et al.* (1), and Keifer *et al.* (26).

[2] A few unreasonably high or low estimates omitted.

ber of offspring) has nearly exhausted whatever genetic variability may have once existed in most breeds reared under a variety of environmental circumstances. Breed differences for some components of fertility do apparently exist, at least in some environments, and their existence leads to the hypothesis that breeds may have plateaued at different levels for different reproductive factors. Thus, reproductive performance may have potential for improvement through crossing.

The above statements on probable ineffectiveness of selection for fertility within breeds must be taken with some reservations since Knox (29) found a difference in calf crop of 12.2 per cent in favor of large type as compared to compact Hereford cows. He hypothesized that the large cows were better adapted to the rigorous New Mexico range conditions where the experiment was conducted and thus able to maintain higher reproductive rates. Stonaker (40) found that conventional cows raised 8.4 per cent higher calf crops than Comprest cows under Colorado range conditions. Studies of heritability of various components of reproductive ability have not been made under severe environmental conditions. Such studies could conceivably give different results than those reported thus far.

Probable Effectiveness of Selection

The fact that hereditary differences exist in important production characters is of academic interest until considered in relation to the amount of variability present in a population and the intensity of selection which can be obtained.

The formulas developed by Dickerson and Hazel (14) have been used and extended where necessary to estimate progress attainable for a few traits and a few selection systems (Table 2). The estimates apply to *large populations where only one character is being selected for at a time.* The selection plans are: (80 per cent calf crops and 50 per cent sex ratio assumed)

1. *For Cows:* (cows calve first at 3 years and 5 per cent annual attrition assumed) 60 per cent of all heifer calves retained for breeding with 50 per cent of these culled on calf performance after 2 calf crops. Remainder used to 10 years of age.

TABLE 2

Estimates of Annual Genetic Improvement Possible in Large Beef Herds Under a Few Possible Breeding Systems when *Selection Is For One Trait Only*

	Weaning Weight[1]	Postweaning[2] Feedlot Gain	Efficiency of[3] Postweaning Gain	Area of[4] Rib Eye	Tenderness[5]
Bull Plan A (Natural Service)	4.3 lb.	.043 lb. day	−8.40 lb.	.029 sq. in	−.088 lb.
Bull Plan C (Natural Service)	4.8 lb.	.047 lb. day	−9.24 lb.	.040 sq. in	−.120 lb.
Bull Plan D (Art. Insem.)	5.9 lb.	.060 lb. day	−11.82 lb.	.034 sq. in	−.112 lb.
Bull Plan E (Art. Insem.)	6.5 lb.	.059 lb. day	−11.82 lb.	.065 sq. in	−.195 lb.
Bull Plan F (Art. Insem.)	6.3 lb.	.065 lb. day	−12.66 lb.	—	—
Bull Plan G (Art. Insem.)	8.8 lb.	.069 lb. day	−13.26 lb.	.074 sq. in	−.222 lb.

[1] Assumed heritability of 30 per cent; standard deviation of 40 lb.

[2] Assumed heritability of 45 per cent; standard deviation of .3 lb. for males and .25 lb. for females; gain expressed in terms of average daily gain.

[3] Assumed heritability of 40 per cent; standard deviation of 60 lb. Efficiency expressed as pounds of TDN consumed per 100 lb. gain. Improvement in feed efficiency is denoted by reduction in feed required.

[4] Assumed heritability of 50 per cent; standard deviation of 1.0 square inch. Selection based entirely on information from sibs and progeny.

[5] Assumed heritability of 50 per cent; standard deviation of 3.0 lb.; expressed in pounds of force required to shear a one inch core in the Warner-Bratzler shear. Selection based entirely on information from sibs and progeny. Improvement in tenderness is denoted by reduction in pounds of force required.

2. *For Bulls:* (30 per cent annual attrition assumed for bulls over 3 years of age)

Plan A. 5 per cent of all bulls saved, used in natural service at ages of 2 and 3, then discarded.

Plan C. 5.6 per cent of all bulls saved and bred to 20 cows each as yearlings. The top 20 per cent on basis of individual and progeny information returned to service as 4-year-olds and survivors used naturally to 9 years of age.

Plan D. .04 of 1 per cent of bulls saved and used artificially without culling, starting at 2 years, on 2,500 cows each per year to 9 years of age.

Plan E. .5 of 1 per cent of bulls saved and bred artificially as yearlings to 40 cows each. The top 6½ per cent of these on basis of individual and progeny information returned to service as 4-year-olds and bred artificially to 2,500 cows per year to 9 years of age.

Plan F. .01 of 1 per cent of bulls saved and bred artificially to 10,000 cows each per year starting as 2-year-olds and used to 9 years of age.

Plan G. .5 of 1 per cent of bulls saved and bred artificially as yearlings to 40 cows each. The top 2 per cent of these on basis of individual and progeny information returned to service as 4-year-olds and bred artificially to 10,000 cows per year to 9 years of age.

The foregoing plans are not necessarily the most efficient which could be devised nor would some of them necessarily be desirable or economically feasible from an industry-wide standpoint. They do, however, represent widely divergent plans which will serve to illustrate opportunities for progress through breeding.

Bull plans A and C represent what might be accomplished under natural service with relatively simple plans of mass selection alone or mass selection combined with progeny testing. Bull plans D, E, F, and G represent potentials with artificial insemination used with and without progeny testing.

With some qualifications to be discussed later, the estimates for possible improvement in weaning weight and postweaning gaining ability look very promising. For both these traits it is relatively easy to get information on all animals raised. Taken over a 10-year period, a potential improvement of 43 pounds in weaning weight or .43 pounds in average daily gain with even the simplest forms of mass selection represent gains which would in the case of weaning weight represent 10 per cent or more of current averages and for average daily gain 15 to 20 per cent of current averages.

The estimates for improvement in efficiency of gain are less realistic since they assume complete individual feeding records on each animal—a procedure seldom, if ever, possible. However, from 2/3 to 4/5 the potential improvement would come from selection of bulls and obtaining individual efficiencies on bulls is not impossible though costly. Fortunately, rate and efficiency of gain have a high enough relationship for one to be a fairly good indicator of the other. Recent data from State and Federal research in Virginia (J. A. Gaines, unpublished) indicate a saving of approximately 47 pounds of total digestible nutrients per cwt. put on full feed at weaning and fed for a time constant period of 168 to 200 days. If a relationship of this magnitude is a general one, selection for rate of gain will serve to a very considerable extent to effect concurrent improvement in efficiency of gain.

As can be seen from Table 1, the available heritability estimates for carcass traits are much fewer in number than for the various measures of growth rate and the generally expected values are therefore less well defined. However, calculations are presented for illustrative purposes on possible genetic gains for one commonly used estimator of carcass leanness, rib eye area, and for tenderness as evaluated by the Warner-Bratzler shear. Since to date there are no methods of accurately estimating most carcass traits from live animals, we have assumed that all selection would have to be on the basis of sib and progeny tests. This means that selection intensity and genetic progress will necessarily be lower than for traits which can be measured on the animal, itself. Noting the sizes of the estimated genetic gains for carcass traits in relation to sizes of standard deviations will make this point clear. This emphasizes the need for methods of estimating carcass traits in live animals. Progress can be made without them, but will necessarily be slow.

The examples given may be useful estimates of progress possible in cases where marked deficiencies in one trait make it advisable to select for it alone for a time. Usually, however, concurrent selection will be practiced for several traits. Progress for individual traits will depend upon their heritabilities, the relative emphasis put on each one and on the genetic relationships among them. If equal emphasis is put on selection for each trait and if the traits are genetically independent, progress for any one of n traits should be $1/\sqrt{n}$ times as rapid for each one as if it were the sole object of selection. Thus, if selection were for four independent traits, progress for any one would be reduced by half. Substantial progress can still be made in selection for several traits at a time but this relationship emphasizes the necessity of keeping the number of items selected for as low as possible if maximum selection pressure is to be put on the important characters.

Our knowledge of genetic correlations is still very meager. Koch and Clark (30, 31, 32) studied a large volume of data from Miles City, Montana, on animals raised under range conditions and observed negative genetic correlations of undetermined size between maternal abilities of cows and genic values of calves for growth. They also found a small negative genetic correlation of —.05 between gain from birth to weaning and subsequent summer pasture gains of heifers. Carter and Kincaid (7) observed positive genetic correlations of .66 and .51 between 182-day weights and subsequent gains of steers and heifers, respectively, when the steers were fed out in dry lot immediately after weaning and the heifers were wintered to gain ¾ to 1 pound daily and their gaining ability evaluated while grazing on bluegrass-white clover pastures during their summer yearling year. Blackwell *et al.* (2) also observed positive genetic correlations between pre- and post-weaning gains. As pointed out by Carter and Kincaid (7) this relationship may well be influenced by environmental conditions. Indications to date are thus that concurrent selection for weaning weight and post-weaning gaining ability will be effective for both but it is uncertain whether it will be more or less effective than if they were genetically independent.

Studies of data from time constant or weight constant feeding periods have usually shown rather high phenotypic correlations between rate and efficiency of gain and Carter and Kincaid (7) found a genetic correlation of .32. Thus, improvement in rate of gain can be expected to result in improved efficiency.

Genetic relationships between production and carcass traits have not been studied to date but phenotypic relationships (6, 7, 46, 47) have in general indicated positive relationships between desirable production and carcass traits but these have not been high enough to suggest they would permit effective use of preslaughter performance data as indicators of important carcass traits.

On the assumption that they are essentially independent genetically, concurrent selection for weaning weight, post-weaning gaining ability, rib eye area at a standard weight, and tenderness of lean tissue should in a 10-year period result in increases of 21.5 pounds in weaning weight, .22 pound in average daily post-weaning gaining ability, .14 of a square inch in rib eye area and a decrease of .44 pound in average shear force with the simplest mass selection breeding plan. With plans making use of progeny testing and extended use of superior sires through artificial insemination, increases of 44 pound, .35 pound, 37 square inch, and

—1.11 pound, respectively, might well be possible in a 10-year period.

Improvements of the magnitude suggested for the simple selection schemes would represent improvement of about 5 per cent in weaning weight and would be largely a net increase. The increase of .22 pound in average daily gain would probably be associated with a 6 to 8 per cent saving of feed during a normal fattening period. These gains, while not revolutionary or spectacular in any one year are of obvious long time importance. Changes in carcass traits would be in desired directions but would be of lesser magnitude. Increased emphasis on carcass traits should result in a more rapid rate of improvement in them but would necessarily mean less intense selection for the production traits and hence less progress for them.

The degree of future advances in management practices and/or ability to control the reproductive cycle of the cow will in my opinion determine the extent to which artificial insemination will be used with beef cattle in the future. Its general use could extend the opportunities for selection—of that there can be no doubt. We are less sure whether or not the magnitude of possible changes would be of the order indicated since slight deviations from normal distributions might markedly affect the selection differentials attainable when very low percentages of sires are selected for use. There are also certain inherent dangers in concentrating too much on relatively few sires.

The figures on probable selection effectiveness are admittedly theoretical—not yet having been tested in long-time, carefully controlled selection experiments with beef cattle. Looking to other species (16, 33) it is evident that long continued selection for specific traits often, and perhaps usually, results in selection becoming partially or wholly ineffective in spite of apparent existence of hereditary variability. Usually, however, this has occurred only after many generations of selection and after selection has moved the mean several standard deviations in populations not under selection prior to the experiment. The resistance to selection may be due to genic imbalances which result in lowered "fitness" in the selected individuals, to superiority of heterozygotes, or to other as yet undetermined mechanisms.

Looking specifically to meat animals, selection for specific traits in sheep has apparently been effective as has selection in swine although selection combined with mild inbreeding appeared to have been ineffective or relatively so for many traits.

Although not as scientifically rigorous as would be desired, several studies point in the direction of strains of cattle developed with selection for performance characters having superiority in growth rates and efficiency of gain without marked carcass differences as compared to cattle with no background of selection. In Ohio studies (41) the progeny of bulls from two mildly inbred strains with histories of selection for performance traits grew faster and more efficiently and had carcasses of at least equal value as compared to progeny of bulls from stocks with no selection background of this kind. Urick and Windecker (43) found that steer progenies of 7 sires resulting from several years of selection for performance in crosses gained an average of .25 pound per day more (and with no overlap in progeny averages) as compared to 7 randomly selected groups of steers from "reputation" herds in the area. Carcass data (unpublished information from the above authors) showed only small average differences in items measured but the progenies from selected parents averaged slightly higher in dressing percentage, grades for finish and marbling, and in rib eye area. Scores for conformation were equal.

Two experiments (27, 39) have been conducted in which selection for gaining ability was shown to be effective for at least a single generation.

To summarize, although we can never be sure of anything until it has been demonstrated in practice, there is strong reason to believe that consistent selection for important items affecting both economy of production and consumer desirability of product will be effective and lead to marked improvement over a period of at least several generations. It should be stressed that genetic improvement tends to be cumulative and permanent and that improvement of even a few per cent in gross efficiency often means a several fold increase in net income.

Crossbreeding and Hybridization

The term crossbreeding is rather loosely used to include breeding systems involving crosses of two or more pure breeds and systems in which grade or mixed ancestry characterizes part of the parents.

Crossbreeding studies among the three British breeds, the Hereford, Angus, and Shorthorn, have been few in number and have given conflicting results. Knapp *et al.* (28) reported results of a study at Miles City, Montana, in which Shorthorn bulls were bred to Hereford cows, the resulting heifers to Angus bulls, and the daughters of this cross in turn to Hereford bulls. The performance of steers and growing heifers of each cross was compared with that of high grade Herefords raised in the same year.

In this experiment (Table 3) the crossbreds had heavier weaning weights, particularly in the second and third generations, when the crossbreds were out of crossbred cows, faster daily gains on feed test and slightly higher dressing percentages and carcass grades. Likewise, crossbred heifers were heavier at 18 months. The weighted average calf crop was 4.5 per cent in favor of crossbred matings. The favorable results for crossbreeding in this experiment cannot be taken as necessarily conclusive since it included only one of the parental purebreds. It is impossible to state definitely whether the good results were due to crossbreeding or to the superiority of the Shorthorn and Angus sires used.

In an Ohio test summarized in Table 4, reciprocal crosses were made between the Angus and Hereford breeds. The crossbreds had lower death losses (5.1 per cent vs. 8.3 per cent) and higher weaning

TABLE 3
Results from Crossing Three British Breeds of Beef Cattle*

	Average of two-year results in each generation					
	1st Generation		2nd Generation		3rd Generation	
	Crossbreds (Sh. x Here.)	Purebred Hereford	Crossbred (Ang. x Sh. x Here.)	Purebred Herefords	Crossbred Here. x (Ang. x Sh. x Here.)	Purebred Herefords
Percent calf crop[1]	92.7	87.6	85.1	75.3	74.5	85.9
Growth of heifer calves:						
No.	53	55	37	123	14	252
Av. Wean. Wt., lbs.	393	386	418	378	452	368
Av. 18 mo. wt., lbs.	776	726	781	705	738	699
Performance of steers						
No.	57	67	24	91	20	161
Av. Wean. Wt., lbs.	423	403	440	390	467	388
Feedlot av. daily gain, lbs.	1.92	1.75	2.00	1.86	2.32	2.10
Final wt., lbs.	948	879	974	887	1033	912
Gain per 100 lb. TDN, lb.	18.3	18.0	17.4	18.3	18.9	19.0
Av. Dressing %	57.8	56.8	60.1	58.5	59.0	58.0
Av. Carcass Grade	Good+	Good	Ch−	Good+	Ch+	High Good+

[1] Based on calves weaned in relation to cows bred.
* From *U. S. Dept. Agr. Circ.* 810, 1949.

weights than purebred calves from the same breed of cow. The average gain and dressing percentages of the crossbreds very slightly exceeded the average of the purebreds while average pounds of total digestible nutrients required per cwt. gain and carcass grades were virtually the same. Although the crossbreds in this experiment slightly exceeded the average of the purebreds in several regards and were not inferior in any respect, the amount of heterosis was relatively small and could scarcely justify crossbreeding unless the difference in death losses could be shown in experiments of larger scale to be a consistent result of crossbreeding. Unfortunately, the performance of the crossbred cows as mothers was not tested.

Damon *et al.* (12, 13) made reciprocal crosses between the Angus and Hereford breeds and found no evidence of heterosis in growth rates to slightly over a year of age or in conformation or slaughter grades. Godbey *et al.* (22) reported results in which crosses between the Angus and Hereford breeds resulted in markedly heavier weights at 210 days of age than for either of the pure breeds but, unfortunately, the two purebred cow herds were at different locations and the same bulls did not sire the purebred and crossbred calves.

In view of the conflicting evidence, the question of whether enough hybrid vigor can be obtained from crosses among the British breeds to make crossing a feasible procedure must be left as uncertain at present. It is anticipated that experiments now underway will clarify the situation during the next few years.

Extensive crossbreeding work, principally in the Southern States, on crossing Zebu type bulls of the American Brahman breed with British type cows has rather consistently shown that as compared to grade or purebred British types the crossbred calves (1) gain faster to weaning and average 25 to 30 pounds heavier at normal weaning ages of 6 to 8 months, (2) have usually but not always gained somewhat more slowly and required more feed per cwt. gain under winter feedlot conditions, (3) have gained considerably more rapidly under summer pasture conditions

TABLE 4
Eight-Year Summary of Weights, Gain, Feed Efficiency, and Carcass Quality of Purebred Angus, Purebred Hereford and Their Reciprocal Crossbred Calves*

	Calves from Angus cow		Calves from Hereford cows	
	Purebred Angus	Crossbred Hereford x Angus	Purebred Hereford	Crossbred Angus x Hereford
No. calves dropped	101	94	104	102
No. calves raised to weaning	91	92	97	94
Av. birth wt., lb.	59	64	68	65
Av. weaning wt., lb. at 224 days	382	392	329	353
Av. daily gain on pasture, lb.[1]	0.94	0.97	1.08	1.08
Feed lot performance				
Av. daily gain, lb.	1.62	1.68	1.66	1.68
T.D.N. per 100 lb. gain., lb	670	632	599	639
Slaughter data				
Av. dressing percentage	60.3	60.8	59.7	60.3
Carcass grades				
Choice	67	77	58	58
Good	22	14	31	35
Commercial		1	2	

[1] Pasture data 4 years only.
* Adapted from Ohio Res. Bul. 703, 1951.

as yearlings or 2-year-olds, (4) have had advantages of 1 to 4 per cent in dressed yields at slaughter, (5) have averaged about the same in carcass grade when slaughtered as weanling calves but lower when slaughtered at older ages, (6) have produced carcasses differing little in per cent of the various cuts, and (7) when retained as brood cows have raised calves usually averaging 75-80 pounds heavier (4, 5, 8, 12, 13, 22, 24, 35, 45).

In two experiments (12, 13, 25) in which both Brahman and the parental British breeds have been maintained in the same herds with the same bulls siring purebred and crossbred calves, lifetime growth rates of the crossbred calves have exceeded both parental breeds by considerable margins. The performance of Brahman crossbreds is thus one of the best examples of heterosis or hybrid vigor to be found in the animal breeding field.

A recent study (Cartwright, unpublished) of fertility and calf viability in a Texas herd where Hereford, Brahman, and F_1 crossbred cows were maintained over a period of years gave the following results:

Breed of Cow	No. Cow Years	Percent of Cows Bred Dropping Calves	Percent of Cows Bred Weaning Calves
Hereford	765	72.8	65.1
Brahman	244	72.9	54.9
Crossbred H-BR	379	87.6	80.7

Possible effects of heterosis on fertility and calf mortality have been ignored too often in crossbreeding studies. If the above results are representative, these things may be of more importance than other traits studied.

The favorable results from Brahman crosses led to the establishment of new breeds based on crossbred foundations. In several tests (Texas Misc. Pubs. 223-F, 258-F, 305-F, 321-F, Flor. Mimeo Rpt. and others) representatives of these breeds have shown excellent performance in certain aspects of productivity but it is still uncertain whether their performance will equal that of first cross animals from parents selected for performance.

A few recent studies (1; R. A. Damon, unpublished) have indicated that meat from high grade or purebred Brahmans is somewhat lacking in tenderness. In general that of first-cross animals has been slightly less tender than that from British types but with some evidence of more between sire progeny variability in Brahmans than in Herefords (9, 10).

During recent years there has been interest in research with the Charollais breed. In view of the limited number of these animals available in this country, research has thus far been limited to top cross tests. In the two tests conducted to date (12, 13, and unpublished; and Woodward *et al.* unpublished) calves sired by Charollais bulls have grown faster than other types, the carcasses have had higher percentages of lean and less fat but the lean has proved to be about equally tender and palatable. Carcass grades have been lower by current standards. For example, the following results from steers fed in a recent Miles City, Montana, test are striking:

It remains to be seen whether these generally favorable results with the crossbreds can be duplicated but, if so, present indications are that they may be due, in large part, to hybrid vigor.

The most striking indications of hybrid vigor in beef cattle are thus from work involving crosses between British types and two breeds, the Brahman and Charollais, of very diverse origins. This suggests the need for intensification of research on disease control and quarantine procedures which will permit the importation of additional breeds and types of cattle for trials as beef producers in this country particularly for use in test crosses.

Several experiments on inbreeding beef cattle in which the lines will eventually be evaluated in crosses are underway but due to their long-time nature very few results are available as yet. Preliminary results from the Colorado Station (40, and Colorado Gen. Ser. Pubs. 642 and 683) and the Miles City Montana Station (37) make the performance of crosses of selected in-

	Sires Bred to Randomly Selected Groups of Hereford Cows		
	Five Progeny Groups of Herefords	Two Progeny Groups of Charollais x Herefords	Group of High Grade Charollais
No. steers	36	14	7
Av. wean. age	186	173	170
Av. weaning wt.	409	454	430
Av. daily gain (252 da. test)	2.34	2.69	2.38
Av. final wt.	999	1137	1034
Av. dressing percent	58.0	58.2	59.3
Av. carcass grade	L. Choice	H. Good	H. Good
Av. Composition 9–10–11 rib:			
% lean	47.1	50.1	53.2
% fat	33.7	30.2	26.4
% bone	19.3	19.7	20.4
Av. shear value[1]	12.0	12.8	13.9
Av. tenderness rating[2]	5.3	5.3	5.0
Av. flavor rating[2]	5.9	5.8	5.7

[1] In pounds, with smaller values indicating more tender meat.
[2] Subjective panel rating with 7 being most and 1 least desirable.

bred lines look promising. It is, however, far too early to more than hazard a guess as to whether performance of crossline and topcross animals will be superior to that which could be expected from populations in which an equivalent amount of effort had been expended in mass selection programs.

Summary

Direct selection of beef cattle for traits of economic value should be effective and if widely and systematically practiced could potentially improve several traits important in economical production by from 5 to 10 per cent over present averages in a 10 year period. Concurrent improvement could be made for carcass traits but at a slower rate since most selection for these traits has to be on a sib or progeny test basis.

Evidence is inconclusive on the amount of hybrid vigor or heterosis which can be expected in crosses among the British breeds of beef cattle but insufficient research has been done with these breeds on traits of low heritability relating to fertility and viability which would be expected to be most responsive to crossbreeding.

There is marked evidence of heterosis in several traits measuring both growth and fertility in crosses between British and Brahman type cattle and this may be a major factor in the rather widespread use of Brahman crossbred types in certain areas of the South. Preliminary results suggest that heterosis may be important in crosses between Charollais and British type cattle—also breeds coming from very diverse origins. This general concept emphasizes the need for intensive research in the disease field to make importations from additional countries possible.

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Physiological Factors Affecting the Efficiency of Beef Cattle

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Effects of Climatic Factors on Beef Production

Competition of Other Beef-Producing Areas

At the 1955 Symposium on "Breeding Beef Cattle for Unfavorable Environments" it was emphasized that there are vast areas, especially in the southern hemisphere, where beef cattle can be produced. Many of these areas are subtropical or tropical, some are dry and some are wet, and many suffer from alternating wet and dry seasons. In many of these areas the British beef breeds are not well adapted, do not grow or reproduce at normal rates, and may not even survive in the unfavorable environment. This problem is being overcome by the selection and modification of native cattle, by the introduction of other breeds, by cross breeding, and by the creation of new breeds.

In addition, there are large areas where cattle are well adapted but where feed may be abundant during one season and scarce during another. There are good possibilities of producing feed grains in some of these regions and of introducing cattle feeding systems similar to those of the corn belt in the United States. This may be a question of improved agronomic practices and proper livestock management. The possibility that the world's meat supply may be considerably expanded should not be overlooked. As we overcome climate stresses or modify animals to meet them in the United States, we may expect others to be engaged in the same effort elsewhere, and it may be necessary to improve efficiency to meet new competition.

The Nature of Heat Stress

Homeothermic animals attempt to maintain a constant body temperature. If body temperature fluctuates appreciably the health or productivity of the animal may be affected. Unfortunately, cattle are more efficient in heat production and conservation than in heat loss. In European breeds of cattle body temperature rises gradually when the environmental temperature exceeds 70° F. and increases rapidly at ambient temperatures above 80° F. Zebu cattle show no appreciable increase in body temperature until ambient temperature exceeds 90° F. In most cases the introduction of Zebu blood increases heat tolerance. Rising ambient and rectal temperatures are accompanied by an increased respiration rate. The initial increase in respiration rate may increase heat loss from the animal, but as the heat stress increases the respiratory muscles may become fatigued and respiration rate declines. In some cases there is an excessive ventilation of the lungs and blood pH is disturbed.

Cattle are usually classified as nonsweating animals. However, they do have a primitive type of sweat gland and appreciable moisture may be evaporated from the skin. Surface evaporation is an important means of heat loss. It has been shown that moisture loss does in crease with increasing temperature and that Zebu cattle lose more body heat than European breeds, especially at high temperatures.

In general, an animal with a large surface area in relation to body mass has an advantage in heat loss. Some workers have attributed the heat tolerance of the Zebu to the large amount of loose skin and the large appendages. More recent work suggests that animals which are heat tolerant may differ in the efficiency of energy utilization. They may produce less heat per unit of body weight to perform the various body functions.

The Effects of Heat Stress

Exposure of animals to the sun, especially during the summer or in tropical regions, imposes a heavy heat load. This has a direct effect on the grazing habits of cattle. European breeds of cattle tend to seek shade at temperatures above 80° F., whereas Zebu cattle or crosses graze in the direct sun and seldom seek shade. Obviously, as feed intake is reduced growth rate or milk production decline. Studies at the Missouri Station showed that Shorthorn cattle grew more rapidly at 50° F. than at 80° F., Brahma cattle grew as well or better at 80° F., and Santa Gertrudis cattle grew nearly as well at 80° F. These animals were maintained in climatic chambers and the effects are those of temperature not complicated by solar radiation.

There is some difference of opinion as to the role of climate and temperature on reproduction in cattle. High summer temperatures are often accompanied by reduced quantity and quality of forage and decline in summer fertility may result from a combination of factors. However, research with several species indicates that high temperatures may affect spermatogenesis and semen quality and early embryonic survival, and, thus, reduce fertility.

In European breeds of dairy cattle, increasing ambient temperatures above 75° F. definitely reduce milk production. Whether lactation is affected by temperature in beef cattle in a normal fluctuating summer environment is unknown, but the possibility exists that reduced summer milk production might affect the growth of calves.

Practical Prevention of Heat Stress

As pointed out by Ittner *et al.* (6), 51 per cent of the cattle in the United States are located in areas where the average July temperature exceeds 75° F., and in some regions the daily temperature frequently exceeds 95° F. If maximum growth is to be obtained, the decreased feed intake which accompanies rising temperatures must be prevented. Ittner *et al.* (6) published an excellent review of methods of increasing beef production in hot climates.

California studies showed that a well designed shade will reduce radiant heat load from the sun and sky more than 50 per cent. Cattle shades should be at least 10 to 12 feet high and the long dimension oriented East and West. If protected from the sun, cattle may lose considerable heat to the sky, since, for example, when the air temperature was 100° F. the cloud-free sky was 28° F. cooler (2). Shades covered with a heavy layer of hay or straw are very effective in the reduction of solar radiation. Bright metals, not oxidized or rusted, white painted wood or metal, or plastic have all been used successfully. Materials which absorb the radiant energy of the sun and radiate to the animals are undesirable. As shown by the California group, heavy wooden corrals impose a greater heat load on cattle than wire fences. Several experiments were carried out to study the cooling of shade surfaces with water. Wetting the lower roof of double roofed shades increased the rate of gain and reduced respiration rate of cattle (a measure of comfort), but the results were of questionable economic value.

The use of water for cooling swine, poultry, and cattle has been the subject of many experiments. The evaporation of one gram of water from the body surface at 91.5° F. removes 580 calories of heat. If the temperature of the water is less than the surface temperature of the animal, there will be an additional loss of heat due to conduction. In California studies, when water was applied in relatively large amounts by a shower nozzle, there was a consistent improvement in rate of gain. The use of mist or fog-type nozzles was not as effective in cattle as the coarser sprays. These types are, however, effective and widely used by swine producers.

Itner *et al.* made extensive studies of the effects of cooling the drinking water of cattle in the desert areas of California. Non-cooled water in this region often has a temperature of 90-100° F. Water cooled to 60-70° F. by mechanical refrigeration or evaporative cooling towers increased daily gain from 0.19 to 0.50 pounds per day. The cattle drank less of the cold water, but the consumption of the cooled water was followed by a reduction in body temperature for several hours.

The California group also investigated the role of air movement and air temperature on the comfort and performance of cattle. The air may affect both convective and radiation heat exchange and the evaporation of moisture from the body surface. In desert areas evaporative cooling of the air is widely used for air conditioning homes, greenhouses, and other closed structures. Hereford cattle gained 0.36 pound per day more when they had access to a 3-sided shade cooled by evaporation, but Brahma-Hereford crosses showed no difference. It was shown that cattle kept in corrals constructed with wire, cables, etc., which allowed unrestricted air flow gained significantly more than those kept in a heavy wooden corral which affected air flow, and which absorbed and radiated heat to the cattle. The use of fans also increased rate of gain, presumably because increased air movement increased convective heat loss and the evaporation of water from the skin.

Research Possibilities

Because the climatic environment affects growth, reproduction, and lactation of mammals, it is one which merits considerable attention. The problem of heat production and heat loss is basically one of thermodynamics. The same principles apply to machines or to living things. Much of the research thus far carried out is basic in nature and deals with the physiology and biochemistry of the animal. The principles of heat production, heat conservation, and heat loss of animals are becoming better understood. There are obvious species differences, breed differences, and possibly strain or family differences. The geneticist and the physiologist are working closely together to develop animals which are heat adapted to particular environments. The intricate relationships of the environment and the endocrine system, the role of the nervous system, the regulation of appetite, and the environmental factors in bone, muscle, and fat development are largely unknown.

The nutritional requirements of animals in an "average" environment are becoming better understood, and there is adequate evidence to indicate that during the next decade we must reinvestigate these requirements for each species under different environmental conditions.

Practical environmental control is not an art, but the application of basic principles. The design of a shade for cattle takes into account the four basic methods of heat transfer: radiation, convection, conduction, and evaporation. The application of these principles at the moment is chiefly a problem of economics. Animals kept in a completely controlled environment regulated for a particular function such as growth, lactation, or egg production can be expected to improve in performance. The cost of the controlled environment must be more than offset by the increased return from the animal. Heating a brooder or farrowing house is essential in northern climates. The use of properly designed shades and simple spray cooling systems for swine is becoming a standard practice. Improvements in mechanical heating and cooling systems, the adaption of the heat pump for farm use, the possibilities of using solar energy for both heating and cooling will have a far reaching effect on livestock production in the future.

Problems in Reproductive Physiology

Spermatogenesis and Sperm Preservation

The success in Russia and Denmark of the practical application of the artificial insemination program initiated by the Russian physiologist Ivanoff in 1899, stimulated American, British, and other scientists to undertake research in sperm physiology. The development of rather simple semen diluters by Phillips and Lardy in 1940 and Salisbury, Fuller, and Willett in 1941 did much to insure the success of artificial breeding in the United States. Several United States workers were able to preserve the motility of sperm frozen at low temperatures but it remained for British workers, Polge *et al.* 1949, to demonstrate that sperm could be preserved for relatively long periods in the frozen state and remain capable of inducing pregnancy in cattle. These researches have been reviewed by Willett (16), Andrews (1), and others.

The collection of semen at weekly intervals is routine at bull studs throughout the United States; if 10 million motile sperm are used per insemination, sufficient sperm for breeding 50,000 cows per year can easily be obtained. The principle reason for the use of artificial insemination is that it greatly extends the use of proved sires. Under conditions of natural service it is common for a bull to sire no more than 20-30 calves per year. If the bull is of inferior genetic makeup, this is sufficient or even excessive. However, if the bull has been shown to be superior in transmitting ability of milk, growth rate, or meat quality, his limited use is a tragedy. With a few exceptions, most beef cows in the United States are being bred to bulls of unknown transmitting ability, and many of our really good sires are being mated to very small numbers of females.

A recent study by Hafs *et al.* (4) showed that aged dairy bulls are capable of producing an average of 23.6 billion motile sperm per week. This is sufficient semen for 100,000 cows per year if 10 million motile sperm are allowed per insemination or 200,000 cows if 5 million sperm are used per cow. With present techniques for preserving semen, either nonfrozen or frozen, it is obvious that we are wasting a great potential in germ plasm. If we believe that livestock improvement depends on the use of proved sires then we must prove more of them in terms of growth rate, feed efficiency, and carcass quality. And having proved them, we must extend their use to the entire cattle population. This is not now being done to the limits of our technical information.

Reason for Lag in Artificial Insemination

Dairy cattle, whatever the system of management, are closely observed at milking and those which are in estrus can be retained for insemination. Beef cattle kept under farm conditions are usually not closely observed, the facilities for sorting and holding them are often poor or entirely lacking, and artificial breeding has been dismissed as impractical. Since the constant availability of frozen semen from outstanding beef bulls, many owners of commercial farm herds have decided that the advantages of using a proved bull outweigh the annoyance of catching the cow. Some employ a new type of gun which fires a tranquilizing drug into the cow and enables the inseminator to perform without difficulty even under pasture conditions.

Under range conditions in the United States and other parts of the world where cattle are raised in large numbers, the problem of identifying cattle which are in heat and restraining them for artificial insemination becomes a major undertaking. There has been a long-felt need for a practical method of regulating the reproductive cycle of the cow. If a predictable number of cows could be treated so that they would be in heat at a definite time, ovulate and conceive in reasonable numbers, artificial breeding would be widely adopted.

The Regulation of the Estrual Cycle

The normal estrual cycle and possible means of regulation have been discussed in an excellent review by Hansel (5). The average cow has a cycle 20-22 days in length. Estrus generally lasts 16-20 hours. Both cycle length and duration of estrus may be less in tropical areas. Cattle differ from other farm animals in that ovulation, the release of the egg from the ovary, occurs 9-14 hours after heat ends. Fortunately, cattle do become pregnant when inseminated at any time during estrus and even when inseminated prior to ovulation after heat ends. Under practical conditions it is preferred to inseminate during the latter part of estrus for maximum conception rate.

For more than 20 years it has been generally accepted that the development of the ovary, the initiation of estrus, the release of the ovum and the formation of the corpus luteum are under the control of the anterior pituitary gland. It has been believed that the pituitary gland produces two distinct gonad regulating hormones, one called the follicle stimulating hormone (FSH) and a second the luteinizing hormone (LH). If this is the case the use of these hormones in proper amounts and in correct sequence should enable us to control the breeding cycle at will. Unfortunately, it has never been possible to accomplish this with any degree of regularity in either normal cattle or those which fail to exhibit normal cycles.

It is now becoming apparent that the control of the reproductive cycle is more complex than it first appeared. There is good evidence that stimulation of the nervous system may initiate the production or release of specific chemical substances which are then transported to the anterior pituitary gland and activate the production or release of FSH, LH, or other hormones. In some species, e.g., the rabbit, copulation initiates a neural mechanism which causes the release of the ovulatory hormone; rabbits do not ovulate spontaneously. Cattle and other farm animals ovulate spontaneously without the necessity of copulation. Several recent studies have shown that neurohumoral substances are involved. It now appears that the hypothalamic area of the brain, the posterior pituitary gland, and possibly the adrenal may be involved in addition to the anterior pituitary gland.

Veterinarians have for many years altered the estrual cycle of individual cattle by the removal of the corpus luteum. This requires the manipulation of the ovary by rectal palpation of the ovary. The corpus luteum produces a hormone, progesterone, which inhibits the initiation of estrus. Removal of the corpus luteum relieves the inhibition and the cow comes in heat within a few days. However, only about 25 to 50 per cent of treated cows become pregnant following treatment.

A number of investigators have employed the technique of injecting relatively large doses of progesterone. In a recent study by Nellor and Cole (1957) 89 per cent of a group of beef heifers came in heat 15-19 days after a single progesterone injection. However, the conception rate has been below 20 per cent. More research is needed to determine the cause of the low conception rate.

Willett (16) reviewed the status of superovulation, the production of an unusually large number of ova in cattle. A large number of treatments involving combinations of FSH, LH, and progesterone have been used. It is clear that cattle can be induced to produce large numbers of ova at a single time, that many of the ova are capable of fertilization, and that fertilized ova may be transferred from one cow to another. However, estrus and ovulation have not been synchronized, many ova are defective and embryonic mortality is high.

The control of the estrual cycle would enable beef producers to breed large numbers of cattle during a short period of time. It would speed the use of artificial insemination and greatly increase efficiency in range areas where large numbers of cows are ordinarily widely dispersed. Much basic research must be done before this can be accomplished.

The Physiology of Growth

This subject was reviewed by Andrews (1). Growth is a complex phenomenon which is influenced by the genetic makeup of the animal, by the hormones of the anterior pituitary, thyroid, and adrenal glands, and by the ovarian and testicular hormones. Growth rate is profoundly affected by nutritional status, parasites, and disease.

We must now concern ourselves not only with the rate of growth, but the nature of growth in terms of bone, muscle, and fat and in the efficiency of growth. Basically, we would prefer to improve growth by genetic means, in the hopes of fixing and perpetuating those factors which are related to it. Since we have only limited means of recognizing desirable genetic makeup, we must concern ourselves with the possibilities of altering growth in other ways.

As early as 1943 Lorenz showed that the implantation of diethylstilbestrol would increase fat deposition and improve carcass quality in chickens. Purdue studies between 1946-1949 showed that the implantation of diethystilbestrol in cattle and sheep produce true growth stimulation. It is now recognized that several estrogenic substances, diethylstilbestrol, hexestrol, dienestrol, and estradiol will increase muscle growth in cattle and sheep and do not increase fat deposition as in chickens. It has long been recognized that males grow more rapidly than females. This is apparently due to the effects of the testicular hormone, testosterone. There are a large number of substances in the male hormone group (androgens). The androgens have strong anabolic effects and bring about nitrogen retention and protein formation. Many experiments involving androgens have been carried out. They will, at proper levels, promote growth in cattle and show promise for reducing fat deposition in swine. While the androgens are produced by chemical synthesis, the cost of production remains high, especially in comparison with diethylstilbestrol and its derivatives.

Perhaps one of the most striking effects of the estrogenic compounds on the growth of ruminants is the improved feed efficiency which accompanies the increased growth rate. The use of estrogen has found wide acceptance among cattle feeders and it is estimated that about 80 per cent of all beef-type cattle are either implanted with or fed estrogens. Approximately six different products are now available commercially for cattle.

The principal growth regulating hormone is produced by the anterior pituitary gland and is called the growth hormone. It has been known since 1921 but thus far has been confined to investigational use. The growth hormone is a protein, is very difficult to isolate, would be extremely difficult to synthesize, and must be injected frequently to produce a response. There is good evidence that animals differ genetically in growth hormone secretion rate. If a means of estimating growth hormone levels in the live animal could be devised, it might be possible to more effectively select for rapid growth. Research of this type is underway in several laboratories.

The thyroid gland is involved in growth, especially of the young animal, and it is also concerned with energy requirements, reproduction, milk, and egg production. In some of the lower species the thyroid is necessary for metamorphosis. Prior to the widespread use of iodized salt, subnormal thyroid function (goiter) limited or prevented swine and sheep production in many areas of the United States. There is good evidence in cattle that reduced thyroid activity may be a limiting factor in high milk production. Materials are commercialy available for the correction of lowered thyroid function but their practical use in cattle has been limited.

Theoretically, a controlled reduction in thyroid activity should reduce metabolic rate, reduce feed requirements, and stimulate fattening. A large group of compounds, goitrogens, is available for such purposes. As early as 1940 it was shown that partial removal of the thyroid would increase fattening in cattle for short periods of time, and that the use of goitrogens would increase gain or improve feed efficiency for short periods. In recent years highly potent goitrogens have been used in cattle feeding and may be beneficial under certain conditions.

One of the areas which is of considerable current interest is the role of plant hormones on the animals which consume them. The first effects were essentially bad. In Australia subterranean clover may contain sufficient estrogenic hormone to cause excessive mammary and genital development of sheep, serious prolapse of the vagina or rectum, and sterility. It is known that certain legumes, including alfalfa and ladino clover, may have appreciable estrogenic activity. It has been theorized that a portion of the growth promoting or lactation stimulating effects of forage may be hormonal in nature. It has been demonstrated that some legume hays will increase growth rate in sheep and cattle (1). There are very great differences in the estrogenic activity of alfalfa samples. The variability may be related to stage of growth, season, environmental factors, and genetic makeup of the plant. Purdue studies involve the selection of alfalfa for both high and low estrogenic activity.

It would appear that we have only begun to understand the regulation of growth. The determination and selection of animals with genetotypes related to endocrine makeup, the development of new materials for growth regulation, and the development of feeds and forage with desirable hormonal activity have real possibilities in livestock improvement.

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Some Nutritional Factors Involved in Beef Production

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EFFICIENT meat production from beef cattle requires the sound application of nutritional principles derived from experimental investigations with not only beef cattle but many other animal species. Most principles of nutrition have developed from research with laboratory and farm animals other than cattle and can be applied directly or indirectly to beef cattle production. The symbiotic relationship between the ruminant and the microflora of the rumen, however, is always in the background influencing the nutrition of cattle. Digestion and utilization of cellulose is the most important result of this relationship. Furthermore, it is becoming apparent that we can, by various feeding regimes, influence the end products of microbial digestion. These may influence feed intake, body composition, milk composition and, as a result, feed evaluation, and utilization. The purpose of this paper, therefore, is to review certain areas in nutrition which deserve emphasis in considering the production efficiency of beef cattle. The reader is referred to the fine review by Riggs on Beef Cattle Nutrition in the 50th Anniversary issue of the Journal of Animal Science for information on areas not covered in this paper.

Ruminant Digestion

The reticulo-rumen is a favorable environment for the rumen microflora (1, 2, 3). Not only does the ruminant provide adequate substrate (food and water) for microbial activity but it also removes end-products (fatty acids) and disposes of non-digested substrate into the rest of the alimentary canal. In return, the microflora digests cellulose (4, 5) which provides volatile fatty acids as an energy source for the ruminant. This gives the ruminant a unique advantage over meat animals with simpler stomachs and makes available food (beef) for human consumption not otherwise available from fibrous feeds. As a further service to the host, the microflora synthesize amino acids and vitamins which can be utilized by the ruminant (6). This markedly decreases the number of nutrients needed in cattle rations.

Carbohydrate Utilization

Fiber

Roughages are classed as such because they are high in fibrous compounds—cellulose, hemicellulose, and lignin. A recent review on this subject has been made by Hansen *et al.* (7). The evidence adequately presented by Baker and Harris (8) shows that ruminants use cellulose because the rumen microflora secrete cellulases to digest the cellulose. Fatty acids, resulting from this process, are then absorbed and utilized by the host (9, 10, 11). Much research effort has been made on methods of enhancing fiber digestion but it has become apparent that lignin is the most important factor influencing roughage digestion (11, 12, 13, 14). Not only is lignin unattacked but the depressing effect on cellulose digestion of various roughages seems to result from lignin preventing the action of microbial cellulose enzymes. More recently, Salsbury *et al.* (15) have shown that holocellulose, free from lignin and isolated from roughages of varying digestibilities, was equally utilized by isolated rumen microorganisms. Quicke and Bentley (16), using similar techniques, concluded that cellulose digestibility was related to lignin content in timothy but not in brome or orchardgrass. Nevertheless, when their data were combined and recalculated, the correlation of cellulose digestibility and ash-free, acid-insoluble lignin was —0.90. Meyer and Lofgreen (17) have shown a very high correlation between lignin and total digestible nutrient content of alfalfa. Moreover, further work with growing lambs showed a high correlation (—0.94) between weight gains and lignin content (18).

Recent reviews (19, 20, 21) point out that much of the physiology and chemistry of lignin is being solved. Nord and Schubert (21) have presented a scheme for synthesis of and a structural formula for lignin. Pigden (22) points out that lignin affects the curing properties of grasses. He also showed histologically that the progress and site of lignification were not similar in the grasses he studied. Meyer *et al.* (18) showed that the effect of lignin differed in the utilization of alfalfa and oat hay by sheep.

Apparently roughages are utilized best when fed to animals being maintained rather than fattened (23, 24). Roughages, especially those higher in crude fiber, have relatively higher heat increments (23, 24) than concentrates. This heat would be useful to beef cattle maintained at low environmental temperatures even though it would be useless at critical temperatures or above, and would be particularly harmful at high environmental temperatures (25). Armstrong *et al.* (26, 27) have presented information to indicate that the heat increment produced by various proportions of volatile fatty acids not apparent at levels below maintenance is found with fattening sheep. Acetic acid is largely responsible for the heat increment effect in fattening and a decrease in heat increment occurs when the proportion of propionate is raised. Since the research of Phillipson (28), others (29-32) have verified that roughages result in the production of a higher proportion of acetate by rumen microorganisms while concentrate additions increase the proportion of propionate.

Roughages can vary from poor-quality feeds such as rice hulls, practically worthless as a feed, to high-quality pasture approaching a fattening ration in quality. Utilization of roughage can be considered from two standpoints: first, and possibly the most important, is how can a feed such as pasture or hay be managed to make it the highest quality commensurate with greatest economic yield? Second, if the production of the feed cannot be manipulated to improve quality, how can it be used to obtain the most nutritive value?

Pasture. Sound pasture or range management must consider requirements of the plant as well as the animal. Few fields of research involve such careful consideration of plant-animal relationships that is required in grazing management. Cultivated pastures can vary in the production of quality and quantity of livestock feed by varying the plant species (33, 34), stocking rate (35), method used for grazing (35, 36, 37), grazing frequency (34), and intensity of grazing (38). In addition, lack of water, length of day and growing season are important factors. The grazing animal has an influence because he can select the highest quality feed available (34, 38). For example, Weir and Torell (39) showed that grazing sheep select from a grass range a feed containing substantially more protein and less fiber than that found in hand-clipped samples from the same area. As the season progressed and the forage became sparse, the animals were not able to selectively graze because they had already selected the most nutritious feed. McMeekan (35) has a particularly good discussion on the effects of stocking rate. Heavy stocking rates may cut down on rate of gain but meat production per acre increased because the animals were forced to consume more of the lower quality forage. There is much research to be done to develop principles of pasture utilization and then apply them to the many conditions that exist.

Management to obtain a consistent supply of feed from pasture or range is one of the greatest problems confronting a beef operator. Periods of lush feed supply or periods of shortages are generally operating, with the irrigated pasture or the pasture in adequate rainfall areas, or, in other words, quantity and quality of feed available per day are never consistent. Because of this, the most critical management problem is adjusting animal numbers to obtain the greatest economic production per acre commensurate with optimum daily gain. In most areas, spring and early summer periods have adequate available forage, while late summer and autumn are periods of short feed supply. If one stocks a field for the former, then the feed supply is short in the latter period and gains or body condition drop. Hay or concentrates should be fed or animal numbers decreased. It cannot be overemphasized enough that this area of pasture maagement is too often overlooked. On the other hand, too much forage in the spring creates a management condition often ignored. If there is too much forage, the more palatable, nutritious species are overgrazed, and coarse, more undesirable plants increase. Cutting some pasture for hay or judicious clipping after grazing would be in order.

On the other hand, the main problem on the range or pastures in inadequate rainfall areas are the seasons when little or deficient feed is available. Additional nutrients (energy, protein, phosphorus, and/or vitamin A) are generally supplied by supplements (40, 41). This is expensive and cattle are too often in poor condition because this was neglected.

Hay and Silage. Forages are harvested to provide a source of feed during winter seasons, to provide feed when it is desirable to feed cattle in a dry lot, or to provide feed to other areas.

Hays and silages are among the most variable of harvested feeds. Not only are there great variations between species, but even greater variation sometimes occurs within a species. When hay is placed in the same federal grade, great differences in response are found. For example, Moore (42) reports that alfalfa hays, graded U. S. No. 2, produced daily gains which varied from 0.84 to 1.62.

After attention to such management practices as seed-bed preparation, irrigation and weed removal, the first control a cattleman has over hay quality is selection of the species. Swift *et al.* (43) have suggested and embarked on a program of determining the nutritive value of single forage species at different maturity stages. This is a sound step towards choosing the highest quality species. Then if mixtures of forages are used, feeding value can be calculated according to the proportion of the various species.

The second step over which control can be exercised is the proper stage of maturity for highest yield of nutrients. The best time for cutting is difficult to determine. Reid *et al.* (44) point out that in the Northeast the digestible dry matter (Y) can be accurately predicted from days elapsing from April 30 (X), $Y = 85.0 - 0.48X$. This gives a simple method of predicting quality. Also they suggest dry matter content as a simple indicator of nutritive quality. Meyer *et al.* (18) have shown that height of alfalfa is a possible indicator of quality.

The production of the highest quality forage for hay is not always the most economical time for harvest because yield of dry matter would be down. Conversely, yield of dry matter is not the best criteria because quality might be so low that net yield of available nutrients would be down. This was also pointed out by Reid *et al.* (44). Additional evidence by Meyer *et al.* (45) showed that even though dry matter yield of oat hay was highest at the milk stage, greatest yield as measured by meat production was in the flower or dough stage. Examples of important work in this area have been conducted by Forbes and Garrigus (46), Dawson *et al.* (47), and Kivimae (48).

Even though high-quality forage is cut, this does not guarantee that high-quality forage will be fed to the cattle. Weather conditions, method of harvesting, and method of storage often dramatically decrease forage value. Dehydration (49, 50), barn drying (51), ensiling (49, 50, 52, 53, 54), and mechanical treatments to speed drying such as hay crushers (51) can often be used to save nutrients. One of the most comprehensive studies was that made by Shepherd *et al.* (55) Barnett (56) has an excellent discussion on silage.

Pelleting hay is a relatively recent method of handling and feeding hay. When hay is finely ground and pelleted, feed consumption increases and results in a greater daily gain (57, 58). Little practical difference seems to occur in digestibility (57, 59). Possibly there will be a great future for pelleted hays because bulk reduction improves the ease of handling, storage, and reduces feed refusals. Some caution is needed in the acceptance of pelleting because high-concentrate rations are not always well utilized as pellets (60). Furthermore, parakeratosis of rumens from lambs fed pelleted feed has been reported as a serious problem (61). Use of large pellets or wafers of coarsely-chopped or long hay are also possibilities for a means of packaging hay (62).

Generalizations are difficult to make regarding the method of choice for harvesting and preserving forage for cattle feed because of the many economic considerations. Nevertheless, yield should be measured in terms of the particular nutrients needed rather than dry matter and the most inexpensive "sure-fire" method used for harvesting.

Poor-Quality Roughages. Roughages are classified in this category primarily because they are high in lignin and cellulose, lignin being the predominate reason. As pointed out earlier, not only is the absolute quantity of lignin important, but probably the site of deposition is as important. The lignin content of poor-quality roughages varies between 12 and 20 per cent (7). Cellulose digestibility by rumen microorganisms in poor-quality roughages was as high as that from alfalfa when lignin was removed.

A very successful research effort was that of Burroughs, Gerlaugh, and associates (63-65) in demonstrating that corn cobs can be well used in cattle rations if missing nutrients are supplied. Beeson and Perry (66) developed a supplement which successfully satisfies the nutritional deficiencies of many poor-quality roughages. Others have studied poor-quality prairie hay (67) and cotton gin trash (68). There is a great need to re-evaluate these and other poor-quality roughages when properly supplemented for maintenance, wintering, or fattening through the use of the net energy principle.

Starch

Large quantities of starch from grains, particularly during fattening, are consumed by cattle. The rumen microflora, as with cellulose, seem to be necessary for starch utilization by the ruminant. Esden and Phillipson (5) point out that very little starch reaches the lower gastrointestinal tract, and that little amylase has been found in the saliva of ruminants (8) Moreover, Larsen *et al.* (69) have presented data to indicate little starch breakdown in the small intestine. More confirmatory data are needed in this area.

Even though the ruminant is uniquely prepared to utilize roughage, the feeding of large quantities of cereal grains is an economical practice. Many times concentrates are much the cheaper source of energy for fattening ruminants and make up the largest proportion of the ration. Some years ago Mead and his co-workers (70, 71) raised dairy heifers and bulls to four years of age on rations devoid of roughage. Growth was satisfactory but some problems occurred with bloat and other digestive disturbances. The National Research Council (72) has suggested that a certain minimum of crude fiber be in fattening rations. The need of a certain amount of fiber, however, has not been proved. If such work is done, constituents other than crude fiber should be the criteria. Use of roughage *per se* as a standard for comparison in concentrate-roughage ratio studies is unfortunate. A precise description of the roughage quality in terms of chemical constituents is needed; lignin and cellulose might be best. Although rates of gain are sometimes equivalent over a wide range of concentrate-roughage ratios, a certain amount of concentrate is needed to obtain optimum fat laydown (73, 74). Lofgreen *et al* (75) showed though little differences existed between daily gains of steers fed high-roughage rations and those fed higher levels of concentrate, a higher energy content occurred in the weight gain of those fed concentrate because of a higher fat content.

Nitrogen Utilization

The protein nutrition of ruminants is unique, interesting, and of great practical value in the ultimate production of high-quality protein for human consumption. The rumen microflora play an integral role because all nitrogenous substances must pass through the rumen and microorganisms utilize much of the nitrogen from feedstuffs for synthesis of their own characteristic protein (6, 11, 76). There is a tendency, therefore, for the biological values (absorbed protein utilized by the animal) of proteins to approach a common value because much of the dietary protein is converted to microbial protein. McDonald (77, 78) has shown that 40 per cent of zein and 90 per cent of casein were degraded in the rumen and utilized for the synthesis of microbial proteins and clearly demonstrated a difference between proteins in their progress through the tract. Even though most workers (79-82) have found that most common feed proteins were similar in value, higher biological values were found for blood fibrin and whole egg protein and lower values for gelatin and urea as a protein source. Explanations for these differences may be in the proportion converted to microbial protein (77, 78) or loss of ammonia from rapid protein degradation in the rumen (83, 84).

Huffman (11) points out that legumes are abundant sources of protein for ruminants but it is becoming clear that research is needed on how best to utilize legume proteins. Some years ago Turk *et al.* (85) had shown that the biological value of alfalfa protein could be raised by adding carbohydrate to the ration. Recently Meyer *et al.* (57) confirmed the reports of Gray and Pilgrim (86) that there is a great loss of nitrogen from an all-alfalfa hay ration before reaching the abomasum. Presumably the nitrogen from alfalfa was lost as ammonia (83, 84) because Annison (87) has reported little amino acid absorption from the rumen.

It has been realized for many years that non-protein nitrogen was utilized by ruminants (88) but conclusive proof was offered by Loosli *et al.* (89) showing amino acid synthesis from diets with urea as the main nitrogen source. The excellent review of Reid (88) brings out the optimum conditions needed for maximum urea utilization as a source of protein. A low level of true protein and a high level of starch favor urea utilization. Sugars and cellulose are inferior to starch. Sugars disappear too rapidly from the rumen and cellulose is too slowly available. It appears that urea satisfactorily replaces up to 25 per cent of the protein equivalent in a ration containing 11 to 13 per cent protein equivalent.

Vitamin Needs

A most important peculiarity of ruminants (6) is the synthesis of the B-complex vitamins and vitamin K by the rumen microflora. Being synthesized in the forepart of the digestive tract allows maximum absorption and is a second important peculiarity (90). Moreover, there is no clearly-defined demonstration that supplements of B-vitamins to cattle with well-developed rumens improved growth, reproduction, or ration digestibilitv (91).

The demonstration of value, need, and requirement of vitamin A by Guilbert and Hart (92), proved an important adjunct to cattle feeding. Under usual conditions of management where cattle are exposed to sunlight or consume sun-cured hay, additional vitamin D has not been shown necessary. Vitamin E has been shown to be required by cattle (93) but the deficiency could only be produced on solvent-extracted rations. Reproduction problems were by no means an important symptom of an E-deficiency (94). An important aspect of vitamin E nutrition was demonstrated by Muth *et al.* (95), showing that selenium might be important in white muscle disease of sheep. An interaction of selenium and vitamin E had previously been shown with rats and chickens (96).

Nutrient Requirements

No discussion on requirements is necessary since the National Research Council Requirements have recently been revised (72). Some recent work on energy requirements by Winchester (97) and Garrett *et al.* (98) should be mentioned, however. Some discussion on factors influencing requirements might be in order.

Maintenance

"The energy cost of maintenance is the net dietary energy required to keep the organism in a 'steady' energetic state—the net dietary energy required to replace the energy expended while carrying on 'maintenance' life processes. . . ." (99). According to the estimates of Axelsson and Eriksson (100), 95 per cent of the metabolizable energy is used to maintain the body while only about 5 per cent is required for development of the fetus of a pregnant animal. Even in periods of growth the maintenance requirement is about 66 per cent, on an average. Therefore, the energy cost in beef production is largely one of the maintenance need. Breeding heifers at one year of age rather than at two years of age is one example of saving maintenance costs (101). Continuous growth of beef cattle on the range (40) or maintaining rapid gains in the feedlot are also good examples. Maintenance energy requirement can be considered a constant overhead cost. Efficient beef production, at all stages of the life cycle, should keep this cost as low as possible.

Three important factors influence the maintenance requirement for energy: basal metabolism, activity, and environmental temperature. The major maintenance energy expense is for basal metabolism, varying from about 50 to 85 per cent (99). The animal with no activity, consuming no food and producing no product requires a certain quantity of energy to maintain life processes. Periods of low feed or energy intake will lower the basal metabolic energy production (103, 104), and the low basal metabolic rate will continue for a period of time even after refeeding at a luxuriant level. This is probably one of the explanations for the steers of Winchester and Howe (105), restricted in feed intake for a period of time, making as efficient gains as those continuously full-fed their rations, even though the restricted steers were fed for a longer period of time. These data are not necessarily in conflict with those of Guilbert *et al.* (40) because Guilbert's steers were restricted in growth on the range by energy, protein, phosphorus, and vitamin A deficiencies, while Winchester's animals were restricted in energy or protein (106).

The energy an animal must expend in the activity of obtaining feed is part of the maintenance requirement. No doubt the range animal must use more energy for this activity than the animal fed in a small pen in the feedlot. Lofgreen *et al.* (107) have shown that steers spend more time grazing in search of feed than when fed green feed in a small feedlot. It seems desirable to keep animal activity at a minimum for maximum production. There is practically no information on the energy required for various activities of beef cattle while feeding. Conversely, no conclusive data exist that some exercise is desirable.

The energy required to keep warm is also a maintenance need but the environmental temperature at which the net energy of feed is used for this process is quite low (99). There is little information about the magnitude of the effects of wind, rain, or snow on energy needs. Armstrong *et al.* (108) have begun studies with sheep along these lines.

Protein needs during maintenance are largely those of replacing the loss of metabolic nitrogen in the feces of cattle fed high-fiber roughage such as that found on the range (109). Winchester *et al.* (106) have made some estimates of the digestible protein requirement of cattle held at a maintenance level of energy intake. Apparently digestible protein requirements should include consideration of the energy intake (106) and the indigestible fiber intake (109). Indigestible fiber increases fecal loss of nitrogen.

With the exception of vitamin A, little is known of the maintenance needs by cattle for other nutrients.

Growth and Fattening

Body Composition. The young beef animal contains more water and less fat than the mature steer (110) and the growth process can be roughly considered as one of dilution of the ash, protein, and water with fat. Moulton *et al.* (111, 112) showed that the first weight gains of a calf contain about 10 per cent fat while the gains contain 90 per cent fat at 3 to 4 years of age. While the proportion of water to protein to ash changes as the animal ages, their proportion remains relatively constant compared to the proportion of fat to these constituents (110). Callow (113) emphasizes that the level of fatness is the major factor in the percentage of muscular tissue.

More information is needed on the effect of nutrition on carcass composition. Means are at our disposal to more easily study carcass composition as influenced by feeding. Kraybill *et al.* (114) have presented data which demonstrates the ease of water and fat determination from specific gravity of the carcass. We have found this method easy to apply (98); all that is required is weight of carcass in air and under water. The excellent paper of Reid *et al.* (110) presents many additional equations for the application of such data.

Rate of Gain. The genetic make-up of an animal has a limiting effect on rate of gain. Environmental factors, which include nutrition, can be used to influence rate of gain. The first factor to be considered is feed intake.

The general problem in human nutrition is one of lowering food intake (115) while we in Animal Husbandry are interested in maximum feed intake. It is well accepted that the more an animal eats the more he gains. The data of Baker *et al.* (116) can be used to demonstrate the correlation of feed intake and daily gain. This correlation was 0.91, while a non-significant —0.07 existed between dry matter digestibility and daily gain. A further example of the importance of food intake by beef cattle is furnished by Black *et al.* (73) when carcass grade was found to be highly correlated with feed intake ($r = 0.72$). It therefore behooves the beef man to be vitally interested in feed intake and know all the "why" about it. The series of papers on food intake presented to the New York Academy of Sciences is well worth reading (117-121). The neural regulation of food intake (119) is an area deserving investigation. Damage to certain areas of the hypothalamus causes an increased food intake of such animals as the rat and dog, but so far this has been unsuccessful with sheep at California (122). Feed preparation has an influence on feed intake. Fine grinding and pelleting of hay increases feed intake and hence, weight gains (57, 58, 123). The main concern in feed intake is one of energy intake, and the addition of concentrates increases energy intake. This is a well-known fact of cattle fattening.

Rate of gain decreases during the later phases of fattening, primarily due to an increased fat content in the gain (111), but maintenance needs also increase because of increased size. The gain of energy, however, may be as great or greater, but the apparent gain decreases.

Discussions by Willey *et al.* (124) and Knox and Koger (125) indicate that type may or may not influence rate of gain. This type of research is difficult because one is never certain that the types compared are representative of populations. Selection for certain strains within a "type" for rapid rate of gain might be possible. However, both Gerlaugh and Gay (126) and Durham and Knox (127) agreed that feeder grade did not seem to be associated with subsequent gain.

Measurement of Gain. One of the big sources of error in any comparison of nutritional treatments is that associated with weighing conditions. For example, Balch and Line (128) report that over 84 per cent of the weight change of cows when changed from winter feeding to grazing was rumen fill. Recent studies (129, 130) emphasize the value of (10- to 15-hour) periods without feed and water before cattle are weighed in order to reduce variation. Koch (129) further suggests that much of the variation due to fill could be reduced by three weighings with several days between weighings. Hubbert (131) showed that, even with a 12-hour stand without feed and water, fluctuations occur for three weeks and that weights of beef cattle immediately following periods of stress should be used with caution. It seems that for best results a 12- to 15-hour stand without feed and water is the minimum necessary for accurate estimations of weight gains. Furthermore, the cattle should be adjusted to feed and environmental conditions before experimental weights are taken.

It is common to express results in dairy cow experiments in terms of fat-corrected milk. Should we not be thinking along terms of the production of "fat-corrected carcasses" when we speak of nutritional effects in beef cattle? Not only would this correct for rumen fill, taking into account differences in fat content, but would also represent the end economic product. Representative animals could be killed at the beginning of an experiment to obtain initial fill and fat content determined by specific gravity. Gain in "fat-corrected carcasses" could be calculated by difference. Another possibility would be to use the final carcass weight corrected to a common fat content as the final measurement in an analysis of covariance with initial weight as the independent variable. This corrects the carcass for variation of initial weight of the steers. Accurately defined weighing conditions, of course, would be necessary.

Efficiency of Gain. Many, many variables enter into this term when expressed as gain per unit of feed consumed or feed required per 100 pounds of gain. In reality these terms are apparent expressions of efficiency of feed utilization because one variable is expressed in terms of another variable (gain and/or feed intake). The first factor affecting these terms is the net available energy in the feed. The higher energy rations, higher in concentrate, usually produce the most gain per unit of feed consumed. Secondly, the energy content of the gain affects these expressions of apparent efficiency of feed utilization. Weighing conditions, as discussed earlier, would have an influence since the fill in the gastrointestinal tract would vary depending on how the animals were handled. This fill would create large errors if assigned to gain in weight.

Fat content in the gain would have an influence. A low fat content in the gain would make an animal appear more efficient if gain per unit of feed consumed were the expression of efficiency of gain. The following data were calculated from the paper of Garrett *et al.* (98):

Note that when fat content in the gain increased, the relative value of rations 2 and 3 compared to ration 1 was less when calculated from gain per 100 pounds feed

	Fat content of the weight gain	Gain per 100 lb. feed consumed		Energy gain per 100 lb. feed consumed	
Ration	%	lb.	% of ration 1	mcal.	% of ration 1
1	17.8	6.9	100	8.1	100
2	30.1	9.0	141	15.0	185
3	32.9	10.6	154	20.0	247

consumed than calculated from energy gain per 100 pounds feed consumed. This point is illustrated more vividly by Lofgreen and Otagaki (132) when practically equal gains in weight occurred per 100 pounds of feed consumed, 10.1 and 10.2, but the energy gain per 100 pounds of feed consumed was 21.9 and 25.9 mcal. because fat in the gain was 41.3 and 51.5 per cent respectively.

Age, maturity, and size would influence feed required per unit of gain because the more mature animals have a larger proportion of fat in their gain. The older, larger animals would appear more inefficient; one important reason for the decrease in apparent efficiency of feed utilization as a fattening period nears the end. This gross efficiency measurement of energy utilization is closely related to physiologic age (99). In addition, the older animal is larger and a larger proportion of the feed is needed for maintenance requirement.

MacDonald (133) made calculations from a theoretical study of the energy cost of beef production. He suggested that the lowest calory cost per pound of body weight, while varying with rate of gain and calving percentage, is produced at a body weight of 850 to 1,100 pounds. He did not consider body composition but this is probably satisfactory if we agree that protein production is one of the main purposes of beef production.

Reproduction and Lactation

The primary functions of adult cattle in the beef herds are reproduction and lactation. Most of the nutrient requirement is for maintenance. Bulls need extra nutrients, primarily an energy source, for the extra activity during breeding season, while cows have the nutrient requirement for the developing fetus and milk production. Jakobsen (134) and Jakobsen *et al.* (135) in two very fine papers present information on the protein and energy requirement. Earlier, Reid (136) discussed the relationship of nutrition to fertility.

Even though there are reports (137) that the lactating ability of the beef cow makes a major contribution to the growth of the calf, little direct evidence can be found on requirements during lactation of the beef cow. Wallace (138), in some studies on the effect of level of nutrition on the growth of lambs before and after birth, showed that 96 per cent of the variation in weight gains from birth to 112 days is due to differences in consumption of milk and supplements by lambs. He also presents a great deal of information to show the effects of level of nutrition on the vigor of the lamb and dam at birth.

Much more information is needed in this vital field of beef cattle nutrition. Undoubtedly the first experiments should be conducted in pens where accurate records of feed consumption can be kept; then applications can be made to the pasture and the range. Here, level of nutrition could be a very fruitful field of research.

Feed Evaluation

Recently, Blaxter (23) presented evidence in a comprehensive review to the effect that use of the net energy principle is superior to total digestible nutrients (TDN) in evaluating feeds. TDN overevaluates poor-quality roughages and/or underevaluates high-quality roughages and concentrates. TDN, digestible energy or metabolizable energy does not take into account energy lost as heat increment (energy lost as heat as a result of consumption of food). Heat increment is much higher for roughages. The National Research Council recently used digestible energy as one means of expressing energy requirements. The digestible energy values of the feeds, however, were calculated from the previously determined TDN. Garrett *et al.* (98) have, among others, shown that digestible or metabolizable energy was not any more accurate than TDN as a measure of food energy. It was realized in this study that digestible energy is simpler to determine and a definite physical unit.

Measurement of the energy value of feeds for ruminants, therefore, will not be greatly improved unless a system utilizing the net energy principle is used to evaluate feeds. If it is agreed that net energy is the most satisfactory means of evaluating feeds, then a move to a system using the net energy principle might be called for. Mistakes would be made, but I do not hesitate to predict that this would stimulate much needed research in this area. The system has been used in Europe in a satisfactory manner, and is therefore workable. It is true that more data are needed on various feeds; data are needed, no doubt, on each feed for various levels of production and for various physiological functions. Morrison's *Feeds and Feeding* (139) gives actual and estimated values for many feeds and thus supplies a start in this direction.

Kleiber (24, 140) has suggested that a Replacement Equivalent system similar to the Scandinavian Feed Unit be used to evaluate feeds. This involves using two feeds such as corn and soybean meal and/or barley and cottonseed meal as standards, replacing them with the feed to be evaluated to produce the same energy gain. This system uses the net energy principle and has the additional value of conducting determinations on feeds under conditions similar to the way cattle are generally fed. Corrections could be used to refine the method by estimating carcass composition from specific gravity. This system utilizes experiments from which monetary returns would be realized and therefore would not be expensive. We have used a similar system in calculating feed value (37, 57, 98, 132); it was workable and checked well with animal response and Morrison's values for net energy (139). A master project involving several experiment stations on a national basis would be a suitable approach. At first, experimental procedures would need to be worked out, refined, and applied. Study of the effects of levels of feeding and purpose for which the energy is needed would logically follow. Then feeds could be evaluated as easily as in digestion trials.

Chemical analysis would add to the precision of feed evaluation. Mitchell (141) suggested that use of chemical analysis for a precise constituent would add materially to the usefulness of digestible energy or nutrients in evaluating feeds. Walker and Hepburn (142) demonstrated the usefulness of crude fiber or lignin by regression equation to predict digestible energy content of mixed grass hays. Crude fiber was more useful than lignin. Later work (143) with grass silages showed lignin to be the best indicator of quality. Meyer and Lofgreen (144) have devised a system of evaluating alfalfa hay by an analysis for crude fiber. Both TDN and digestible protein were predicted from the crude fiber analysis. Furthermore, replacement values in terms of barley and cottonseed meal could be calculated. Previously, Walker and Hepburn (142, 143) utilized a similar idea by estimating the starch equivalents of their hays and silages from chemical analysis.

Summary

The symbiotic relationship between ruminants and the rumen microflora is one of the most important factors affecting the production efficiency of beef cattle. Utilization of cellulose from fibrous feeds by the microflora provides fatty acids as energy sources for the ruminant.

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Management Systems and Production Efficiency in Beef Cattle

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Management Systems

Bradford and Johnson (1) in their farm management book categorize beef cattle fattening into 13 systems. These 13 systems were set up by farm management research workers from the North Central states in the early 1950's. They are:

Group I. Fall purchase of 400-pound calves

System A—1. Begin October 15 at 400 lbs.
2. Full feeding, dry lot
3. End at 1,000 lbs.

System B—1. Begin October 15 at 400 lbs.
2. Winter on roughages
3. Full grain feeding on pasture
4. End at 1,000 lbs.

System C—1 and 2. Same as in System B
3. Pasture with no grain during first half of grazing season
4. Grain during last half of pasture period
5. Finish in dry lot at 1,000 lbs.

System D—1 and 2. Same as in Systems B and C
3. Pasture with no grain during grazing season
4. Fatten in dry lot for 90-100 days
5. End at 1,000 lbs.

System E—All-roughage system
1. Begin October 15 at 400 lbs.
2. Winter on pasture and dry roughages
3. Pasture with no grain during grazing seasons and sell

Group II. Purchase of 650-pound (medium to low grade) feeders

System F—1. Begin in April or May at 650 lbs.
2. Full grain feeding on pasture

System G—1. Begin same as for System F
2. Pasture with no grain during grazing season
3. Fatten in dry lot

System H—1. Begin October 15 at 650 lbs.
2. Winter on roughages
3 and 4. Same as 2 and 3 in System G

Group III. Purchase of 650-pound (high-good to choice) feeders

System I—1. Begin April or May at 650 lbs.
2. Full grain feeding on pasture

System J—1. Same as in System I
2. Pasture with no grain during grazing season
3. Fatten in dry lot

System K—1. Begin October 15 at 650 lbs.
2. Winter on roughages
3 and 4. Same as 2 and 3 in System J

Group IV. Purchase of two-year-olds

System L—1. Begin October or November at 800 lbs.
2. Fatten in dry lot

3. Finish to (a) medium to low-good; (b) high-good to choice

System M—1. Begin April or May at 800 lbs.
2. Fatten with grain on pasture
3. Same as in System L

There are literally hundreds of systems of producing cattle. You will immediately agree that the 13 fattening systems mentioned do not include 1) the calf producing systems, 2) the commercial and custom beef feeding operations, 3) the use of feed additives and growth stimulants, or 4) the assumption of changed breeding habits of beef females.

You will also note that these 13 beef fattening systems are tied closely to the apron strings of Mother Nature. Remember how often the fall months of October and November and the spring months of April and May were mentioned. A decade ago more feeder cattle were placed on feed in these four months than is true today. There is much less seasonality in the placement of cattle on feed and consequently less seasonality in the slaughter of fed cattle. I shall refer to this again but want to point out that the packing and distribution sectors of the beef economy desire less seasonality than now exists.

One of the more systematic approaches to research in beef production was reported in U.S.D.A. Technical Bulletin 900, entitled "Relation of Feed Consumed to Food Products Produced by Fattening Cattle," by Aaron G. Nelson (2). Even though this bulletin is 14 years old, it provides many guide lines for research in this area. Several different types of research have been done: Smith (3) reported on a linear programming analysis in a beef cattle feeding program; Hoglund (4) analyzed feed substitutes for beef production; and Stangeland (5) reported on input and output relationships in livestock production.

There is a family of reports on feeding trials from a majority of the Agricultural Experiment Stations in the United States (6). A new addition is usually added to each family each year (7). The researchers test new ideas so that those which prove useful can be adopted in the industry. These reports on cattle feeding show the weight gains which can be obtained by feeding rations which are balanced, are high in energy, and are supplemented with hormones, biologicals, chemicals, or tranquilizers. Or, they show how economically gains can be achieved on rations with high roughage contents.

These reports represent a sample of the research work which has been done on the subject of producing beef. Valuable data have been published, but I would raise this question: Do the social scientists know about all the research of the animal scientists and do the animal scientists know about the research of the social scientists? I believe there are many opportunities for interdisciplinary cooperation in designing feeding experiments and interpreting research results.

Regardless of the exact number of systems used to produce beef, the industry has made progress as noted in the July 1959 issue of Agricultural Situation (8). Harold Breimyer wrote:

> "The cattle industry has made great strides in productivity. Production of beef per animal on farms is almost a half higher now than 30 years ago.
>
> "This record is the more remarkable because the cow, unlike the sow and ewe, seldom has multiple births. One calf per cow each year is the usual limit. This is a handicap to increases in productivity.
>
> "Rising productivity of the cattle herd has helped beef output in the United States to double since the 1920's. Only half of that increase is attributable to more cattle on farms. The other half is due to their higher productivity.
>
> "Cattle numbers on farms have increased no faster than the human population in the last 30 years. But because more beef is produced per animal, beef output has outrun population, enabling

consumption per person to increase 25 per cent.

"Lacking the advantage of multiple births, the bovine's greater productivity comes about in other ways. Trends since the early 1920's illustrate six of these.

"1. More of all cattle are beef cattle. The percentage of beef-type cattle in the herd has been rising since 1939 (from 47 per cent to 67 per cent today). Although dairy cattle also produce beef, they don't do so quite as well as beef cattle.

"2. A higher percentage of all beef cattle are cows. Among cattle kept for beef, the proportion of cows has risen from less than 35 per cent before 1940 to about 40 per cent today.

"This is not so meaningful in itself. But it does reflect how much the proportion of steers and heifers has decreased, as they are raised faster now than formerly. In the 1920's steers often were held until they were 3 or 4 years old, and each one appeared in the inventory that many times. Now most steers are slaughtered before they're 30 months old [a few before they are 12 months old—and they weigh over 900 pounds, too].

"3. The calving rate is higher now. Multiple births are still rare, but *more* cows now have *one* calf. The number of calves born per 100 cows has increased from 75-80 in the mid-1920's to 85-90 in the last few years.

"4. More calves are raised to maturity. Until 1940 about 40 per cent of all calves were slaughtered as calves, and 60 per cent as mature cattle. In 1958, only 29 per cent were slaughtered as calves, and 71 per cent as mature cattle. More feedlot feeding, and improved breeding have speeded this trend.

"5. Death loss has been reduced. Since 1924 the percentage death loss has declined a fifth.

"6. Finally, average dressed weights of cattle slaughtered have increased [about 80 pounds per head]. There may be some question as to whether so much heavier weights are desirable. Insofar as they are associated with improved type, little objection can be raised. At times, too many over-fat cattle have been marketed. In any event, when weights are heavier more beef is produced per animal."

When we compare beef with other commodities, we can rightly raise the question about the speed of adoption of innovations which will be needed to keep beef competitive. Byerly (9) reported that the increase in production per head of beef and veal increased 18 per cent from the 1925-29 period to the 1951-55 period. This compares with increases of 25 per cent for pork, 53 per cent for eggs, and 118 per cent for chickens. These data show that beef cattle have increased production per unit slower than other red meat competitors and only one-sixth as fast as chickens.

The 1958 annual report of the Ralston Purina Company (10) says that it took nearly 11 pounds of feed to produce one pound of beef in 1930. Today it takes around 7.5 pounds. In 1930 the average daily gain was two pounds; today it is nearly three pounds per head.

USDA researchers writing in the 1959 Outlook Chart Book (11) said, "With the striking exception of broilers and turkeys, the average amount of livestock products produced per pound of concentrates has not changed greatly in the last 20 years."

On the surface there seems to be a contradiction in these reports. This points up a prime requisite for all of us in this industry. We must be sure to define the terms clearly and we must use comparable statistics. And we have statistical problems in this industry, as Ives (12) ably states:

> "Our statistical difficulties arise mainly from the twin facts (a) that cattle are not produced and marketed as an annual crop, and (b) that we are not dealing with a single, homogenous commodity. Instead, the production

process can be as short as a few weeks, as in the case of veal calves, or as long as 8 or 10 years, in the case of cows culled from breeding herds. In between these two extremes is the bulk of our beef supply which goes through various degrees of feeding and which may take as little as 90 days or as much as 12 months or longer. Furthermore, this finishing process may begin at various stages of maturity, and the resulting beef can differ widely in its quality factors."

In addition, we need to exercise caution when we use the statistics dating back to the 1920's.

Another factor we need to consider is that our plant breeders, our soil nutritionists, and our agricultural engineers have provided knowledge which enables land to produce more feed per acre and for animals to obtain more T.D.N. and vitamins per ton through improved varieties, improved growing, and improved handling of pastures and roughages.

We need also to recognize the large body of facts which have been uncovered about the use of feed additives, minerals, implants, and tranquilizers. Most tests prove that these reduce costs of gain, speed gains, and cut down death losses (13). But if they are used and we compare the results with research data from earlier years, we are not comparing the efficiency of feed conversion *per se* nor the production efficiency of beef cattle in an earlier period with the same beef cattle in the latter period. New variables have been added and they should be recognized.

Increases in productivity have come, as stated above, from advances in feeding, breeding, and in disease and parasite control. If we examine the area of beef breeding, here are some of the things we find. Three-fourths of the states now have performance testing programs. Professor J. H. Knox (14) reported that "most production traits have heritabilities from 30 to 50 per cent. This means as much as one-fourth of the superiority of the parent may be expected in the offspring if selection is applied to one parent only and about twice this amount if applied to both parents." Knox further reported that some performance testing is done to locate the best animals in a region or the nation and the herds or lines of breeding from which they come. In other cases the purpose is to help the owner find more productive animals in his own herd and develop plans for using them after he finds them.

Many states are publishing bulletins on the performance tests in their herds (15). Breed associations are also testing and reporting their results. Typical of a number of releases from breed associations and testing programs was the release from the American Hereford Association on June 22, 1959, reporting gain results of a pair of Hereford bulls owned by breeders in Utah. The release said, "Top animal in the gain program gained 3.02 pounds per day during the 105-day test. The bull required only 5.25 pounds of feed to put on one pound of gain in comparison to the average of 6.41 pounds of feed required by the 30 bulls in the Utah State University program." The Performance Registry International has registrations in 33 states and 2 foreign countries (16). The USDA has its own performance program and individual ranchers and farmers check the performance of their herds. Mr. George F. Ellis, Manager of the Bell Ranch in New Mexico, (17) wrote:

> ". . . It is true that we have been following the breeding program at Bell Ranch for the past eleven years designed to increase the efficiency of our cattle. In that time, we feel that we have gotten very good results. We have been able to increase our calf weaning weights about fifty (50) pounds. At the same time, we have increased the grade of our cattle remarkably. When we began we only had 9 per cent calves which would grade fancy. For the past three (3) years we have had sixty (60) per cent of better fancy calves."

I am sure that breeding experiments have increased productivity of beef animals. However, the 50-pound increase at the Bell Ranch probably was obtained from a combination of better care, better disease control, better feeding, as well as better selection and breeding.

Rapid advances have occurred in research dealing with the breeding of animals. Swine researchers have discovered how to regulate the oestrus cycle of gilts and sows. By using their research it will soon be possible to breed an entire herd of sows on the same day. Since boar semen cannot be diluted as can bull semen and freezing ruins boar semen, the ability to control the oestrus cycle is a significant technical breakthrough for the swine industry.

A decade of research has been conducted on the regulation of the oestrus cycle in beef cows. Dr. John Nellor at Michigan State, who has developed a method for controlling the ovulation of sows and who has also worked with the oestrus cycle in cattle for 10 years, reported to the writer that several hurdles remain to be crossed in connection with beef cows (18).

Let's assume Nellor and his colleagues are someday successful with cows. This will permit an expanded use of artificial insemination in beef cow herds, particularly in the Western states. If all cows can be treated so that their oestrus cycles can be controlled, then artificial insemination with semen from bulls with desirable traits will be much more practical.

Size of Operations

There are approximately 3.5 million cattle producers in the United States. This number includes the very small and the very large producers. The number of producers has been decreasing and the size of the average operation has been increasing. These trends will continue as specialized knowledge becomes more important for economical operations.

Even though the size of operations has increased, census data show that the average cattle farm in the U. S. markets only 8,000 pounds of beef animals per year. This is 8 1,000-pound animals or 16 500-pound animals, the national average. The distribution is skewed in the beef industry as it is in all other agricultural industries. A large number of farms market a small proportion of the total output.

Census data show that Iowa in 1954 marketed an average of only 21 head of cattle per farm. Seventy per cent of Iowa's farms reported selling 19 or fewer cattle. Eighty-seven per cent of the farms sold less than 40 beef animals. In California an average of 54 were sold, with nearly one-half the farms selling fewer than 10 head. Colorado reported average sales of 49 head in 1954, with one-half of the farms selling fewer than 10 head. These units seem small when compared with the cattle feedlot which fattens 75,000 head per year.

You can readily see how difficult it is to introduce innovations and systems into an industry with so many small units. In my opinion, this huge industry with no great geographic concentration and with millions of managers means that new methods and ideas are adopted slowly.

Over 10 million head of fed cattle are marketed annually in the United States (19). Fed beef makes up about 45 per cent of the total beef output. In the last 15 years, both the number of cattle on feed and the ratio of marketings to inventories have increased. In 1946, 4.2 million head of cattle were on feed January 1 and 6.2 million head were marketed during the year. In 1956, 6.0 million head were on feed January 1 and over 10.5 million were marketed. So, 10 years ago the ratio was about 1.50 and now it runs closer to 1.75. With more year-round feeding and hotter (higher energy) rations, this ratio is expected to increase.

The corn belt still ranks first in cattle feeding but is losing, percentagewise, some cattle feeding to other areas. Twenty years ago over 80 per cent of all cattle on feed, when the January 1 inventory was taken, were in the corn belt. Today this is down to around 70 per cent. The western states have picked up these 10 percentage points. Added to the increase in January 1 inventory numbers is faster feeding done in the West. On the average, California feeds three batches of cattle in each feedlot each year, Colorado feeds over two and the corn belt not quite two per year.

Traditionally, corn belt cattle feeders have fed relatively small lots of cattle and have worked cattle feeding into winter months to utilize labor when field operations were light. Feeding in the western states is generally of a different type. Small feedlots in the West account for only a small percentage of all cattle fed. Scott (20) reported that in 1952-53 only 1 per cent of all cattle on feed in California were in feedlots of less than 100 head. For the West as a whole, only 10 per cent of all cattle on feed were in lots of under 100 head. Of the 496,000 head of cattle in California feed yards on January 1, 1957, 92.7 per cent were in lots whose capacity exceeded 1,000. Only 0.3 per cent were in small farm feedlots handling 100 head or less.

The farmer-feeder is still dominant in the corn belt, but commercial feedlots are springing up. Specialization in cattle feeding has been made possible by push-button feed mills and automated feeding operations. Custom feedlots have started operating in the corn belt, the South and the Southwest, as well as in the West.

These definitions are used in this paper:

Farmer-feeders—farmers who earn the major share of their income from non-cattle feeding enterprises. Cattle feeding often is an operation which utilizes labor in the months when field work is at a minimum.

Commercial feeders—cattle feeders who earn the major share of their income from feeding their own cattle. They generally have cattle on feed each month of the year. They may or may not also grow crops.

Custom feeders—cattle feeders who have facilities and do the feeding of cattle which other people own. They may also feed their own cattle, but a large share of their income comes from the receipts from feeding cattle belonging to others. Often they do not grow crops.

Trend in Size of Cattle Feed Yards

Hopkin studied feed yards in California and showed that there are economies of size (21). Knight and Bortfeld came to the same conclusion in Kansas (22). Table 1 shows the nonfeed costs and other cost factors of six groups of feed yards of different sizes. The economies of size include both the economies of intensive use of plant and economies of scale. You will remember that California feeders feed up to three separate lots of cattle per year and corn belt feeders do not average two lots per year.

In talking to the operators of over 30 cattle feed yards in Colorado, California and Arizona, the writer concluded that the size of the large yards would continue to increase because the operators said there were additional economies expected by adding more pens. Montfort, near Greeley, Colorado, planned to expand from 28,000 to 30,000 in 1959. Several small yards—farmer feed yards—were observed to be empty. Local people said that the smaller operators were having problems obtaining feeder cattle and competing with the larger yards. Hopkin showed that the net nonfeed costs were 50 per cent higher for the smallest group of yards compared with the largest group. This is quite a difference and very difficult to offset, even if home-produced feed and underemployed seasonal farm family labor are used in the feeding operation.

The writer concluded from talking with owners and managers that there will continue to be an increase in the size of feed yards. Increased size permits a specialization of functions within a feed yard. When the numbers of cattle are increased sufficiently, one man can spend full time mixing rations, another can

TABLE 1
A comparison of average daily nonfeed costs per head and other factors by size of yard

Size group	I	II	III	IV	V	VI
Range in feedlot capacity	Below 1,200	1,200–2,499	2,500–4,999	5,000–7,999	8,000–13,999	14,000 & above
Number of feed yards per group	17	14	13	12	11	10
Average capacity	486	1,498	3,205	6,479	10,531	18,053
Average number fed	784	2,300	4,947	10,984	20,160	35,568
Average investment per head fed in feed-yard facilities	$23.53	$24.93	$23.83	$18.85	$19.62	$17.44
Average nonfeed costs per day	(cents)	(cents)	(cents)	(cents)	(cents)	(cents)
Labor (other than office)	5.79	4.08	4.20	3.81	3.52	3.30
Depreciation and repair of equipment	1.37	1.45	1.39	1.10	1.14	1.01
Taxes	.79	.83	.79	.63	.65	.58
Interest on investment	1.57	1.66	1.59	1.26	1.30	1.15
Insurance	.36	.37	.36	.28	.29	.26
Fuel and power	.56	.74	.57	.57	.45	.39
Vet and medicine	.35	.38	.30	.31	.26	.31
Death loss	1.05	.87	1.16	.99	.83	.73
Administration and overhead	.81	.80	.74	.35	.48	.84
Gross nonfeed costs	12.65	11.18	11.10	9.30	8.92	8.57
Credit for manure	.88	.88	.88	.88	.88	.88
Net nonfeed costs per day	11.77	10.30	10.22	8.42	8.04	7.69

Source: John A. Hopkins, Economies of Size in the Cattle-Feeding Industry of California, *Journal of Farm Economics*, Vol. XL, No. 2, May 1958, Appendix Table 1.

spend full time "riding the pens," a third can spend full time "doctoring cattle," and a fourth can spend full time marketing cattle. Financing should also be considered as a reason why size will increase. Operations of large commercial and custom cattle feed yards undoubtedly have access to credit through institutions not generally open to smaller operators. This access will permit them to expand further if they operate as successful businessmen. I feel that normal agricultural credit institutions have not yet adjusted their lending to average farm operators to permit these farmers or ranchers to increase to the size necessary to provide incomes comparable with incomes in other vocations.

Vertical Integration in the Beef Industry

Vertical integration is the control by a single firm of two or more stages in the chain of production, processing, and distribution. This control may be partial or complete; as a minimum it involves some business relationship that is closer than an open market relationship. The chain extends from the supply of inputs or production resources (feed) to the point at which the commodity (beef) reaches the consumer. Vertical integration may come about by cooperative arrangements, by the use of contracts or by ownership.

Using this definition, I researched the current status of integration in the beef industry in the United States in the spring of 1958. In my paper at the Institute of Animal Agriculture in April, 1958, I reported that from 10 to 20 per cent of the fed cattle slaughter was coming from integrated arrangements. In the meantime I have done more research and have concluded that the percentage continues in this range.

The present trends in the cattle industry indicate that capital can be substituted for labor. One of the efficient cattle feeders in Colorado told me that one man could feed 3,500 to 4,000 cattle daily. Contrast this to the 16 head marketed annually from the average cattle farm in the U. S. We have recognized that antibiotics and synthetic hormones encourage more efficient feed utilization and more rapid gains. Top management is needed to capitalize on intensive operations and not make costly mistakes in using new feeding techniques. These points have encouraged integrated operations.

To learn why retail food companies, meat packing companies, and ranchers (the principal integrators) were interested in integrated beef cattle operations, the writer interviewed retail food company and meat packing executives, ranchers, secretaries of state cattle associations, national association executives, USDA and college experts, feedlot owners, and managers and bank executives. The writer traveled 10,000 miles collecting information which is given here in condensed form[1] (23).

Meat packers shipping meat interstate report their operations to the Packers and Stockyards Administration (PSA). Retail food companies who operate meat packing plants also report on their meat packing operations to the PSA. The PSA Docket (24) reported the number of cattle fed by packers in 1954, 1955, 1956, and 1957 and showed that between 500,000 and 560,000 head of cattle were fed in each of these 4 years. This number amounts to around 5 per cent of all fed cattle marketed per year. When the packers not covered by the PSA Act and the ranchers who have cattle custom fed are included, the percentage more than doubles. There are other integrators besides the three principal groups mentioned, but the number of cattle integrated by them is small. These facts lead the writer to conclude that between 10 and 20 per cent of the industry is integrated.

A bulletin published in 1952 (25) reported that packers gave the following reasons for feeding cattle: 1) the need for a more uniform supply of desired grades and weights, 2) to finish animals that are in feeder flesh when bought but which packers must buy in mixed lots, 3) to provide animals for slaughter when weather conditions shut off receipts, 4) to carry out supplemental feeding tests, 5) to create more interest in cattle feeding in a particular area, and 6) to permit the plant labor force and other facilities to be used more efficiently.

In the interviews with packing company executives in 1958 these reasons were reiterated. One reason given by all companies was flexibility. Being able to capitalize on all opportunities is extremely important in the meat packing industry. Having a supply of cattle ready for slaughter at all times was reported to be a valuable asset to packers who slaughter cattle.

World War II was cited as an important reason why packers fed cattle. O.P.A., rationing and other rules, regulations, and restrictions which were in effect during the war encouraged many packers to enter the cattle feeding business so they could have cattle to slaughter and to reduce the cost of fat cattle.

Being business firms interested in earning profits, packers also reported there were times when they believed that their earnings could be improved by buying feeders and adding the finish themselves. In their opinion, market prices for feeder cattle relative to the expected future market prices for slaughter cattle sometimes seemed low and favored the purchase and feeding of the feeder cattle.

The number of cattle fed by packers has not increased during the past five years. Packers are feeding fewer cattle in their own facilities because of the increased number of commercial and custom feed yards, lower profits on the average from feeding, and the availability of more fat cattle. Packers are having more cattle fed in custom yards because of the location of these yards, the larger number of custom feed yards, and because custom

[1] The American National Cattlemen's Association sponsored this study as a part of the research done for its Fact-Finding Committee. Dr. H. DeGraff, Research Director of the Fact-Finding Committee, gave permission for material in the report to be used in this paper.

yard operators will feed as the packer directs and finish and deliver the cattle when the packer wants them.

Meat packers are expected to feed about the same percentage of the total number fed as they have in the past five years. This means an increase in actual numbers as fed cattle numbers rise to 11 then to 12 million head. Specification buying by retailers means that packers must have access to certain grades and weights of slaughter cattle so that they can fill their specialized orders.

Food retailing companies who feed cattle generally own and operate packing plants or have a financial investment in packing plants. In many respects they have interests which are identical with strictly meat packing companies.

The writer's interviews led to the conclusion that the laws and policies in effect during World War II were the dominant reason for food chains entering the meat packing business and thence feeding cattle. One retail executive said, "My company began operating packing plants during World War II. We did it to obtain meat supplies—supplies at prices in line with the retail price permitted under O.P.A." Other retail executives reported essentially the same thing. "Retail food stores must have meats," they said. Since beef makes up 10 to 12 per cent of total store sales, they indicated they had to have beef.

The war period gave meat packing and cattle feeding experience to several executives in many retail food companies. This experience convinced a few companies that they could continue to operate packing plants to their advantage. On the other hand, other company executives reported they felt a larger return could be obtained on their dollars by getting out of the packing business. With beef supplies available at reasonable prices they got out of the packing business and began buying all meats from packers.

In 1957 a report was prepared by the USDA (26) on the current activities and problems under the Packers and Stockyards Act. This report states: "There are 14 chains presently filing reports as meat packers under the Act. This number includes 6 of the leading chains . . ." The USDA was including:

American Stores Co.
First National Stores Co.
Food Fair Stores, Inc.
A & P Tea Co.
The Kroger Co.
Safeway Stores, Inc.
Alpha Beta Packing Co.
National Tea Co.
Steen Bros. Food Stores
T & W Packing Co.
Giant Food Shopping Center, Inc.
Shaffer Packing Co.
Southland Corp.
Tom Boy, Inc.

Of this number, American, Food Fair, Safeway, Alpha Beta, National, Steen Bros., and T & W slaughtered. The other seven did not slaughter, but had processing or sausage plants. Since that time, Safeway sold its final slaughter plant and Shaffer was purchased by another chain and still does not slaughter.

There has been a downward trend in the number of chain-owned meat packing plants since the end of World War II. Chains own and operate fewer packing plants because of low profits in meat packing, larger supplies of beef and other meats and public pressures. Cattle feeding by food chains has declined because there are fewer chain-owned plants, custom cattle feeding yards have increased in number, and the availability of cattle and beef has increased. With plentiful meat supplies and no controls I would expect a decrease in retail food chain cattle feeding and meat packing operations.

Ranchers have increasingly held onto calves and feeder cattle and have had them fattened for slaughter in custom yards. The number of rancher-owned cattle which are custom fed will vary with the cattle cycle. Ranchers will sell feeder cattle and calves when they feel that feeder cattle prices are high relative to expected slaughter cattle prices. They will also sell when their supply of capital is low and they can't defer receipts from cattle. They will hold feeder cattle and calves and have them fed out when they think that they are low relative to expected slaughter cattle prices and if they have enough capital to defer receipts from cattle. Ranchers are interested in flexibility, as are others. They are also interested in maintaining and increasing income. Feed supplies and relative as well as expected prices are important in what ranchers decide to do with their feeder cattle and calves. The availability of custom yards and the services they provide will probably encourage more ranchers to have larger numbers of cattle fed out. The larger, better financed ranchers will probably hold title to the majority of rancher-owned cattle which are custom fed.

Increases in numbers of cattle fed out for ranchers will more than offset the decline in numbers fed out for retailers. With packer-fed cattle numbers increasing slightly, the trend is for slightly more vertical integration in the beef cattle industry.

Packer and chain feeding of cattle has contributed to the spreading out of fat cattle marketings through the year. It has helped reduce seasonal swings in cattle prices. Level marketings permit meat packers to use facilities more efficiently. Packer and chain feeding has also created an interest in cattle feeding in certain areas. As local feeding increases, packer and chain feeding often declines. The effect of packer and retailer feeding has been one of influence. The grade, weight, and sex desired by the retail trade have been influenced by packer and retailer feeding.

Summary

Review of the literature dealing with my topic leads me to conclude that the production efficiency in beef cattle is increasing. Compared with other food commodities, the beef story could be brighter. The multiplicity of possible management systems and the resulting heterogeneous beef products which are possible makes the interpretation and synthesis of research results for the industry a most difficult task.

Some of the advances and the factors which have influenced the cattle industry are: 1) less seasonality in cattle production and marketing, 2) faster growing and fattening of cattle, 3) increased performance testing and use of tested breeding stock, 4) better disease and insect control and less death losses, 5) improved management of the herds with increased calving percentage, 6) larger units in both production and fattening, 7) increased use of custom and commercial feeding operations, 8) growing and harvesting of higher quality roughages and feeds, 9) substitution of capital for labor in roughage and feed handling operations, 10) increased use of credit and an increase in vertical integration, 11) decrease in vertical integration on the part of food chain companies, 12) increase in vertical integration on the part of ranchers, 13) use of a wider range of rations—high roughage rations used in some cases and very high energy rations used in others and, 14) expanded use of feed additives, implants, minerals, and other chemicals and biologicals.

The data do not permit a clear summary of the contributions of research to the efficiency of feed conversion in cattle. There is no question about increased beef production per beef animal. The question is how much more efficient feed converters the 1960 models are compared with the 1930 models.

Everyone in the beef industry will need to adopt cost reducing and output increasing innovations. Beef occupies a favored position among protein foods, but continued progress must be made in the industry if it is to maintain this position. Improved management systems and increased production efficiency will be needed to keep beef the king of meats. Comparisons reveal that the pace at which innovations are adopted in the beef industry will need to be accelerated.

Can this industry afford the luxury of a *laissez faire* policy with regard to research? The industry is large and widely scattered. Much unnecessary and costly duplication can be expected from uncoordinated research done by over 50 Agricultural Experiment Stations, the USDA, businesses, and breed associations. It would appear that a beef industry committee or a beef industry congress could serve a constructive purpose in reviewing current research so as to point out the overlaps and the gaps in the total industry research programs.

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Discussion

Session III

How to Produce Beef Economically

ROBERT C. JONES: Dr. Kramer, you indicate substantial savings on large commercial feed business, and yet you expect only slight increase in integration. Would you please reconcile this?

DR. KRAMER: The Montford feed lot in Colorado has been used as an example in many cases. Supposedly, most of the cattle fed there are owned by Mr. Montford and his son Kenneth. What I am thinking, using this as an example, is that the commercial feeder will be the private entrepreneur who buys and puts gains on the cattle and then, after they are ready for slaughter, will make them available for packers. I know and you know where a lot of cattle go from the Montford line, but I am thinking that much of the feeding will be done in the commercial feed lots where this is primarily income from the owner and the operator of the lots. This owner and operator will buy from the cow-calf rancher the feeders and the calves that he puts in his pens, and after he has done the job of putting on finish, he will then make them available to the packers.

Committee Recommendations

Basic research is needed on the nutritional requirements of beef cattle under different environmental, especially climatic, conditions.

Improved methods of controlling the reproductive cycle of range cattle are needed before artificial insemination can be effectively used for increasing efficiency of production in beef cattle commercial herds.

Attempts should be made to increase and coordinate genetic research and to determine the extent which meat quality and economy of gain of animals can be improved through breedings.

Reorganization and extension of performance testing on a uniform national scale for purebred and commercial beef herds is needed.

Studies should be made to determine proper criteria for describing "ideal type" of breeding animals as they relate to desirable traits in carcasses of slaughter animals. Research is especially needed on the relationship of conformation to cutability and beef quality as a guide to breeders, feeders, and buyers of slaughter cattle.

Basic research is urgently needed on the endocrine physiology of growing and fattening beef cattle on the role of feed and other additives on beef production efficiency, and on beef quality and composition.

Closing Remarks

By Dr. R. M. Bethke, *General Chairman*

While great progress has been made in all phases of beef production, the facts are that much thought and research still need to be instigated. For example, I think we need studies that will measure what the consumer wants and is willing to pay for beef.

Second: In order to give the consumer what he wants, studies relating to control of quality in the production and marketing of beef and/or quality identification in the sorting of beef at the central points is needed.

Third: To supply the increasing population with the quality of beef wanted, attention needs to be given to the production of quality beef on a per-acre, per-unit of feed, per-breeding unit, and per-man hour basis. This, of course, involves genetics, nutrition, and management.

Fourth: Improvement is needed in our marketing system, so the producer can produce the beef we want, the amount we want, where we want it, and when we want it. All of these call for greater precision techniques in factors which affect or influence the quality of the beef for tomorrow.

The planning committee of the National Academy of Sciences—National Research Council and Agricultural Research Institute will review comments made at this conference and consider what is needed as far as the future is concerned. And they propose to come up with some recommendations which will be incorporated into the published proceedings of this conference.

Appendix

Attendance

Beef For Tomorrow Conference

October 19-20, 1959

Dr. Stan Aldinger
Yoder Feeds, Inc.
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Dr. G. C. Anderson
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Tillman Bubenzer
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