THE INFLUENCE OF SEX UPON THE QUALITY OF BEEF

by

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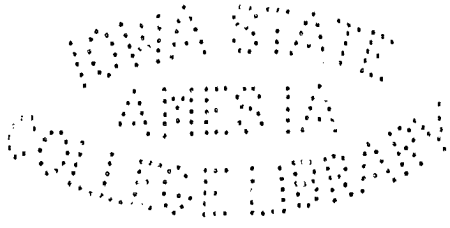

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INTRODUCTION

The equality of steers and heifers for slaughter purposes, when comparable in conformation, weight, and finish has long been accepted as a fact by butchers in England. In the United States heifers are usually discriminated against in the livestock markets after they reach a weight of approximately 700 pounds on the premise of lower dressing percentages, disparate fat distribution, a lower percentage of high price cuts in the carcass, and the widespread belief on the part of consumers that beef from heifers is inferior in quality to that from steers.

In the absence of any substantial experimental evidence to support such claims, a study was undertaken to determine the influence of sex upon the quality and desirability of beef from young cattle of different ages and degrees of fatness.

Quality is a character possessed by all matter. The term is usually applied to denote degree of excellence or natural superiority. Its meaning may be extended to express a difference which sets off one character or a group of characters from another; thus quality becomes a feature or peculiarity by means of which substances may be recognized or differentiated. Sometimes, as in the case of meat, an aggregation of the characters that indicate excellence is referred to as quality.

The task of defining quality in meat is exceedingly difficult, since specifications involving mathematical measurements or mechanical apparatus are not available. It is not, therefore, a tangible matter, yet it is a

factor of extreme importance in meat despite its variability. Nearly everyone has a fair idea of what is meant by quality, but the term has been so loosely used with reference to meat that it often leads to confusion; hence it was deemed advisable to describe this important character of beef. A statement by Davis and Whalin (11) is quite significant:

> Quality is a characteristic of the flesh and the fat included therein. It pertains primarily to the thickness, firmness, and strength of both the muscle fiber and connective tissue. It also involves the amount, consistency, and character of the juices or extractives which surround and permeate the muscle fiber and connective tissue. It is strongly influenced by marbling which is due simply to the presence of droplets of well filled fat cells along the connective tissue and between the muscle fibers.

Slater (38) believed that the definition of quality in beef should be extended to include, "the size, shape and condition of bone, ratio of bone to muscle and fat, and the quality, thickness and character of the connective tissue encasing the muscular divisions." Quality, therefore, is defined largely in terms of the physical properties of beef such as lean, fat, bone, and connective tissue as well as the character and proportion of each of these constituents of the flesh, and applies equally to the small cut, the wholesale cut, and the beef carcass.

Quality of beef is influenced by many factors. Sex was one of the factors enumerated as influencing the quality of beef by the Committee of the National Cooperative Project, "A Study of the Factors Which Influence the Quality and Palatability of Meat." (44).

The difference in sex of bovine animals is not restricted to that of a generative function, for it is recognized that differences also

occur in the fleshing character of these animals. Thus the differentiation in the function of reproduction may also impose upon the animal a differentiation in the metabolic functions which are manifested in the relationships of the quantity of various tissues such as lean, fat, and bone in the animal structure.

The differences between the male and female of the species in fleshing characteristics are best portrayed by the proportion of the flesh constituents in the animal structure. It is reasonable to assume that an alteration in the ratio of the lean, fat, and bone may likewise result in an alteration in the quality of the meat, at least to some extent, since these changes in ratios between the flesh constituents naturally involve fatty deposits, thickness, and firmness of both muscle and fat, and the amount and character of the meat extractives. Any differences, therefore, between the physical properties of the flesh from steers and heifers may logically be construed as differences between sexes in the quality of beef.

Differences in the physical composition of the wholesale cuts would conceivably bring out differences in the weight of the constituent parts of the cut not otherwise indicated. This shift in the ratio of lean, fat, and bone between two similar cuts may be suspected of causing a difference in the quality between the two pieces of beef.

The deposition of fat received special attention in this study because of its important association with the quality of the meat. It is generally recognized that considerable economic value is attached to the occurrence of marbling in the muscles, a feature attributable to the

presence of intramuscular fat. Furthermore, preliminary microscopic observations had shown fat to be deposited intracellularly in beef, and pointed strongly to the possibility of intracellular fat being correlated quantitatively with the general state of adiposity in the animal structure. Accordingly, histological examinations were made to determine the size and abundance of fatty bodies within the muscle cells from steers and heifers.

The color of beef varies with age, degree of muscular development, and fatness of the animals. The color of the musculature of the young calf, for example, differs greatly from that of a mature animal. Increases in age, with attendant changes in diet, produce rapid changes in the color of the flesh. The color of the muscle usually changes from pale pink in the calf to a cherry-red in the yearling beef and to a dark hue in the older animals.

The color of flesh is not only modified by the intensity of the muscle protoplasm but may be influenced by the constituents which compose the flesh, such as mixtures of muscle and fat. Since optical measurements of color vary widely due to visual imperfections of those who judge the color, specially constructed instruments were used in an attempt to determine color independent of the personal equation.

The attributes of quality paramount to all others in importance are those involving tenderness and flavor of beef. Tenderness is a property of the connective tissue and muscle fibers, while flavor originates with the fluid present in muscle tissue and in the solubility of certain organic substances and inorganic salts. It has not been shown to what extent odor affects the taste, but it has been demonstrated that elimination of the

olfactory sense tends to nullify the sense of taste. Therefore, muscular substances volatile in character may affect the flavor.

These two important attributes of quality are latent characteristics of the flesh and are most appropriately determined by the organoleptic test. Accordingly the factors relative to the quality and palatability of beef were evaluated for roasts from beef animals differing in sex, age, and degree of fatness.

It was the purpose of the investigation to make a detailed study of steers and heifers of different degrees of fatness to determine differences in the physical composition of the animal carcasses, deposition of fat, color of the flesh, and the organoleptic values of the meat.

REVIEW OF LITERATURE

Sex Differences in Beef Carcasses and Their Constituent Parts

Various methods have been employed by investigators to determine differences between beef animals influenced by such factors as age, degree of fatness, and sex. A very commonly used method was to compare carcass yields to live weights. Another method was to compare the wholesale cuts from corresponding parts of the carcass. A more recent method - one which more accurately indicates the difference between parts and in the aggregate between carcasses - was to compare the weight of the constituents, such as the lean, fat, and bone of one part of the carcass, with a corresponding part of another carcass. Some investigators were of the opinion that since lean and fat were the most important constituents in a beef carcass, differences between steers and heifers had greater significance when expressed in terms of those constituents.

Wilson and Curtiss (46) reported what is probably the first carefully planned experiment to determine the development of carcasses and wholesale cuts from five steers, and from five open and five spayed heifers. The fifteen animals were well fattened. Slaughter and block tests were then made of the carcasses. The average final weight of the steers was 1582 pounds, open heifers 1318 pounds, and the spayed heifers 1426 pounds. These investigators reported that the dressing percentage of heifers was 0.9 percent and 0.4 percent respectively, below that of

the steers. The results of the block tests showed that steer carcasses had approximately 2½ percent heavier rounds, but that the yield of the two most valuable primal cuts, loin and ribs, was greater from carcasses of heifers; also, that the heifers were correspondingly lower in the percentage of cheaper cuts than the steers. However, on the basis of yield and values of the primal cuts, these investigators concluded that carcasses from steers were slightly superior to those from heifers. Their conclusions were strengthened when substantially the same results were obtained from a second experiment (47).

The carcasses of three steers, different in ages and degree of fatness, were separated into wholesale cuts by Edinger (12). He observed a tendency for the weights of the more valuable cuts to increase and those of the cheaper cuts, such as plate, shank, and neck to decrease correspondingly as the general adiposity of the carcass increased. His observations agreed with the results reported by Wilson and Curtiss (47) and by Hall and Emmett (20). When the wholesale cuts were separated into lean, fat, and bone, Edinger (12) found that as the animal increased in flesh it also increased in the proportion of fat to lean and bone in the more valuable cuts of the carcass, and that the parts of the carcass which served as larger depots increased their proportion of fat to lean and bone even more rapidly. According to Hall and Emmett (20), a prime carcass has 57 percent lean, 30 percent fat, and 13 percent bone. The best carcass used by Edinger, though considerably younger, had 49.61 percent lean, 32.93 percent fat, and 17.11 percent bone. This compared favorably in fatness to the analyses quoted above from Hall and Emmett.

Trowbridge (43) reported the distribution of lean, fat, and bone from four steers differing in degree of fatness and age. One steer was five years old and weighed 1785 pounds. The others were three years old and weighed 755 pounds, 1063 pounds, and 1250 pounds respectively. The carcass from the five-year old steer contained 40.70 percent fat and 46.87 percent lean. The percentage of fat in the carcasses from the three-year old steers varied from 12.19 percent to 26.92 percent, and the lean from 64.69 percent to 57.25 percent.

The physical composition of mature and immature "marketably fat" steers was reported by Foster (14). His results showed that the mature carcass contained 5.53 percent more lean, 6.93 percent less fat, and 1.38 percent more bone than did the immature carcass. The hindquarter, however, had 4.43 percent more lean, 3.26 percent less fat, and 1.18 percent less bone than the corresponding part of the carcass from the mature steer . Other differences observed were the larger percentages of round and loin in the immature steer. Since the ages of these steers were nine years and three years respectively, even greater variation in the distribution of these tissues would appear reasonable.

Physical analyses of carcasses from three steers and three heifers of different ages and degree of fatness were made by Sleeter Bull at Illinois (7). No difference was reported in dressing percentage between steers and heifers when slaughtered as calves, or after 140 days of feeding; but the yield of carcass favored the heifer after 200 days of feeding. The fats obtained from the internal organs were greater in the heifer, but not enough greater to affect the dressing percentage materially.

Slight difference was noted in the distribution of lean, fat, and bone in steers and heifers after 140 days of feeding. The heifer, after 200 days of feeding, was 85 pounds heavier than the steer and had a lower percentage of lean and bone, but it had considerably more fat than the steer. Bull concluded from his analysis that 700 pound heifers had a distinct advantage over steers of similar breeding and weight in the matter of finish, and that the yield in the more valuable regions of the carcass was almost as good, but that 800 pound to 900 pound heifers were slightly inferior to steers of equal weight because they were over-fat.

Tests have shown that the composition of the wholesale prime rib cut is closely correlated with that of the entire side. Studies by Lush (32) showed the fat content of boneless meat from the wholesale rib-cut to be an excellent indication of the fat content of the entire body. The physical composition of the whole prime rib-cut from well fleshed carcasses was found by Sleeter Bull (7) to represent quite accurately the physical composition of the entire carcass. Helser, Nelson, and Lowe (22) reported that the percentage of lean, fat, and bone areas in the prime rib-cut was a good indication of the various proportions in the rest of the carcass. In their study concerning the influence of age upon the quality of beef they found that the proportionate fat increase in prime ribs occurred much more rapidly during the fattening of calves than of yearlings or of two-year old steers, but that the fat was most equally distributed throughout the lean in the yearlings and two-year old animals.

Tenderness

Mechanical methods for testing tenderness of meat were reported by Lehmann (30) who tried to duplicate the masticating process by a mechanical apparatus. With this apparatus he demonstrated that increased tenderness of striated muscle was induced by ripening or aging. Lehmann (30) also observed that the amount of connective tissue, fat, and the size of muscle fibers contributes to the relative tenderness of meat.

Warner (45) developed an apparatus to determine the shearing strength of beef muscle. A similar mechanism was used by Helser (22), in testing the shearing strength on the longissimus dorsi muscle over the twelfth rib from calves, yearlings, and two-year old cattle. The Warner shearing machine was also used by Black, Warner, and Wilson (6) on meat from good and medium grade three-year old beef steers fed grass and grass plus grain. They found that the shearing strength of the muscle varied widely between animals within the lots.

Mitchell and Hamilton (34) determined chemically the proportion of collagen to elastin in muscle of tough and tender beef. They found that toughness was a function of collagen and elastin in connective tissue, therefore, tenderness was correlated with the connective tissue character and content of beef muscle.

Liposomes in Muscle Fibers

Early histologists were not able to show true fatty bodies or liposomes within the muscle cell. Development of histological technique, based on the knowledge of the physical and chemical nature of cellular protoplasm, has enabled later investigators to show two types of interstitial granules in the muscle cells.

The occurrence of granules between the fibrils of cross-striated muscle was first discussed by Kolliker (29), who called them interstitial granules. He stated that the granules were widely distributed, being found in vertebrate muscle as well as in insect muscle. He did not, however, differentiate between the true interstitial granules and fat droplets, the former now thought to be non-fatty in nature. Later investigations on this point, conducted by Bell (4) and Bullard (9) seemed to establish conclusively that the granules observed by Kolliker were of two types, true interstitial granules, and fat granules or liposomes. These investigators were able to distinguish between the two types of granules by the reaction to dyes and by the difference in solubility. They did not, however, disprove the possibility of a fatty substance in interstitial granules nor the occurrence of non-fatty substances in the fat droplet. The presence of true interstitial granules as well as the occurrence of liposomes, fat droplets, in muscle protoplasm is now accepted by leading histologists.

Albrecht (1) used the name liposomes to describe the granular substances, thinking that the cellular granules were all fat droplets.

Because other workers were unable to duplicate his results, it was believed that Albrecht was mistaken in his identification, since some of these substances in striated muscle stained by acid fuchsin while others blackened with osmic acid. Neither Bell (4) nor Bullard (10) was able to bring out the presence of fatty bodies in fresh sections of muscle by the use of such stains.

The term "liposome" as applied to the fat droplets found within the muscle cell was also used by Bell (2). The same terminology is used in this treatise.

In reporting the results of his studies on fat deposition in muscle from beef carcasses, Bell (2) (3) stated that no fat was found inside the muscle fibers, i. e. within the sarcolemma, of the very fat animals and concluded that the muscle fiber in the adult was not used for the storage of fat. Bullard (10) found fat droplets inside many of the muscle fibers from three steers that had shrunk about half their normal weight, and displayed marked muscular atrophy. The muscle cells of these animals had likewise shrunk about half their normal diameter, and their outlines were no longer visible. The adipose tissue had been almost entirely depleted of its fat.

Traina (41), examining tissues from rabbits which had died of starvation, found no diminution in quantity of fat in the epithelium, such as in the pancreas, suprarenal, and thyroid, though some of the cells had been reduced to half their normal volume and the connective tissue fat depots almost completely emptied. From the tissues observed, Triana concluded that intracellular fat was neither removed by starvation nor in-

creased by excessive fattening. Kemp and Hall (26) were unable to find fat inside a muscle fiber examined from animals fattened for slaughter.

Bell (2) did not find fat present in the muscle fibers of adult cattle under normal conditions, but small droplets appeared in the later stages of atrophy caused by a prolonged submaintenance ration. This led him to conclude that fat inside the muscle fiber was independent of the nutritive condition of the animal. Later Bell (4) and Bullard (10) demonstrated, with the use of improved technique, that most normal tissues contained numerous droplets of a fatty nature that were seldom, if ever, seen in ordinary examinations for fat.

Observers who used Herxheimer's Scharlach R stain were able to see the fainter liposomes, but the capacity for staining the fainter liposomes seemed to have been lost in the simple alcoholic solution such as was used in ordinary fat staining. Bell (3) reported that simple alcoholic solutions of dyes such as were generally used, extracted a large proportion of the intracellular fat. Kaufmann and Lehmann (25) showed that the extraction of fat from the tissue increased with the concentration of the alcohol in which the dye was dissolved. They found that 70-percent-alcoholic-Sudan solution in tissue staining extracted a great amount of fat, while a 40 percent alcoholic solution removed only a trace of the fat.

Fixtures such as are used in ordinary fat staining likewise remove many of the liposomes. The variable effect of the fixative may be due to changes in chemical composition of the liposomes. The normal disappearance of the liposomes in muscle tissue also points strongly to the activ-

ity of autolytic enzymes within the muscle substance.

Nutritional status exerts a marked influence upon the number and character of liposomes in muscle. Knoll (28) found that starvation for six to nine days reduced the fat droplets visible in fresh heart muscle of pigeons. Bell (3) reported the muscle fibers free of liposomes when rats were kept on starvation rations until they had lost over 20 percent of their body weight. Rats previously starved and then fed on fat meat for several days were found by Bell (4) to have a greatly increased number of liposomes. These droplets also increased in size and susceptibility to the stain as the animals fattened. Foods low in fats were found to produce very little or no change in the liposomes, while fatty foods greatly stimulated the formation of these fatty bodies within the muscle cell.

According to Bell (4) and Bullard (10) freshness of material is a factor of importance in the microscopical examination for liposomes. These fat droplets were shown best when the tissue was examined immediately after slaughter and before post mortem changes occurred. Bell observed that liposomes disappeared if tissues were left unstained for 12 to 24 hours, and often in less time; while Bullard reported that many of the liposomes had disappeared in the space of only two to three hours.

It would seem, therefore, that the amount of microscopically demonstrable fat in muscle depends very largely upon species of animal, proportionate constituents of the food, and the general state of fatness of the animal. The amount of fat stained depends upon the stain used, the technique employed, and the treatment of the tissue before it is stained.

Development of Histological Technique

The technique for showing fat deposits in muscle tissue beyond the sarcolemma has attracted the attention of histologists for nearly three-quarters of a century. The perfection of a technique that will show the presence of fat in such a finely divided form as liposomes has been exceedingly difficult because of the presence of other intimately associated substances thought to be lipoidal in character but also containing a non-fatty element.

In order to render these fatty droplets visible it is necessary, as we have seen, to employ some form of staining solution which will not be a solvent of the substance being studied. It is well known by biologists that free fats and lipoids are soluble in substances such as ether, chloroform, absolute alcohol, zylol, and benzene.

Haines and Rosenbaum (18) compared Sudan III, Scharlach R dye with osmium tetroxide for staining fat. They obtained more reliable results with the dyes than with the osmic tetroxide and attributed it to the fact that fats were not chemically altered by staining solutions made from the two dyes, whereas a simple chemical change was essentially the basis of the osmic acid method of staining. Bell (4) using the same stains, stated that a great many fat droplets (liposomes) which were not stained by osmic acid were stained by the use of Herxheimer's (24) Scharlach R. The dye stain cleared up the tissues of striated muscle so that the fainter droplets were readily observed. He preferred Scharlach R to Sudan III because it had the property of staining the smaller and less refractive

liposomes.

Scharlach R and Sudan III were compared as to their staining capacity by Froboese and Sprõhnle (15). The test included alcoholic concentration, staining time, staining temperature, and saturation. They observed little difference in the reaction of the two stains upon the tissues and organs used for the test. Both dyes were about equally satisfactory, but they preferred to use Sudan III.

Romeis (36), reporting the chemical nature of the two dyes, Sudan III and Scharlach R, stated that the Scharlach R, being a methyl derivative, produced a more intensive stain.

Because of the difficulty in getting desired intensity of color by staining with simple alcoholic solutions, Herxheimer (24) used an alkaline-alcoholic solution and found it to be a greater solvent for the dye, consequently more effective in staining faintly refractive fat droplets.

Erdheim (13), by the Herxheimer method, was able to stain fat droplets in the thyroid which were not visible when simple alcoholic solutions were used.

Dye precipitates are frequently formed on sections stained with Sudan III and Scharlach R. Bell (4) and Bullard (10) encountered difficulties with precipitates when using their alkaline-alcoholic staining solutions. They recommended washing the stained section in 70 percent alcohol to remove the precipitated dye.

Bullard (9) in a study of the interstitial granules, employing all the fat stains in common use, stated that he preferred Herxheimer's alkaline-alcoholic solution of Scharlach R because it usually showed much

more fat than the simple alcoholic solutions even with the same dye. He observed that the alcoholic solutions sometimes failed to stain a large part of the fatty droplets seen in the fresh unstained tissue. He reported no similar experience with Herxheimer's stain.

The long, painstaking investigations conducted by Bell and Bullard have contributed much in perfecting a technique for fat staining. Their findings, in many cases, have made it possible to explain why earlier workers were unable to identify liposomes as normal specific fat droplets in the sarcoplasm of the striated muscle cell.

Variations in Color of Adipose and Muscle Tissue of Beef

The color of lean and of fat, according to Davis (11), is one of the important considerations in determining the quality in beef. It is influenced by a number of factors such as age, breed, degree of fatness, feed, character of feed, and individuality of the animal.

That the intensity of color of muscle increases with age was illustrated by Schmid (37) with colored plates of the wholesale rib cut from a calf, baby beef, medium and a heavy beef steer - the latter two about three years of age. Contrasts in color of muscle fiber in a calf, a well fattened ten-months-old steer, and a thin fleshed six-year old cow were also reported by Schmid.

Differences in the color of fat due to breed were brought out in a report by Kennedy et. al. (27). Later Hall (19) and Helser (23), stated that color of the flesh of dairy cattle (Jersey and Guernsey) was darker than that of the beef breeds. Hammond (21) was of the opinion, although

no comparative tests were carried out, that the flesh from prime Galloway steers and heifers tended to be of a brighter red color than from many other breeds of cattle.

It is to be expected that fleshing condition, or degree of finish of the animal influences the color of flesh, especially if the fat is white and well distributed within the muscle structure. Hammond (21) quotes Leighton and Douglas (31) to the effect that animals in poor condition when slaughtered have meat that is darker in color than those in normal flesh, whereas in well-fed animals the color is lighter. This observation was confirmed by Trowbridge, Moulton and Haigh (42) with colored illustrations of meat from steers fed submaintenance, maintenance, and supermaintenance rations.

Bad nourishment and coarse food caused the flesh in veal to be dark according to Hall (19). He also observed that cattle fed on distillery slop have a soft, washy flesh with a characteristic high color. MacIntosh (33), reporting the influence of feed upon the color of beef, stated that the flesh from steers fattened on native grasses was just as bright as that from steers of similar age and degree of fatness but fed in a dry lot.

Environmental conditions were thought by Helser (23) to be a factor influencing color for he states that range cattle and wild or restless cattle, or heifers slaughtered when in heat, often "killed dark". Hammond (21), stated that wild and domesticated animals of the same species may differ in the color of their flesh. He also stated that muscles of the squirrel, the hare, the deer, and wild fowl, animals which are in continuous active movement, are dark, while the tame rabbit and the domestic fowl

have lighter colored muscle. Of the domestic animals he cited the pig as having the lightest colored meat, some muscles being almost destitute of red coloring. In contrast, the flesh of the horse, one of the very active domestic animals, was cited as the other extreme in color.

The color of beef is often said to be influenced by faulty practices during slaughter and dressing of the animals, especially when delayed or improper bleeding has occurred. Referring to a side of beef and describing the quality of the flesh, Hall (19) stated that the color of fat should be clear white and the flesh a bright rich red. A fiery carcass was defined as one, the surface of which is spotted with highly colored blood vessels, and usually accompanied by a dark colored lean. He thought these conditions of the carcass were due either to a feverish condition, fatigue from long shipment, pregnancy, or excitement at time of slaughter.

Failing to find any experimental evidence to support the conclusions made by Hall (19), Sleeter Bull (7) (8) undertook to verify them. He found that exercise did not influence the color of beef from steers that had walked the equivalent of 1,181 miles, or 8.8 miles per day at the rate of 3.1 miles per hour; that undue excitement of animals just prior to slaughter did not cause the meat to be darker in color than that from animals handled in the normal quiet manner, and that delayed bleeding - for as long as 10 minutes - had little or no more influence upon the color of meat than did kosher slaughter - bleeding without stunning.

Analysis of Color of Muscle and Fat

The color of meat optically determined is expressed as an average of all the various colors which may be found in it. The normal eye does not possess the faculty of differentiating the color rays which, when combined, form the homogeneous color observed with the eye.

Two methods have been devised for measuring the color of meat: one, in which colors of meat are matched with secondary standards having specific color notation; the other in which the stimulus of any color is specified in terms of the intensity or the reflection factor at each wave length throughout the spectrum. The method used to analyze color is determined by the manner in which the results are to be expressed.

The first method, in which the color of meat was matched with one of known color specification, was performed by using color charts. The committee appointed by the National Livestock and Meat Board (44) to outline the technique and procedure for studying quality and palatability of meat recommended two types of color charts, known as secondary standards. One was the rotating disk in which color disks were cut with a radial slit so that several could be slipped together with portions of each visible. A motor was used to spin them at a speed sufficient to produce a homogeneous color on the disk. The sample to be examined was held in juxtaposition to the spinning disk and the colors matched by ocular interpretations. Whenever possible, solar light was used for illumination. At other times a 75-watt tungsten blue-glass bulb which transmitted light comparable to solar light was used.

Three colored disks were employed with the rotating disk: 4/11 standard red; 5/6 yellow red, and black N/1. The readings were recorded in terms of percentages of the exposed area of red, yellow red, and black when the color of the spinning disks matched that of the meat.

A second chart, known as the "A" chart, was devised in the offices of the Bureau of Animal Industry and prepared from the results obtained by analyzing the color of a large number of meat samples. The color in this chart was expressed in ten gradations of red on as many celluloidan strips, each representing a color specification according to the Munsell color notation (35). Under conditions to which it is adapted it is accurate to the degree that it is considered satisfactory for indicating significant differences in color.

The second method by which the measurements of color were expressed in terms of their energy reflection factors was obtained by the use of a specially constructed piece of apparatus known as a color-analyzer. It is an automatic recording photo-electric spectrophotometer. This apparatus was designed by Joseph Razek and Peter J. Mulder at the University of Pennsylvania*. Briefly, it is an instrument equipped essentially with an illuminating unit, lenses, a movable mirror, prism, and a photographic plate holder. By a most remarkable coordination of the movable parts operated by cams and photo-electric cells it is possible, by turning a small crank, to direct a beam of light from the specimen through the prism

*Full description of the Razek-Mulder Color Analyzer is found in "Color Analysis by Photoelectric Spectrophotometry". Anderson, D. E., Unpublished thesis, Iowa State College 1932.

and obtain on a photographic plate a response of sensitivity at each wave length throughout the spectrum.

Cooking Losses and Palatability Tests

One of the most fundamental bases for evaluating quality in beef is the organoleptic test. It is a test which gives expression to the sensory responses of those characteristics desired in beef, such as aroma, flavor, savoriness, and tenderness. This test also involves size and strength of muscle fiber and percentage and character of fat and connective tissue. Obviously such a test would most likely be made only from cooked meat.

The influence of cooking upon palatability is recognized by all Home Economists and the abundant data upon this subject reported in the literature are evidence of the attention which has been given to the development of the proper technique for meat cookery.

Techniques for roasting beef which would retain the inherent qualities of the meat and minimize the shrinkage or the loss of weight during cooking were studied by Bevier and Sprague (5), Grindley and Mojonnier (16), and Sprague and Grindley (40). These investigations reported a wide variation in the losses of meat cooked by different methods and to different degrees of doneness. The first use of a thermometer inserted into the meat for indicating the degree of thoroughness with which meat was cooked is credited to Sprague and Grindley (40). Grindley and Mojonnier found that meat cooked by the roasting process retained a greater proportion of the nitrogenous and mineral substances but a smaller proportion of the fat than meat cooked in water. Later, Grindley and Emmitt (17), reporting on meat losses

due to different methods of cooking stated that "the more pronounced flavor of meats cooked by dry heat as compared with those cooked in hot water is without doubt due to the larger proportion of soluble constituents which the former contains."

Helser, Nelson, and Lowe, (22), reporting on one phase of the cooperative project "The Influence of the Animal's Age upon the Quality and Palatability of Beef," found that the average total percentage losses during cooking were 12.5, 11.4, and 10.6 percent for rib roasts from thinly fleshed calves, yearlings, and two-year-olds respectively. For roasts from fattened calves, yearlings, and two-year-olds the average total percentage losses were 12.7, 13.5, and 15.4 respectively. The character of the losses were well portrayed in this experiment when the authors reported that the thin calf had a volatile loss of 11.9 percent and the fat calf only 6.5 percent. The volatile loss in the two-year-old animals was 9.4 percent and 8.5 percent respectively.

Sleeter Bull (7) compared the cooking loss of standing rib roasts from steers and heifers and reported no significant differences in losses from calves slaughtered at different times. He further stated that finish had little or no effect upon the total loss in cooking, since loss due to evaporation decreased with more fatness while the drippings increased at about the same rate.

A systematic method for evaluating the factors relating to quality and palatability of beef was developed after the inauguration of the National Cooperative Research Project "A Study of the Factors Which Influence the Quality and Palatability of Meat." One of the factors considered

as having an influence on the quality and palatability of meat was " "Methods of Cooking". A committee on the project prepared an outline to be followed whenever a given cut of a particular kind of meat was to be cooked for palatability tests. The committee also prepared a score card for evaluating the factors relating to palatability and for recording the opinion of the judges.

MATERIALS AND METHODS

Selection and Preparation of Cattle

The study of the influence of sex upon the quality of beef extended over a period of three years and included the results of three feeding seasons. Forty-two calves were fed the first year; thirty-four the second and third years. They were of Hereford breeding, equally divided as to sex, and graded choice to select feeder calves. The calves fed during the first and third years were from the same ranch, while those fed during the second year came from a ranch in a different state. The calves in each year's experiment, however, were uniform in size and quality. The average initial weight of the calves in the first year was 395 pounds, 398 pounds for steers and 392 pounds for heifers; in the second year 390 pounds, 395 pounds for steers and 385 pounds for heifers, and in the third year 444 pounds, 450 pounds for steers and 438 pounds for heifers.

Each year the calves were sorted into two lots of steers and two lots of heifers. One lot of each sex retained the original number of animals throughout the feeding period while the other lot furnished the animals for the slaughter tests and the carcass studies. Each lot was fed separately, but all received the same type of ration, which consisted of shelled corn, hand full-fed twice daily, linseed oil meal fed on the shelled corn, alfalfa hay hand full-fed twice daily, and block salt self fed.

There was only a slight difference in the average gains between lots in any one year. When the six lots of steers were compared with the six lots of heifers it was found that the average daily gain was the same, namely, 2.18 pounds; but the steers had slightly greater variation in their average daily gains than the heifers.

Slaughter of Steers and Heifers

One steer and one heifer were slaughtered at the time the experiment was started and at intervals of 90, 120, 150, and 180 days thereafter; thus five steers and five heifers were used each year, or a total of thirty cattle in the study.

The dressing of the animals and the division of the carcasses were performed according to the recommendations of the sub-committee on slaughter as given in the revised outline on, "A Study of the Factors Which Influence the Quality and Palatability of Meat." (44)

Weights were recorded on the warm carcass and on the various parts of the offal. The carcasses were chilled in a temperature of 30° - 34° F. for 48 hours and then reweighed. The percentage of shrinkage was determined from these two weights.

Cutting of Carcasses and Physical Analyses of the Cuts

The carcasses remained in cold storage for seven days and were then divided into the standard wholesale cuts. The cuts were located, whenever possible, by measurements from certain oriented points on the carcass.

The standing rib cut from the left side of each carcass was allowed to age in storage. It was then cooked and the flesh tested for quality and palatability.

The wholesale cuts from the right side of each carcass were carefully hand separated into lean, fat, bone, and tendon to provide data for a study of the physical composition of the carcass and its standard divisions. These detailed data were recorded on fifteen steer and fifteen heifer carcasses, including wholesale cuts and their constituent parts - lean, fat, bone, and tendon.

The complete separation of the parts with a knife is obviously a physical impossibility, especially in extremely fat animals, because of the fatty infiltration through the muscle. Furthermore, the separation of muscle and tendons becomes arbitrary in some instances.

A mechanical tenderness test, using a meat-shearing dynamometer, was made on a section of the longissimus dorsi muscle removed dorsal to the twelfth rib. The dynamometer recorded in pounds the pressure required to shear a sample of meat one inch in diameter. Three shearing samples of this muscle were taken, - one near the transverse process of the vertebra, one in the middle of the muscle, and one near the lateral edge. Each sample was cut three times with the dynamometer except from the animals initially slaughtered. The aponeurosis which invaded the muscle was avoided in sampling whenever possible, since it caused a substantial increase in the pressure required to shear the sample.

Intracellular Fat Content, Size of Fiber and Connective Tissue in Bovine Muscle

Immediately after the dressing of the animals a section of the longissimus dorsi muscle, dorsal to the fourth lumbar vertebra, was removed and prepared for three histological studies. Areas near the center of the muscle and containing a minimum of intercellular fat deposits were used.

Liposome deposits

One of the purposes of the histological study was to determine, if possible, the difference between steers and heifers, slaughtered at varied levels of obesity, with regard to the size and abundance of liposomes within the muscle fibers. Without previous fixing, small cubes of fresh muscle were frozen and sectioned with a microtome. The sections were stained in Herxheimer's Scharlach R solution to show the location of the intracellular and the extracellular fat droplets.*

The staining solution was prepared by dissolving 2 grams of NaOH in 100 cc. of 70 percent alcohol. Two grams of the dye were dissolved in the alkaline solution and then filtered through paper into a container. The container was then closed in order to prevent evaporation which might result in crystallization on the stained section. The stain was much more reliable when prepared from stock ingredients immediately before using. The freshly prepared stain was filtered into a glass bottle from which it was drawn into small staining vessels as needed.

*The fat droplets (liposomes) in muscle fibers are shown as round black spots in microscopic plates, pages 74 to 82 inclusive.

Small blocks of tissue (about 10 mm. cubes) were prepared in such a manner that longitudinal and cross sections of the fibers could be made with a microtome. These blocks were then oriented on the freezing microtome and supported by a gum arabic solution. This kind of supporting substance was preferred to others because its consistency, when frozen, was similar to that of muscle and was easily cut with the tissue. The frozen blocks were sectioned with a very thin safety razor blade held by an attachment on a hand operated slide-rail microtome. The sections, measuring 10-15 microns in thickness, were transferred, as they were cut, to distilled water. When removed from the water with a fine wire gauze dipper they were carried through the staining procedure in the following sequence:

70% alcohol	1 minute
Stain	2 minutes
70% alcohol	2 - 3 seconds for rinse
Water	2 - 3 seconds for rinse

Mounted on the glass slide.

The stained section was mounted on the glass slide in Farrant's fluid and the cover glass placed over the tissue.

Microscopic studies of the sections were made as they were prepared. This was found to be very important, as only a very slight evaporation of the staining solution caused crystallization of the dye which produced a translucent effect upon the specimens.

Microscopic photographs of the sections were made as a means of preserving a record of the findings, since no fixatives were used in prepar-

ing the specimens.

Photographs were made by substituting an ordinary 3½ x 5 Graphlex camera for the eye-piece on the microscope. The field was focused on the plate of the camera. The time of exposure was determined by the visibility of the field, the magnification, and by previous experience. Two magnifications were used: 800 dia. exposed 12 - 20 seconds, and 200 dia. 4 - 8 seconds. Many excellent specimens were not illustrated by photo-micrographs because of the precipitated dye on the tissue or because the thickness of the section hindered the reproduction of details observed in the section. Only a few of the details in a specimen and none of the smaller less refractive liposomes were reproduced in the photo-micrograph of the thick sections.

Color Determinations of Steer and Heifer Beef

Color determinations were made on a cross section of the longissimus dorsi muscle between the twelfth and thirteenth ribs after the carcasses had remained in cold storage for seven days.

Three different instruments were employed to determine color of beef, - the "A" chart, the rotating color disks, and the Razek-Mulder color analyzer. The "A" chart and the rotating disk were used to determine the color of the freshly cut muscle and the same surface after exposure for 30 minutes to daylight and room temperature (70° - 75° F.). The color analyzer was employed to determine the color of beef after the surface was exposed 30 minutes.

Samples of beef to be analyzed by the color analyzer were prepared

by placing a full cross section cut of the longissimus dorsi muscle, dorsal to the twelfth rib, between two pieces of sodium-free glass. This particular type of glass was necessary since it yielded a minimal spectral response; consequently it did not interfere with the color response being recorded from the meat. The glass also served to protect the cut surface from loss of moisture and to retard the change in color of the meat caused by oxidation of the muscle substance. Each sample of muscle was allowed to "brighten" for 30 minutes; then it was placed between two pieces of glass and the color analysis recorded in terms of energy reflection factors on a photographic film especially made for such recordings.

The method of measuring color with the rotating disks and the "A" chart was essentially one of matching the color of the meat with a color standard having a specific color notation. The color readings were then interpreted in terms of their color attributes, namely, hue, brilliance or value, and chroma.

Rotating disks consisting of three circular dials of standard colors, red, black, and yellow, were arranged on a spindle to expose segments of the colors in different amounts. When the color disks were properly adjusted and rotated, the surface appeared as a homogenous color to match that of the meat. The proportion of the exposed segments of the colored disks constituted the color readings.

The colors used in all of the colorimetric readings from the rotating color disks were of the Munsell Notation (35), and results of color determinations were recorded as percentage areas of the colors exposed. Since only three colors, black N/1, red 4/11, and yellow-red 5/6 were

used, the sum of their areas on the rotating disk equaled 100 percent.

The "A" chart, known as the beef color standard, was prepared from the disk readings of a considerable number of samples of mature beef. It consists of ten plates, each with a color notation. The colors ranged from a very light red (No. 1) to an intensely dark red (No. 10). While these do not include every slight deviation of color, the notations are satisfactory for significant differences in color under the conditions to which they are adapted.

The formula for calculating hue, brilliance, and chroma was developed by Nickerson in the office of the Bureau of Agricultural Economics for determining the color of certain agricultural products such as cotton and hay. Since beef color comes within the limitations prescribed for agricultural products, the same formulae were also used in converting the percentage of exposed areas of the colors into terms of hue, brilliance, and chroma.

The colors were recorded by the Color Analyzer on photographic plates in the form of a curve. The curve near the top of the plate shows the response obtained from the standard white, while the lower is the curve of color response for the sample analyzed. The ratio of response of the sample to that of the standard white is the energy reflection factor. From these two curves, then, it is possible to determine the reflection factor of the sample at any wave length as a ratio to that of the standard. It was assumed that the standard white gave a perfect reflection at all wave lengths and that exactly the same amount of light fell upon the sample as upon the standard at each wave length. On the basis of this

hypothesis the reflection factors were calculated, using values obtained at every 25-millimicron intervals between 400 and 700 millimicrons.

Cooking Methods and Palatability Tests

All cooking and palatability tests were made from the standing rib cut and were carried out in the experimental kitchen of the Foods and Nutrition department of Home Economics under the personal supervision of Miss Belle Lowe. The equipment and the method for cooking the beef roasts were recommended by the Sub-Committee on Cooking of the National Cooperative Project on Meat Investigations (44).

Equipment

Ovens were equipped with glass doors and Lorain temperature controls. The temperature of each oven was further checked by a thermometer graduated in two degree intervals but accurately readable to one degree intervals through the glass doors of the ovens. Roasts were cooked in ordinary open black, sheet iron pans.

Preparation of the meat

Two roasts were taken from one side of each beef carcass; the first, consisting of the ninth, tenth, and eleventh ribs, was cooked after aging ten days; the second, consisting of the sixth, seventh, and eighth ribs, was cooked after aging thirty days.

The roasts were wiped with a damp cloth, and a thermometer was inserted so that the bulb was in the center of the longissimus dorsi muscle

end, as nearly as could be estimated, equidistant from each surface of the roast.

The roasts were seared for 20 minutes at a temperature of approximately 260° C. in an oven that had been preheated to 275° C. then removed to another oven, the temperature of which was 125° C. They were cooked until the interior temperature of each roast reached 57° C. Each roast was weighed before and after cooking to determine the volatile and dripping losses.

Sampling for palatability tests

The cooked roasts were carved and samples served to each member of a committee who judged and evaluated the palatability of the meat according to the cooked meat grading chart. See page 106. Each member received samples that were anatomically comparable.

The judging committee consisted of six members; three from the Foods and Nutrition Department, two from the Animal Husbandry Department, and one from the Veterinary Anatomy Department. All members of the committee had previous experience in judging meat and possessed discriminating tastes with regard to the various characteristics of meat.

RESULTS

There were variations in initial and final weights of steers and heifers, in the yield of wholesale cuts, in the yield of primal cuts, and in the lean, fat, and bone obtained from carcasses of animals slaughtered at different ages and degrees of fatness. These variations were considered in comparing steers and heifers, and, whenever possible, information concerning two or more of these variables was used to interpret sex differences. This was accomplished by the method of analysis of variance and of covariance (39).

Initial and Final Weights of Slaughter Cattle

The initial and final weights of the thirty cattle which were slaughtered for the study are shown by years in table I.

It is seen from the data that there were variations in initial and final weights of the steers and heifers. Comparing sexes as to final weight by the method of analysis of variance, table Ia*, it was found that they did not differ significantly. In the first two years the steers were slightly heavier than the heifers while in the third year the reverse was true. Since the steers and heifers differed in initial weight, the final weight was adjusted by covariance for initial weight. With the adjustment,

*The total variation with nine degrees of freedom and the variation between dates of slaughter with four degrees of freedom were purposely omitted from the table since information contained in these two variates did not have a direct bearing on this study.

the differences in final weight were still not significant in any one of the three years. From this it was concluded that the differences in final weight were explained by differences in initial weight and were not due to differences in gains made by the cattle while on feed. Weights recorded monthly while the cattle were on feed indicated that the steers and heifers made approximately the same rate of gain.

The empty body weights obtained by deducting the weight of the alimentary content from the final weight of the cattle are included in table I. When the alimentary content was removed from the body the differences between sexes in the empty body weights were materially reduced in the first two years but increased in the third year. Although the results as shown in table Ib indicated that the steers had the greater fill irrespective of weight, the differences between sex in any one year were not statistically significant.

The sex differences between weights of carcasses were also less than those between weights of live animals during the first two years and greater in the third year. It was brought out by analysis of covariance of carcass yield on live weights, table Ic, that although the heifers were lighter weight than the steers in the first two years and heavier in the third year the differences between weights of carcasses in steers and heifers were not due to sex but to differences between live weights of animals slaughtered.

TABLE I

Weights of Cattle Slaughtered for Physical and Organoleptic Tests

Days	Initial Weights		Final Weights		Empty Body Weights		Carcass Weights	
	Steers	Heifers	Steers	Heifers	Steers	Heifers	Steers	Heifers
				First Year				
0	360	335	360	335	279	260	184	167
90	393	350	625	555	516	454	362	313
120	421	387	695	700	569	593	393	404
150	418	371	795	770	668	638	448	439
180	505	430	905	880	747	769	529	545
Sums	2097	1873	3380	3240	2779	2714	1916	1868
				Second Year				
0	346	286	346	286	258	217	173	142
90	370	380	530	515	425	425	290	296
120	427	439	660	660	529	542	368	382
150	392	343	750	668	590	537	407	369
180	417	363	868	735	715	638	496	449
Sums	1952	1811	3154	2864	2517	2359	1734	1638
				Third Year				
0	376	405	376	405	286	322	177	226
90	455	450	592	635	478	529	326	364
120	452	436	710	680	573	552	402	384
150	463	470	825	785	659	651	454	464
180	456	482	815	840	728	739	516	537
Sums	2202	2243	3318	3345	2724	2793	1875	1975

TABLE Ia

Test of Significance of Sex Difference in Final Weight of Steers and Heifers, Adjusted for Variation in Initial Weight

Source of variation	D/F	Initial weight Sx^2	Cross products Sxy	Final weight Sy^2	Errors of Estimate: Sum squares	D/F	Mean squares
			First Year				
Total	5	6332.0	3257.5	3400.0	1724.18	(4)	
Between sex	1	5017.6	3136.0	1960.0			
Sex x date	4	1314.4	121.5	1440.0	1428.77	(3)	476.25
					295.41	(1)	295.41
			F = 1.61				
			Second Year				
Total	5	4580.5	7325.0	14119.0	2405.08	(4)	
Sex	1	1988.1	4089.0	8410.0			
Sex x date	4	2592.4	3236.0	5709.0	1669.62	(3)	556.54
					735.46	(1)	735.46
			F = 1.32				
			Third Year				
Total	5	923.5	738.0	3907.5	3317.74	(4)	
Between sex	1	168.1	110.7	72.9			
Sex x date	4	755.4	627.3	2834.6	2313.68	(3)	771.23
					1004.04	(1)	1004.04
			F = 1.30				

TABLE Ib

Test of Significance of Sex Difference in Empty Body Weight from Steers and Heifers, Adjusted for Variation in Full Body Weight

Source of variation	D/F	Full body weight Sx^2	Cross products Sxy	Empty body weight Sy^2	Errors of Estimate: Sum squares	D/F	Mean squares
			First Year				
Total	5	3400	2587.00	3058.62	1090.22	(4)	
Between sex	1	1960	915.94	418.74			
Sex x date	4	1440	1671.06	2639.88	700.68	(3)	233.56
					389.54	(1)	389.54
			F = 1.6678				
			Second Year				
Total	5	14119	8560.17	5334.55	144.53	(4)	
Between sex	1	8410	4596.75	2512.54			
Sex x date	4	5709	3963.42	2822.01	70.42	(3)	23.47
					74.11	(1)	74.11
			F = 3.1575				
			Third Year				
Total	5	2907.5	2251.69	2294.16	507.89	(4)	
Between sex	1	72.9	181.27	470.87			
Sex x date	4	2834.6	2066.42	1823.29	316.87	(3)	105.62
					191.02	(1)	191.02
			F = 1.3086				

TABLE Ic

Test of Significance of Sex Difference in Carcass Weight of Steers and Heifers, Adjusted for Final Live Weight

Source of variation	D/F	Final weight Sx^2	Cross products Sxy	Carcass weight Sy^2	Errors of Estimate: Sum of squares	D/F	Mean squares
			First Year				
Total	5	3400	1567	1574.0	851.81	(4)	
Between sex	1	1960	672	230.4			
Error	4	1440	895	1343.6	787.33	(3)	262.44
					64.48	(1)	64.48
			F = 4.07				
			Second Year				
Total	5	14119	5568	2423.0	227.19	(4)	
Between sex	1	8410	2783	921.6			
Error	4	5709	2785	1501.4	142.80	(3)	47.60
					84.39	(1)	84.39
			F = 1.77				
			Third Year				
Total	5	3907.5	1810.0	2655.0	1583.14	(4)	
Between sex	1	72.9	270.0	1000.0			
Error	4	2834.6	1540.0	1655.0	818.34	(3)	272.78
					764.80	(1)	764.80
			F = 2.80				

Dressing Percentages of Steers and Heifers

The ratio of carcass weight to live weight, commonly expressed as dressing yield, is always one of the major factors in evaluating slaughter animals. It is influenced by alimentary content, or fill, and the quantity of internal fats, i. e. the omental and the intestinal fats.

The differences in dressing yields between steers and heifers based on full body weights and on empty body weights are shown in table II.

TABLE II

Average Carcass Weight and Yield from Full and Empty Body Weights of Cattle

Days on feed		Full body weight	Empty body weight	Chilled carcass weight	Percentage of Carcass: Full body weight	Percentage of Carcass: Empty body weight
0	S	361	274.5	178	49.44	64.85
	H	342	266.8	178	51.76	66.72
90		583	473.1	326	55.89	68.92
		568	469.5	324	57.07	69.01
120		686	557.0	388	56.31	70.10
		680	562.3	390	57.35	69.36
150		790	639.0	436	55.22	68.28
		741	608.7	424	57.12	69.66
180		863	730.0	514	59.63	70.36
		818	715.3	510	62.32	71.34

S - Steers
H - Heifers

Carcass yield from full body weights

The percentage of carcass to live weight of the steers and heifers at the 0 day period of feeding was 49.44 and 51.76 respectively; at the end of 180 days of feeding it was 59.63 and 62.32 respectively. At the 0 day period the heifers had 2.32 percent greater yield of carcass to live weight than steers, and at 180 days the heifers had 2.69 percent greater yield than steers.

The differences in dressing percentage between steers and heifers at the end of the 120, 150, and 180 day feeding periods appeared to be rather large, table III. Comparing the sexes as to carcass yield by the method of analysis of variance, table IIIa, it was found that they did not differ significantly.

Carcass yield from empty body weights

When the yield was calculated from the empty body weights of steers and heifers, table II, the percentage of carcass at the 0 day period was 64.85 and 66.72; at the 180 day period it was 70.36 and 71.34 respectively. Obviously the dressing percentage would be greatly increased due to the elimination of the alimentary content of the live animals. However, by this method of determining carcass yield, it is possible to account for much of the difference between the full body weights of the steers and heifers.

TABLE III

Percentage of Carcass to Liveweight of Cattle Slaughtered at the 120, 150 and 180 Day Feeding Periods

Days on feed	120		150		180	
Year	Steers	Heifers	Steers	Heifers	Steers	Heifers
1	56.54	57.71	56.35	57.01	58.45	61.93
2	55.76	57.88	54.27	55.24	57.14	61.09
3	56.62	56.47	55.03	59.11	63.31	63.93
Sums	168.92	172.06	165.65	171.36	178.90	186.95
Means	56.31	57.35	55.22	57.12	59.63	62.32

TABLE IIIa

Analysis of Variance in Carcass Yields between Steers and Heifers after 120, 150, 180 Days on Feed

Source of variation	D/F	Mean Squares		
		120 Days	150 days	180 days
Total	5	.6559	3.0388	8.4603
Between sex	1	1.6433	5.8410	8.1337
Between years	2	.1683	3.0865	11.0719
Sex x years	2	.6498	1.5921	6.0119
		F = 2.53	3.67	1.35

Variation in internal fats

Comparing the yields of internal fat from heifers with those from steers, table IV, it was found that during the first 90 days on feed heifers had very little more than steers, but after this period they had markedly more internal fat than steers.

TABLE IV

Internal Fats of Steers and Heifers Expressed as Percentages of Live Weight

Days	Live weight	Omentum	Intestinal fat	Miscellaneous	Total
0	* 361	.399	.401	.363	1.163
0	⊥ 342	.485	.513	.349	1.347
90	582	.791	.726	.679	2.196
90	568	1.233	.580	.721	2.533
120	688	.987	.602	.741	2.330
120	680	1.694	.729	1.108	3.531
150	790	1.377	1.083	1.168	3.628
150	741	1.698	1.158	1.503	4.359
180	863	1.668	1.163	1.082	3.913
180	818	2.082	1.611	1.470	5.163

* Steer
⊥ Heifer

When the quantity of internal fats was compared with weights of animals, the differences between steers and heifers up to 600 pounds live weight were negligible. Beyond this weight the internal fats of heifers increased more rapidly than those of steers. In the 600-700 pound cattle the proportion of internal fat to live weight in heifers

exceeded that of steers by 1.20 percent; 700-800 pound cattle, 0.73 percent; and 800-900 pound cattle, 1.25 percent. However, the greater quantity of visceral fat in heifers over that of steers was not of sufficient magnitude to reduce the dressing yields as much as did the greater fill carried by the steers.

Variation in Yields of Wholesale Cuts

The carcasses were divided into standard wholesale cuts according to the method outlined under Procedure and the weights of the wholesale cuts and the ratio of their weights to that of the chilled carcasses are given in tables V and VI.

TABLE V

THE PERCENTAGE OF WHOLESALE CUTS TO CARCASS WEIGHTS

Steers

Days fed	No.	Live weight lbs.	Carcass weight lbs.	Fore qtr. %	Chuck %	Shank %	Navel %	Brisket %	Prime ribs %	Hind qtr. %	Round %	Rump %	Loin %	Flank %	Kidney knob %
0	2	360	184	50.53	25.70	6.00	5.92	4.89	8.02	49.40	24.08	5.45	16.40	2.35	1.12
0	11	346	173	49.39	25.29	6.11	5.09	4.42	8.00	50.06	22.82	6.11	16.80	2.62	1.37
0	21	376	177	50.65	24.94	6.78	6.55	4.21	8.16	49.35	23.70	5.03	15.45	3.22	1.67
Av.		361	178	50.19	25.31	6.30	5.85	4.51	8.06	49.60	23.53	5.53	16.22	2.73	1.39
90	3	625	362	50.92	25.42	5.41	6.91	4.70	8.48	49.18	21.80	4.84	17.96	2.92	1.56
90	13	530	290	50.73	24.33	5.56	6.34	4.79	9.30	48.94	21.55	5.35	16.55	3.56	1.69
90	23	592	326	51.23	25.15	5.06	6.98	5.29	8.75	48.77	20.25	5.06	16.63	3.76	2.70
Av.		582	326	50.96	24.97	5.38	6.74	4.93	8.84	48.96	21.20	5.08	17.05	3.41	1.98
120	5	695	393	50.90	23.96	4.96	7.99	5.57	8.42	49.05	20.95	4.50	18.08	3.46	2.06
120	15	660	368	49.74	22.56	5.77	6.69	5.15	9.00	50.14	19.62	5.21	17.88	4.29	2.67
120	25	710	402	50.78	24.08	4.85	7.44	5.54	8.86	49.22	19.33	5.57	16.00	3.77	4.00
Av.		688	388	50.47	23.53	5.19	7.37	5.42	8.76	49.47	19.97	5.09	17.32	3.84	2.91
150	7	795	448	51.03	23.62	4.76	7.85	5.57	9.23	48.97	20.53	4.24	18.35	3.50	2.35
150	17	750	407	51.70	25.23	5.25	6.41	5.29	9.02	48.07	20.52	4.74	16.95	3.58	1.97
150	27	825	454	51.24	23.55	5.16	7.71	6.06	8.76	48.76	19.03	4.94	17.04	4.18	3.00
Av.		790	436	51.32	24.13	5.06	7.32	5.84	9.00	48.60	20.03	4.64	17.45	3.75	2.44
180	9	905	529	51.68	23.07	4.98	8.85	6.04	8.74	48.27	17.31	5.71	16.93	5.66	2.66
180	19	868	496	50.77	24.28	5.01	6.48	5.62	9.11	49.18	19.26	4.74	17.12	4.20	3.51
180	29	815	516	52.24	23.68	4.96	7.78	6.42	9.40	47.76	16.73	5.30	17.03	4.96	3.16
Av.		863	514	51.56	23.68	4.98	7.70	6.03	9.08	48.40	17.77	5.25	17.03	4.94	3.11

TABLE VI

THE PERCENTAGE OF WHOLESALE CUTS TO CARCASS WEIGHTS

Heifers

Days fed	No.	Live weight lbs.	Carcass weight lbs.	Fore qtr. %	Chuck %	Shank %	Navel %	Brisket %	Prime ribs %	Hind qtr. %	Round %	Rump %	Loin %	Flank %	Kidney knob %
0	1	335	167	50.26	26.32	5.45	5.66	4.54	8.29	49.74	22.81	5.72	17.10	2.39	1.72
0	12	286	142	49.29	25.14	6.36	4.82	4.36	8.18	50.15	23.75	5.43	16.93	2.79	.96
0	22	405	226	49.27	24.82	5.20	5.86	4.36	9.03	50.71	22.90	5.13	17.76	2.59	2.00
Av.		342	178	49.61	25.43	5.67	5.45	4.42	8.50	50.20	23.15	5.43	17.26	2.59	1.56
90	4	555	313	49.78	24.31	4.87	7.06	5.12	8.42	50.06	20.87	4.95	17.90	4.37	1.97
90	14	515	296	50.54	24.78	5.10	6.57	4.69	8.95	49.44	20.80	5.62	17.80	3.35	1.63
90	24	635	364	49.73	23.94	4.60	7.11	5.70	8.38	50.27	19.07	5.53	16.97	5.01	3.35
Av.		568	324	50.02	24.34	4.86	6.91	5.27	8.58	49.92	20.25	5.37	17.56	4.24	2.32
120	6	700	404	49.32	22.17	4.37	7.92	5.98	8.88	50.66	19.67	5.20	17.39	4.95	3.45
120	16	660	382	50.26	23.71	4.27	7.19	5.64	8.97	49.47	17.27	5.23	17.61	4.59	4.40
120	26	680	384	49.57	23.46	4.37	7.49	5.43	8.82	50.43	17.23	6.10	16.57	5.83	3.89
Av.		680	390	49.72	23.15	4.34	7.53	5.68	8.89	50.19	18.06	5.51	17.19	5.12	3.91
150	8	770	439	49.65	23.03	3.48	8.70	5.45	8.99	50.18	17.00	4.99	18.79	4.87	4.53
150	18	668	369	50.76	24.15	5.01	7.36	5.30	8.42	49.10	18.69	5.10	17.47	4.73	2.70
150	28	785	464	50.27	23.19	4.57	7.85	5.96	8.70	49.73	18.82	5.34	17.50	4.96	2.50
Av.		741	424	50.23	23.46	4.35	7.97	5.57	8.70	49.67	18.17	5.14	17.92	4.85	3.24
180	10	880	545	50.09	22.02	4.56	7.91	6.80	8.80	49.90	16.71	5.03	18.06	5.82	4.28
180	20	735	449	49.51	22.36	3.82	8.06	5.81	8.96	50.33	16.31	4.94	17.73	5.92	5.00
180	30	840	537	51.44	23.05	4.24	8.61	6.60	8.94	48.56	16.30	5.35	17.64	5.12	3.54
Av.		818	510	50.35	22.48	4.21	8.19	6.40	8.90	49.59	16.44	5.11	17.81	5.62	4.27

A comparison of ratios between years, within years, and between sexes was made of the cuts that increased the value of the carcass as well as of those that depreciated it.

The ratio of forequarter to carcass increased as the steers became older and fatter. However, the various parts of the forequarter did not develop at the same rate. The most rapid development occurred in the plate; the ratio increased 3 percent while that of the standing rib increased 1 percent between the 0 day and 180 day period. The weight of the chuck was decreased from 25.31 to 23.68 percent of the carcass during the same period, while the shank was decreased from 6.00 to 4.98 percent.

The most important change in relationship between wholesale cuts and weight of carcass during the entire feeding period occurred in the round. The proportion of this cut to carcass was reduced from 23.53 to 17.77 percent. Two cuts of low value - the flank and kidney knob - increased their ratios by approximately 2 percent each. The ratio of the loin increased less than 1 percent.

In heifers the proportion of forequarter to carcass was approximately the same, irrespective of carcass weights or of degrees of fatness. The proportion of chuck was reduced nearly 3 percent; the shank nearly $1\frac{1}{2}$, while the plate increased about 4 3/4 percent. The ratio of the standing rib was practically unchanged by weight or fatness of the animal.

The percentage of round decreased from 23.15 to 16.40; the ratio of the flank and kidney knob together increased 5.73 percent, while that of the loin and rump increased approximately $\frac{1}{2}$ percent each.

In order to show more clearly the differences in carcasses between

slaughter dates and between sexes, the cutting data were summarized and the mean percentage yield of each wholesale cut reported in table VII. A comparison of the different cuts from carcasses of steers with those of heifers shows that the proportion of forequarter to carcass was greater in steers at each date of slaughter, also the ratio of chuck and of the round was greater. There were no significant differences between sexes in the standing rib cut, the loin, or the plate during the 180 day period. However, the ratio of the plate to total carcass increased faster in heifers than in steers.

TABLE VII

THE AVERAGE PERCENTAGE OF WHOLESALE CUTS TO CARCASS WEIGHTS FROM STEERS AND HEIFERS FED A DIFFERENT NUMBER OF DAYS

Days fed	Sex	Fore qtr.	Chuck	Shank	Plate	Ribs	Hind qtr.=	Round	Rump	Loin	Flank	Kidney knob
0	S*	50.19	25.31	6.30	10.36	8.06	49.60	23.53	5.53	16.22	2.73	1.39
	H+	49.61	25.43	5.67	9.87	8.50	50.20	23.15	5.43	17.26	2.59	1.56
90	S	50.96	24.97	5.38	11.67	8.84	48.96	21.20	5.08	17.05	3.41	1.98
	H	50.02	24.34	4.86	12.18	8.58	49.92	20.25	5.37	17.56	4.24	2.32
120	S	50.47	23.53	5.19	12.79	8.76	49.47	19.97	5.09	17.32	3.84	2.91
	H	49.72	23.15	4.34	13.21	8.89	50.19	18.06	5.51	17.19	5.12	3.91
150	S	51.32	24.13	5.06	13.16	9.00	48.96	20.03	4.64	17.45	3.75	2.44
	H	50.23	23.46	4.35	13.54	8.70	49.67	18.17	5.14	17.92	4.85	3.24
180	S	51.56	23.68	4.98	13.73	9.08	48.40	17.77	5.25	17.03	4.94	3.11
	H	50.35	22.48	4.21	14.59	8.90	49.59	16.44	5.11	17.81	5.62	4.27
Av.	S	50.90	24.32	5.38	12.34	8.75	49.80	20.50	5.12	17.01	3.73	2.37
	H	49.99	23.77	4.69	12.68	8.71	49.91	19.21	5.31	17.55	4.48	3.06

*Steer
+Heifer
=Hanging tender not included

The primal cuts of a carcass are the loin, rib, round, and chuck. The ratios of the combined weights of these cuts to the carcass weights from steers and from heifers fed a different number of days are shown in table VIII. The average yield of the primal cuts at the 0 day period was

TABLE VIII

The Percentage of Primal Cuts to Carcass Weights from Steers and Heifers Fed a Different Number of Days

Days	Percentages								
	1st. Year		2nd. Year		3rd. Year		Means		
	Steer	Heifer	Steer	Heifer	Steer	Heifer	Steer	Heifer	Difference Str.-Hfr.
0	74.20	74.52	72.91	74.00	72.25	74.51	73.12	74.34	-1.22
90	73.66	71.50	71.73	72.33	70.78	68.36	72.06	70.73	1.33
120	71.41	68.11	69.06	67.56	68.27	66.08	69.58	67.29	2.29
150	71.73	67.81	71.72	68.73	68.38	68.21	70.61	68.25	2.36
180	66.05	65.59	69.77	65.36	66.84	65.93	67.55	65.63	1.92

73.12 percent for steers and 74.34 percent for heifers. After the animals had been on feed for 180 days the average yield in primal cuts was 67.55 percent for steers and 65.63 percent for heifers. The period showing the most rapid decrease in yield for the steers was between 150 and 180 days, while the heifers showed their greatest decline between 0 and 90 days. Except for the first period the steers excelled the heifers in yield of primal cuts, but as shown in table VIIIa the difference was not statistically significant.

TABLE VIIIa

Test of Significance of Sex Differences in Primal Cuts from Steers and Heifers, adjusted for Variation in Final Body Weights

Source of variation	D/F	Final cattle weight Sx^2	Cross products Sxy	Primal cuts Sy^2	Errors of Estimate: Sum of squares	D/F	Mean squares
			First Year				
Within dates and sex	5	3400	1697.00	1134.98	287.98	(4)	
Between sex	1	1960	824.60	346.92			
Sex x date	4	1440	872.40	787.96	259.96	(3)	86.47
					28.56	(1)	28.56
			F = 3.028				
			Second Year				
Within dates and sex	5	14119	5272.10	2030.94	62.31	(4)	
Between sex	1	8410	2749.20	898.70			
Sex x date	4	5709	2522.90	1132.24	17.33	(3)	5.78
					44.98	(1)	44.98
			F = 7.786				
			Third Year				
Within dates and sex	5	2907.5	291.15	1002.69	981.00	(4)	
Between sex	1	72.9	112.32	173.06			
Sex x date	4	2834.6	178.83	829.63	821.20	(3)	273.73
					159.80	(1)	159.80
			F = 1.713				

The principal differences between sexes in percentages of primal cuts were in the greater yield of rounds and chucks and in the smaller yield of loins from steers than from heifers. These differences also were not of sufficient magnitude to be statistically significant.

Variation in Physical Composition of Carcasses

A physical analysis was made of the wholesale cuts in which the pieces were separated into their constituent parts of lean, fat, bone, and tendon, and recordings were made of each tissue as an aliquot part of the carcass. The percentages of lean, fat, and bone in the entire side of carcass for each of the fifteen steers and fifteen heifers are shown in table IX. The physical analyses were summarized by determining the average percentage of lean, fat, bone, and tendon from steers and heifers at each of the five slaughter dates. These data are given in table X.

TABLE IX

THE PERCENTAGE OF LEAN, FAT, AND BONE TO CARCASS WEIGHTS IN STEERS AND HEIFERS OF VARIOUS AGES AND DEGREES OF FATNESS

Days on Feed	Steer Live weight lbs.	Steer Carcass weight chilled lbs.	Steer Tissue Lean %	Steer Tissue Fat %	Steer Tissue Bone %	Steer Tissue Tendon %	Heifer Live weight lbs.	Heifer Carcass weight chilled lbs.	Heifer Tissue Lean %	Heifer Tissue Fat %	Heifer Tissue Bone %	Heifer Tissue Tendon %
0	360	184	62.04	13.24	23.37	1.35	335	167	61.60	13.00	24.04	1.36
0	346	173	62.55	14.79	20.99	1.67	286	142	62.42	15.21	20.78	1.59
0	376	177	59.63	17.80	20.22	2.30	405	226	60.69	18.96	17.96	2.39
Av.	361	178	61.41	15.27	21.53	1.77	342	178	61.57	15.72	20.93	1.78
90	625	362	63.67	15.05	19.80	1.48	555	313	60.77	19.34	18.26	1.63
90	530	290	59.75	21.62	17.21	1.42	515	296	59.56	21.89	17.46	1.09
90	592	326	59.64	19.67	16.98	3.71	635	364	55.00	27.00	14.61	3.36
Av.	582	326	61.02	18.78	17.99	2.20	568	324	58.44	22.74	16.78	2.03
120	695	393	60.78	23.01	14.80	1.41	700	404	54.94	29.78	13.97	1.31
120	660	367	56.17	26.45	15.50	1.88	660	382	50.27	35.20	13.03	1.50
120	710	402	56.33	27.58	13.81	2.28	680	384	50.12	33.97	13.67	2.24
Av.	688	387	57.76	25.68	14.70	1.86	680	390	51.77	32.98	13.56	1.68
150	795	448	55.00	27.61	15.27	1.22	770	439	48.67	38.42	12.20	.71
150	750	407	57.71	24.84	15.35	2.10	668	369	55.61	28.41	13.74	2.24
150	825	454	56.70	26.77	14.38	2.15	785	464	53.95	30.46	13.87	1.72
Av.	790	436	56.49	26.41	15.00	1.82	741	424	52.74	32.43	13.27	1.55
180	905	529	49.81	36.65	12.67	.87	880	545	45.28	42.87	11.06	.79
180	868	496	54.31	30.14	14.02	1.53	735	449	50.00	37.73	10.94	1.33
180	815	516	53.24	32.17	12.68	1.91	840	537	50.55	35.13	12.45	1.87
Av.	863	514	52.45	32.98	13.12	1.43	818	510	48.61	38.58	11.48	1.33

The percentage of lean was high and that of fat very low in the carcasses from the so-called "thinly fleshed" animals slaughtered at the 0 day period. Little or no difference between sexes in the distribution of lean, fat, and bone in the carcasses was noted in these young animals;

TABLE X

Average Yield of Skeletal Tissues from Steers and Heifers
(Entire Carcass)

Days on feed	Animal	Lean %	Fat %	Bone %	Tendon %
0	Steer	61.41	15.27	21.53	1.77
0	Heifer	61.57	15.72	20.93	1.78
90	Steer	61.02	18.78	17.99	2.20
90	Heifer	58.44	22.74	16.78	2.03
120	Steer	57.76	25.68	14.70	1.86
120	Heifer	51.77	32.98	13.56	1.68
150	Steer	56.74	26.41	15.00	1.82
150	Heifer	52.74	32.43	13.27	1.55
180	Steer	52.45	32.98	13.12	1.43
180	Heifer	48.61	38.58	11.48	1.33

but as they became fatter, rapid changes in the relationship of these constituents to the carcass developed within the sexes as well as between them.

The proportion of lean tissues to carcass in steers decreased from 61.41 to 52.45 percent, while that in heifers decreased from 61.57 to 48.61 percent in the period of 180 days. The percentage of lean in the carcasses from steers was reduced approximately one-seventh, while that

from heifers was reduced about one-fifth. The negative change in lean content naturally was accompanied by a very rapid positive change in the fat content of the carcasses of the two sexes. The fat in steer carcasses increased from 15.27 to 32.98 percent, and that of the heifers from 15.72 to 38.58 percent during the 180 days that the cattle were on feed.

The most rapid accumulations of fat for both sexes occurred between 90 and 120 days as shown in Figure I. During this period the fat in steers increased from 18.78 to 25.68 percent and that in heifers from 22.74 to 32.98 percent. Stated otherwise, the ratio of lean, fat, and bone to carcass weight at 150 days was approximately the same as that at 120 days, although the steers were heavier by 102 pounds and the heifers by 61 pounds than those slaughtered at 120 days.

Between the 150th and 180th day the average percentage of carcass fat in steers increased from 24.61 to 32.98, while that in heifers increased from 32.43 to 38.58, table XI. The average weight of the animals increased 78 pounds and 86 pounds respectively. Compared with the 90 - 120 day period the steers showed a slight increase in rate of fattening, while heifers showed a substantial decrease. It should be remembered, however, that the fat determined in the carcass analyses included only that found in the larger fat depots. There was a marked increase in the amount of fat deposited between fibers of muscular tissue during the period between 150 days and 180 days. This was not separated from the lean for the reason previously mentioned, but if the intramuscular fat could have been included with that found in the larger fat depots the total fat accumulations undoubtedly would have been much greater than those indicated in the data.

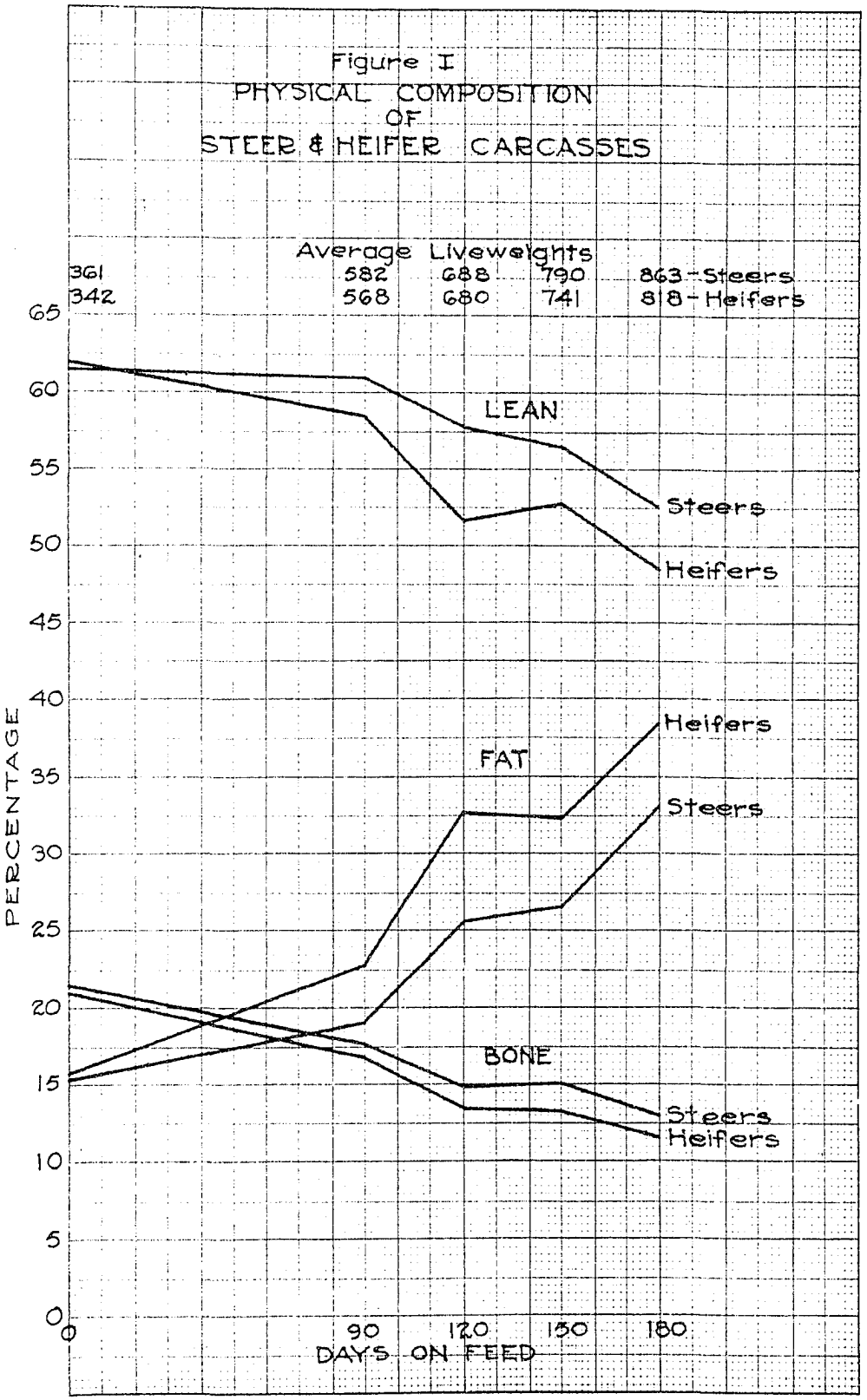


Figure I
PHYSICAL COMPOSITION
OF
STEER & HEIFER CARCASSES
Average Liveweights
361 582 688 790 863 - Steers
342 568 680 741 818 - Heifers
LEAN
Steers
Heifers
FAT
Heifers
Steers
BONE
Steers
Heifers
PERCENTAGE
65
60
55
50
45
40
35
30
25
20
15
10
5
0
0
90
120
150
180
DAYS ON FEED

TABLE XI

Total Weight and Percentage of Hand Separable Fat in Entire Carcasses from Steers

Pounds of Fat

Days	1st. Year		2nd. Year		3rd. Year		Means		Difference
	Steers	Heifers	Steers	Heifers	Steers	Heifers	Steers	Heifers	Hfr.-Str.
0	11.60	10.53	12.40	10.50	15.85	21.23	13.28	14.09	.81
90	26.30	29.79	30.40	31.10	32.06	49.44	29.59	36.78	7.19
120	44.17	59.14	47.02	65.79	55.85	64.20	49.01	63.04	14.03
150	60.19	81.45	48.40	50.65	60.51	70.05	56.37	67.38	11.01
180	94.75	114.88	71.90	80.55	81.79	93.62	82.81	96.35	13.54
Total	237.01	295.79	210.12	283.59	246.06	298.54			

Percentage of Fat to Carcass Weight

0	13.24	13.00	14.79	15.21	17.80	18.96	15.27	15.72	.45
90	15.05	19.34	21.62	21.89	19.67	27.00	18.78	22.74	3.96
120	23.01	29.78	26.45	35.20	27.58	33.97	25.68	32.98	7.30
150	27.61	38.42	24.84	28.41	26.77	30.46	26.41	32.43	6.02
180	36.65	42.87	30.14	37.73	32.17	35.13	32.98	38.58	5.60

Physical composition of wholesale cuts

Although the weights of carcasses and of wholesale cuts from steers were not significantly different from those from heifers, there still remained the possibility that the distribution of lean, fat, and bone in the various regions of the carcasses differed between the sexes. Therefore, a comparison was made between constituent parts of corresponding wholesale cuts from carcasses of steers and heifers. Only those cuts which were deemed of most economical importance were used in the comparisons. They were the rounds, loins, standing ribs, and chucks. The percentages of the constituent parts in each of the wholesale cuts from steers are given in table XII and those from heifers in table XIII.

TABLE XII

RATIO OF LEAN, FAT, AND BONE TO WEIGHTS OF WHOLESALE CUTS TAKEN FROM STEERS AT DIFFERENT INTERVALS DURING THE 180 DAY FEEDING PERIOD

	Cut	Days on Feed				
		0	90	120	150	180
		%	%	%	%	%
Percentage of lean	Round	67.81	69.11	67.89	66.51	65.55
	Loin	65.96	60.91	58.15	55.36	53.06
	Ribs	62.18	57.52	55.83	54.70	48.95
	Chuck	64.75	67.18	65.00	63.90	59.07
	Plate	55.40	54.80	49.58	48.83	43.51
	Carcass	61.41	61.02	57.76	56.47	52.45
Percentage of fat	Round	9.70	10.99	14.08	15.00	18.16
	Loin	15.04	23.85	28.86	31.68	36.08
	Ribs	10.24	21.50	26.87	28.52	35.28
	Chuck	12.57	12.11	17.21	18.34	24.64
	Plate	21.81	25.82	35.69	36.65	44.16
	Carcass	15.27	18.78	25.68	26.41	32.98
Percentage of bone	Round	20.44	17.62	15.27	15.57	14.28
	Loin	18.17	13.34	11.69	11.66	10.16
	Ribs	25.08	18.85	15.52	14.78	14.46
	Chuck	20.66	18.68	15.65	15.72	14.38
	Plate	22.29	19.05	14.09	13.99	11.87
	Carcass	21.53	17.99	14.70	15.00	13.12
Percentage of lean	Primal cuts	65.19	63.68	61.72	60.12	56.66
fat		11.89	17.11	21.78	23.38	28.54
bone		21.09	17.12	14.53	14.43	13.32

TABLE XIII

RATIO OF LEAN, FAT, AND BONE TO WEIGHTS OF WHOLESALE CUTS TAKEN FROM HEIFERS AT DIFFERENT INTERVALS DURING THE 180 DAY FEEDING PERIOD

	Cut	Days on Feed				
		0	90	120	150	180
		%	%	%	%	%
Percentage of lean	Round	67.42	70.07	67.65	67.34	64.38
	Loin	68.29	58.68	54.15	51.79	50.74
	Ribs	62.45	57.44	48.41	49.10	45.05
	Chuck	64.98	64.38	59.38	60.23	56.01
	Plate	50.70	48.53	42.58	46.22	41.11
	Carcass	61.57	58.44	51.78	52.74	48.61
Percentage of fat	Round	9.25	12.08	15.11	16.19	20.67
	Loin	14.77	27.32	33.89	37.22	39.07
	Ribs	10.92	21.17	35.41	34.81	41.56
	Chuck	12.75	16.07	24.25	23.94	29.17
	Plate	26.39	31.89	42.30	40.43	48.42
	Carcass	15.72	22.74	32.98	32.43	38.58
Percentage of bone	Round	20.65	15.57	14.75	14.29	13.08
	Loin	16.46	13.07	11.19	9.66	9.44
	Ribs	24.74	19.76	14.56	13.74	12.00
	Chuck	20.13	17.60	14.31	13.89	12.84
	Plate	22.58	18.26	14.40	12.92	19.83
	Carcass	20.93	16.78	13.56	13.27	11.48
Percentage of lean fat bone	Primal cuts	65.78	62.64	57.40	57.12	54.04
		11.92	19.16	27.16	28.04	32.62
		20.49	16.50	13.70	12.89	10.84

At the time the calves were placed on feed, the fat content in the primal region and in the carcasses of heifers was the same as that in steers. After being on full feed for 180 days the heifers had 4 percent more fat in the primal region and 5 percent more in the whole carcass than the steers.

Of particular interest are the variant rates at which different constituents, especially lean and fat, developed in the wholesale cuts during the fattening process. Since the wholesale cuts were divided into their constituent parts, namely, lean, fat, and bone, and these expressed as percentages of the whole piece, the difference between the percentages of a constituent at any two periods determined the rate of development of that constituent with respect to the other two.

Ratio of lean to weight of wholesale cut. It is shown by the data that over a period of 180 days the proportion of lean to the weight of the wholesale cuts from steers was reduced by the following: rounds, 2 percent; loins, 13 percent; ribs, 13 percent, and chucks, 5.6 percent, an average reduction of 8.5 percent for the four primal cuts as compared to 9 percent for the entire carcass. The proportion of lean in wholesale cuts from heifer carcasses during the same period was decreased as follows: rounds, 3 percent; loins, 17.5 percent; ribs, 17.4 percent, and chucks, 9 percent, or an average decrease of 11.75 percent in the primal cuts as compared to 13 percent for the entire carcass.

Ratio of fat to weight of wholesale cut. The quantity of fat in the wholesale cut naturally affected the percentage of lean, and in cuts in which the fat accumulated much faster than the lean it appeared from the

data that the lean had decreased, whereas, in reality, the quantity of lean had increased, but less rapidly than the fat.

The accumulation of fat in the different wholesale cuts of steers and heifers is clearly shown by the data in table XIV. Over a period of 180 days the steers had increased the deposits of fat in the round, 8.5 percent; loin, 21 percent; standing rib, 25 percent, and chuck, 12 percent. The primal region had an average increase of 16.7 percent, while the fats in the entire carcass increased 17.7 percent. The fatty deposits in the corresponding parts of heifers were substantially greater. The fat of rounds increased 11.4 percent; loin, 24.3 percent; standing ribs, 30.6 percent, and chucks, 16.4 percent, with an average of 20.7 percent as compared with an increase of 22.9 percent in the entire carcass.

TABLE XIV

THE AVERAGE PHYSICAL ANALYSES OF CERTAIN WHOLESALE CUTS FROM STEERS AND HEIFERS AT EACH DATE

Cut	Days on feed	Steers Lean %	Steers Fat %	Steers Bone %	Steers Tendon %	Heifers Lean %	Heifers Fat %	Heifers Bone %	Heifers Tendon %
Round	0	67.81	9.70	20.44	2.05	67.42	9.25	20.65	2.68
	90	69.11	10.99	17.62	2.28	70.07	12.08	15.57	2.28
	120	67.89	14.08	15.27	2.76	67.65	15.11	14.75	2.49
	150	66.51	15.00	15.57	2.92	67.34	16.19	14.29	2.18
	180	65.55	18.16	14.28	2.01	64.38	20.67	13.08	1.87
Loin	0	65.96	15.04	18.17	.83	68.29	14.77	16.46	.48
	90	60.91	23.85	13.34	1.90	58.68	27.32	13.07	.93
	120	58.15	28.86	11.69	1.30	54.15	33.89	11.19	.77
	150	55.36	31.68	11.66	1.30	51.79	37.22	9.66	1.33
	180	53.06	36.08	10.16	.70	50.74	39.07	9.44	.75
Rib	0	62.18	10.24	25.08	2.50	62.45	10.92	24.74	1.89
	90	57.52	21.50	18.85	2.13	57.44	21.17	19.76	1.63
	120	55.83	26.87	15.52	1.78	48.41	35.41	14.56	1.62
	150	54.70	28.52	14.78	2.00	49.10	34.81	13.74	2.35
	180	48.95	35.28	14.46	1.31	45.05	41.56	12.00	1.39
Chuck	0	64.75	12.57	20.66	2.02	64.98	12.75	20.13	2.14
	90	67.18	12.11	18.68	2.03	64.38	16.07	17.60	1.95
	120	65.00	17.21	15.65	2.14	59.38	24.25	14.31	2.06
	150	63.90	18.34	15.72	2.04	60.23	23.94	13.89	1.94
	180	59.07	24.64	14.38	1.91	56.01	29.17	12.84	1.98
Plate	0	55.40	21.81	22.29	.50	50.70	26.39	22.58	.33
	90	54.80	25.82	19.05	.33	48.53	31.89	18.26	1.32
	120	49.58	35.69	14.09	.64	42.58	42.30	14.40	.72
	150	48.83	36.65	13.99	.53	46.22	40.43	12.92	.43
	180	43.51	44.16	11.87	.46	41.11	48.42	9.83	.64

Variations in deposition of fat. These analyses showed that as the animals continued on feed the ratio of lean decreased and that of the fat increased, but it also revealed that some periods showed much greater change in the ratios of fat over lean than other periods. The greatest difference between sexes in the fat content was noted at the 120th day when heifers had 5.38 percent more fat in the primal region than steers. Thenceforth the percentage of fat increased faster in steers than in heifers.

The fattest wholesale cuts in the primal region were the ribs and the loins. The fat in the prime ribs of heifers at 120 days was one-third the total weight of the cut and comprised a greater ratio of the total constituents than the fat in prime ribs from steers at 180 days. The quantity of fat shown in loins is determined very largely by the amount of renal fats left attached. Since it is the practice in the beef industry to include an appreciable portion of the renal fat with the loin, it is extremely difficult for the investigator to judge the proportion of this fat that should remain. The amount of fat reported in loins is, therefore, very largely a matter of judgment by the investigator. Large quantities of renal fat left on the loin affect the ratio of the other constituents, thereby impairing the significance of the results obtained by physical analysis.

The percentage distribution of lean, fat, and bone in the primal cuts is summarized in table XV. The results show the marked influence of the fattening process upon the physical composition of the more highly prized portions which constitute approximately two-thirds of the weight

TABLE XV

COMPARING THE PHYSICAL ANALYSES OF PRIMAL CUTS FROM STEERS AND HEIFERS SLAUGHTERED AT DIFFERENT INTERVALS DURING THE FEEDING PERIOD

Days on feed	Cut	Steers Lean %	Steers Fat %	Steers Bone %	Steers Tendon %	Heifers Lean %	Heifers Fat %	Heifers Bone %	Heifers Tendon %
0	Round	67.81	9.70	20.44	2.05	67.42	9.25	20.65	2.68
0	Loin	65.96	15.04	18.17	.83	68.29	14.77	16.46	.48
0	Rib	62.18	10.24	25.08	2.50	62.45	10.92	24.74	1.88
0	Chuck	64.75	12.57	20.66	2.02	64.98	12.75	20.13	2.14
Av.		65.19	11.89	21.09	1.85	65.78	11.92	20.50	1.79
90	Round	69.11	10.99	17.62	2.27	70.07	12.08	15.57	2.28
90	Loin	60.91	23.85	13.34	1.90	58.68	27.32	13.07	.90
90	Rib	57.52	21.50	18.85	2.13	57.44	21.17	19.76	1.66
90	Chuck	67.18	12.11	18.68	2.03	64.37	16.07	17.60	1.95
Av.		63.68	17.11	17.12	2.08	62.64	19.16	16.50	1.70
120	Round	67.89	14.08	15.27	2.77	67.65	15.11	14.75	2.49
120	Loin	58.15	28.86	11.69	1.30	54.15	33.89	11.19	.77
120	Rib	55.83	26.87	15.52	1.78	48.41	35.41	14.56	1.62
120	Chuck	65.00	17.21	15.65	2.14	59.38	24.25	14.31	2.05
Av.		61.72	21.78	14.53	2.00	57.40	27.16	13.70	1.73
150	Round	66.51	15.00	15.57	2.93	67.34	16.19	14.29	2.19
150	Loin	55.36	31.68	11.66	1.30	51.79	37.22	9.66	1.32
150	Rib	54.70	28.52	14.78	2.01	49.10	34.81	13.74	2.34
150	Chuck	63.90	18.34	15.72	2.04	60.23	23.94	13.89	1.94
Av.		60.12	23.38	14.43	2.07	57.12	28.04	12.89	1.95
180	Round	65.55	18.16	14.28	2.00	64.38	20.67	13.08	1.87
180	Loin	53.06	36.08	10.16	.70	50.74	39.07	9.44	.75
180	Rib	48.95	35.28	14.46	1.34	45.05	41.56	12.00	1.39
180	Chuck	59.07	24.64	14.38	1.92	56.01	29.17	12.84	1.97
Av.		56.66	28.54	13.32	1.49	54.04	32.62	11.84	1.49

of the carcass. No appreciable difference between sexes in composition of the primal cuts was found during the first 90 days of feeding. On the 120th day the heifers had considerable more fat in the primal region than the steers, the ribs and loins from heifers receiving much greater deposits than similar cuts from steers. Little change was noted in the ratios of the constituent parts for either sex on the 150th day over those on the 120th day. Both sexes showed substantial increases in fatness of the cuts at the 180th day, but the steers had made slightly greater gains in fat than the heifers.

Differences in fattening characteristics of steer and heifer calves were clearly indicated by the analysis of the parts of the carcass. The growth of steers was the result of a more consistent accumulation of the constituents that compose the animal carcass, while the heifers seemed to be endowed with greater fattening tendencies at some periods than at others. This was shown by the greater deposits of fat within a period of 90 to 120 days. The primal cuts from heifers at 120 days contained 27.16 percent fat, while those from steers contained only 21.78 percent fat. Both sexes showed a recession in the rate of fattening between 120 and 150 days, but the steers retained much more of the previous rate than did the heifers. During the 150 - 180 day interval the steers increased their fat content of the primal region faster than in other portions of the carcass, whereas, the heifers deposited more fat in the less demanded areas of the body.

Ratio of lean and fat to bone. Fat, however, is only one of the attributes of quality, for quality of meat is sometimes based upon the

proportion of lean and of fat to bone rather than upon total fat content of the piece.

The ratio of lean and of fat to bone in carcasses and certain wholesale cuts is shown in table XVI.

TABLE XVI

Ratio of Lean and Fat to Bone in Carcasses and in Certain Wholesale Cuts from Steers and Heifers

		Lean					Fat				
		Days on Feed					Days on Feed				
		0	90	120	150	180	0	90	120	150	180
Carcass	S	2.64	3.00	3.49	3.38	3.61	.66	.91	1.55	1.62	2.28
	H	2.73	3.10	3.40	3.56	3.77	.71	1.22	2.17	2.20	3.01
Round	S	3.02	3.45	3.77	3.60	4.03	.43	.54	.78	.81	1.12
	H	2.94	3.93	3.95	4.10	4.27	.41	.68	.86	.99	1.40
Loin	S	3.48	4.07	4.52	4.29	4.89	.80	2.34	2.24	2.47	3.33
	H	4.12	4.16	4.57	4.78	4.99	.94	1.96	2.81	3.52	3.85
Rib	S	2.25	2.75	3.23	3.25	3.10	.36	1.02	1.56	1.70	2.23
	H	2.41	2.71	3.00	3.08	3.37	.45	1.01	2.19	2.16	3.13
Chuck	S	2.85	3.22	3.60	3.60	3.62	.55	.57	.95	1.03	1.51
	H	2.93	3.29	3.63	3.79	3.74	.59	.82	1.48	1.53	1.96
Plate	S	2.40	3.07	3.37	3.39	3.64	.31	1.42	2.42	2.52	3.75
	H	2.13	2.47	2.82	3.52	3.90	1.17	1.74	2.76	3.12	4.63

S Steers
H Heifers

During a period of 180 days the ratio of lean to bone in steer carcasses increased from 2.64 to 3.61, in heifer carcasses from 2.73 to 3.77; the ratio of fat to bone in steer carcasses increased from 0.66 to 2.28, and in heifer carcasses from 0.71 to 3.01. These results indicate that for

a feeding period of 180 days heifers have a higher ratio of muscle and a much greater ratio of fat to bone than steers.

The ratio of muscle to bone in the primal cuts, considered as a whole, was very similar in steers and heifers through the 120 day interval, although the ratio of lean was slightly higher in heifers than in steers. Beyond this date the ratio of lean to bone in the primal cuts from heifer carcasses continued to be slightly higher, and the ratio of fat to bone was greatly higher than that from steer carcasses. The ratio of lean and fat to bone in round was greater in heifer carcasses than in steers, although in table VII it was shown that the proportion of round to carcass was greater in steers than in heifers. Similarly, the chucks from heifer carcasses had a higher proportion of lean to bone, but those from the steer carcasses were heavier and contained more lean in proportion to other constituents.

The loins from heifers, besides representing a larger proportion of the carcass than those from steers, had a higher ratio of muscle and of fat to bone than those from steer carcasses.

The ratio of lean to bone in the standing rib cut was similar in steers and heifers in all the tests, but after 120 days the ratio of fat to bone in this cut from heifers was greater than that from steers.

Liposomes in Muscle from Steers and Heifers

Sections of the longissimus dorsi muscle from all the cattle were examined for their liposome content. The method for removing these sections was described under Procedure. Areas containing extensive deposits

of intercellular fat were purposely avoided in this phase of the investigation.

Liposomes were found in every specimen, but they often did not appear in any appreciable quantity until the cattle had been on feed 120 days. A rather outstanding exception in beef muscle occurred, however, in which the liposomes in a carcass containing only 13 percent fat were much larger and more numerous than those in another carcass with a fat content of 27.58 percent.

That the liposome content of muscle is associated with adiposity of animals is brought out by comparing muscle from steers and heifers which had been fed a varied number of days and whose carcasses varied in degree of fatness. It was shown, table X, that heifers were fatter than steers throughout the feeding period. An examination of the muscle substance revealed that heifers also had a greater quantity of fat in a microscopically visible form than steers. The relationship between liposomes is illustrated in plates I to IX in which muscle fibers from animals varying in degrees of fatness are shown.

The animals illustrated in plates I and II were fed 120 days. The carcass of the steer was 23.01 percent fat and that of the heifer, 29.78 percent. The liposomes were fewer and appeared to occur in fewer fibers of muscles from the steer than those from the heifer. Further evidence of the relationship of liposomes to adiposity is found by comparing the liposomic content of muscle from two animals of the same sex fed the same length of time but differing in degrees of fatness. The carcass of the steer, plate VIII, Fig. 2, was 27.58 percent fat or 4.57 percent fatter than the steer illustrated in plate I. The liposomes also were more

numerous than those in the muscle of the thinner fleshed steer.

The similarity of liposome content in muscles from two steers of approximately the same degree of fatness is illustrated in plates III and VI, Fig. 1. The liposomes in muscle were found to be the same in two other steers (25 and 27, plates III and VIII, Fig. 2), which had approximately the same degree of finish although one steer was fed 30 days longer than the other.

The liposome content of muscle from two heifers fed for 150 days but unlike in percentage of fat is shown in plates IV and V. The animal illustrated in plate V was 8 percent fatter than the one in plate IV. In the fatter animal, the liposomes were larger, more numerous, and more systematically arranged in the sarcoplasm.

Liposomes in muscles from a steer and a heifer fed 150 days but unlike in percentage of fat are illustrated in plate VIII. The heifer with 35.20 percent fat was 9 percent fatter and the muscle cells contained a much greater quantity of liposomes than those from the steer. The muscle fibers in plate IX were from a heifer which was fed 30 days longer but with the same fat content of the heifer shown in plate VIII, Fig. 1. More liposomes were shown in the muscle from the longer fed animal.

The most extensive development of liposomes observed in bovine muscle is shown in plate VI. Sections for this plate were removed from a steer carcass which had a 27.61 percent fat content and a heifer carcass which had a fat content of 38.42 percent. The animals were fed 150 days. The remarkable extent of liposome deposit and uniformity in arrangement in longitudinal and transverse rows in the sarcoplasm is well illustrated, and gives some concept of the ratio of fat to the cellular substance. The

liposome development appeared even more abundant when viewed from longitudinal section than from the cross section.

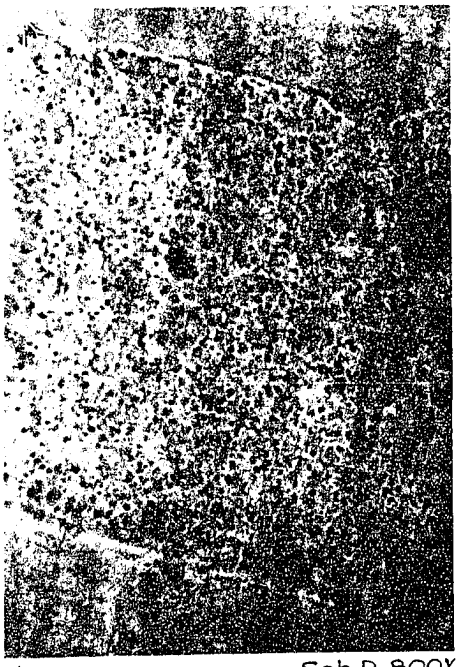
Muscle cells with high liposome content would often be surrounded with rather large quantities of intercellular fat. An outstanding illustration of the extent to which this may occur is shown in a section of muscle from a steer that had been fed 180 days (plate VII). The fatty infiltrations had developed to such degree that muscle fibers were almost completely surrounded with fat. Occasionally an area was found in which the muscle fibers appeared to be embedded in fat. In many cases the fat cells surrounding the muscle fiber did not show definite outlines and when the fat cells of the endomysium were cut in sectioning, the fat was released and spread like liquid oil over the surface of the muscle cells. Such large infiltrations of fat were not observed in any of the sections taken from the other 29 cattle, but it shows the areas and suggests the extent to which these areas might be utilized as a storehouse for fat by beef cattle in advanced stages of obesity.

The extent to which the fatty material was embedded in the sarcoplasmic substance is portrayed in plate X. Sections of muscle similar to those shown in plate IX were stained with hematoxylin and eosin. The fat and fatty substances (soluble in alcohol) were removed during fixation, leaving the sarcoplasm contracted near a central position within the fiber, while the sarcolemma remained somewhat near its original position, Fig. 3.

Cases of advanced adiposity were observed where the fat was found in well defined cellular masses between the muscle fibers inside the perimysium, as is demonstrated in plates XI and XII. In some of the fatter cattle globules of fat were developed in the endomysium to such extent as

to cause distortion and even atrophy of the muscle fibers, plate XII, Fig. 1.

Results of the microscopic determinations reveal that the quantity of liposomes increases as the body fat of the animal increases irrespective of sex or time required to accumulate the fat. The preponderance of liposomes in muscle fibers from heifers as compared to those from steers was attributed to the greater fatness of the heifers throughout the test period, rather than to any sex difference that could be determined.



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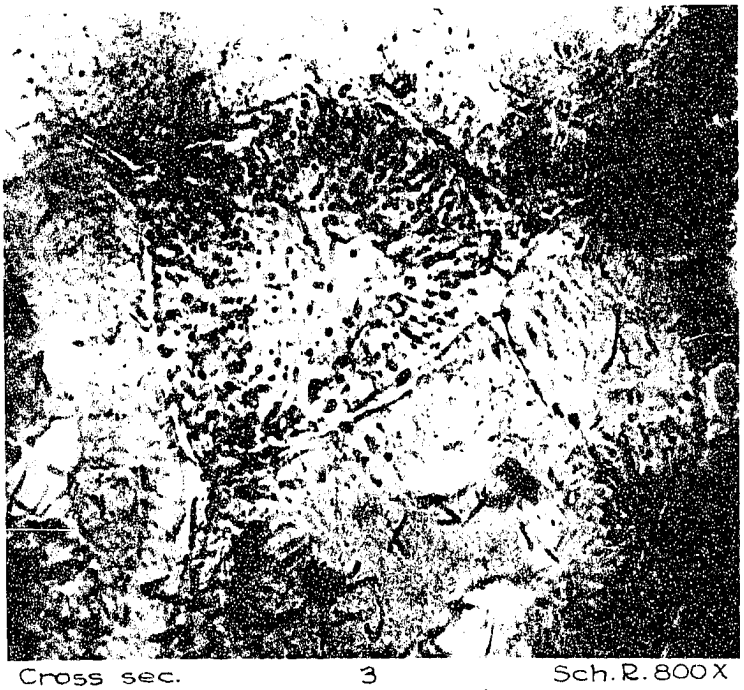
1

Cross sec. Sch.R.800X

2



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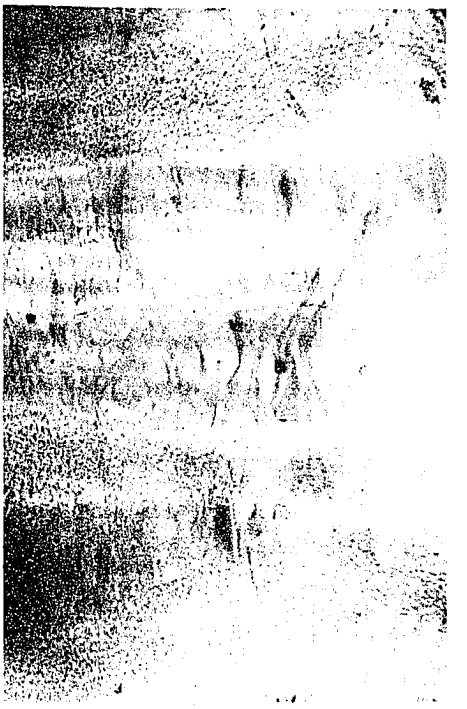
STEER No. 5

Plate I

Liposomes in Longissimus Dorsi Muscle. Steer Fed 120 Days. Carcass Was 23.01 Percent Fat.

Long. sec. Sch. R. 800X
1



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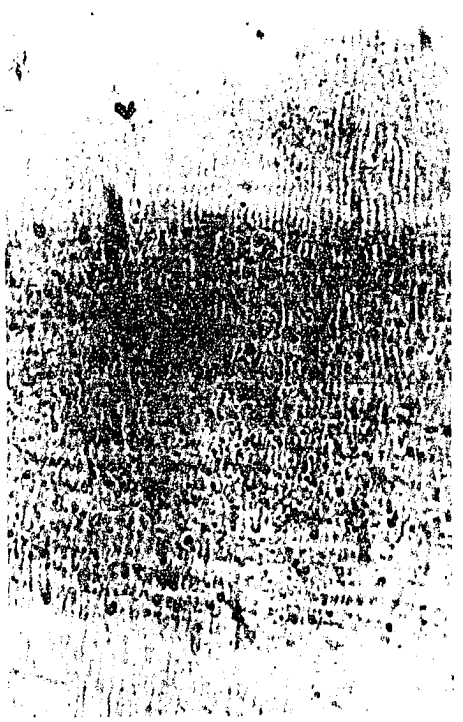
HEIFER No. 6
Plate II

Liposomes in Longissimus Dorsi Muscle. Heifer Fed 120 Days. Carcass Was 29.78 Percent Fat.



Long. sec. Sch. R. 800X
STEER. No. 27
1

Long. sec. Sch. R. 800X
STEER No. 7
2

Long sec. 3 Sch. R. 800X
STEER No. 27

Plate III

Liposomes in Longissimus Dorsi Muscle. Steer Fed 150 Days. Carcass Was 26.77 Percent Fat.

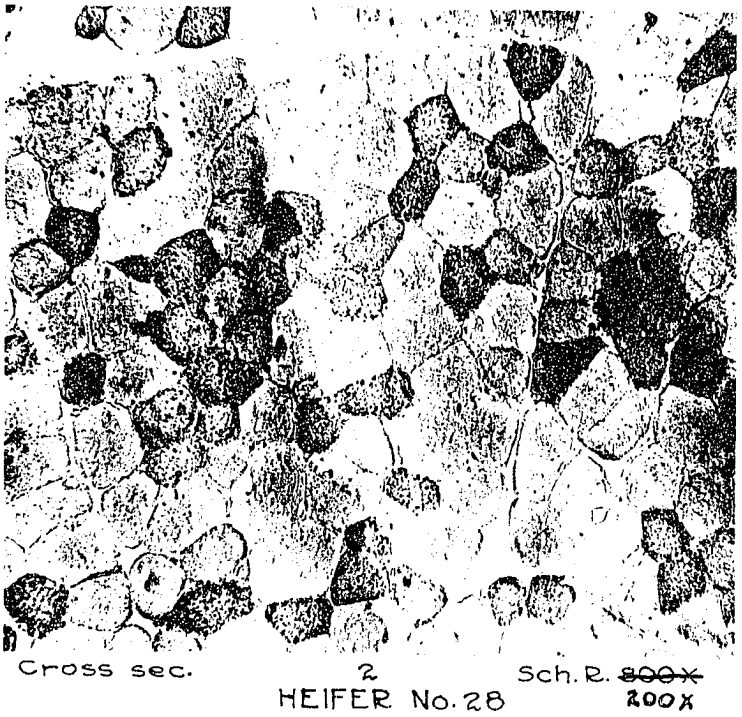
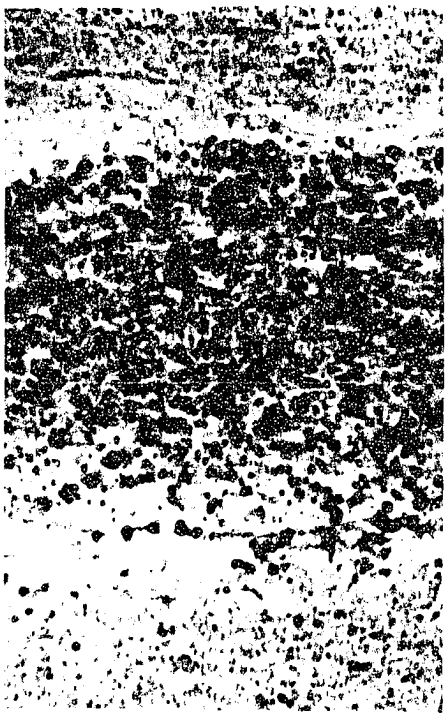


Plate IV

Liposomes in Longissimus Dorsi Muscle. Heifer Fed 150 Days. Carcass Was 30.46 Percent Fat.



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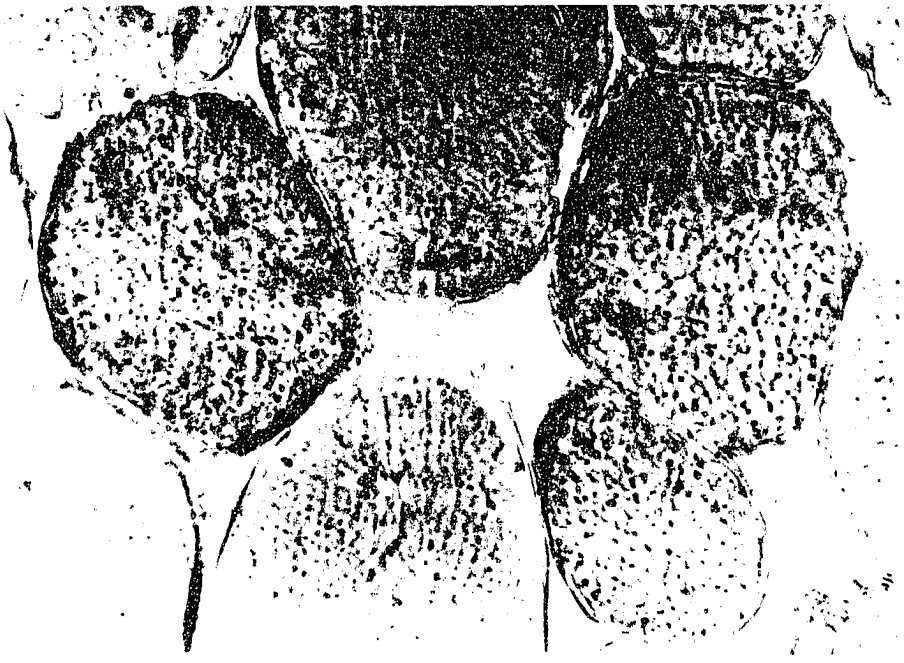
Long sec. Sch. R. 800X

2



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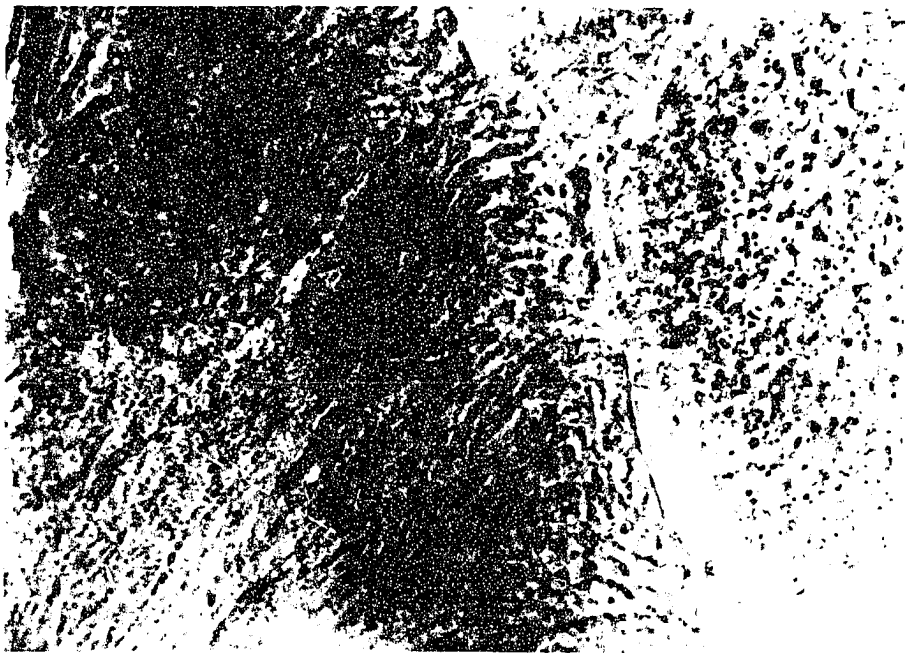
HEIFER No. 8

Plate V

Liposomes in Longissimus Dorsi Muscle. Heifer Fed 150 Days. Carcass Was 38.42 Percent Fat.



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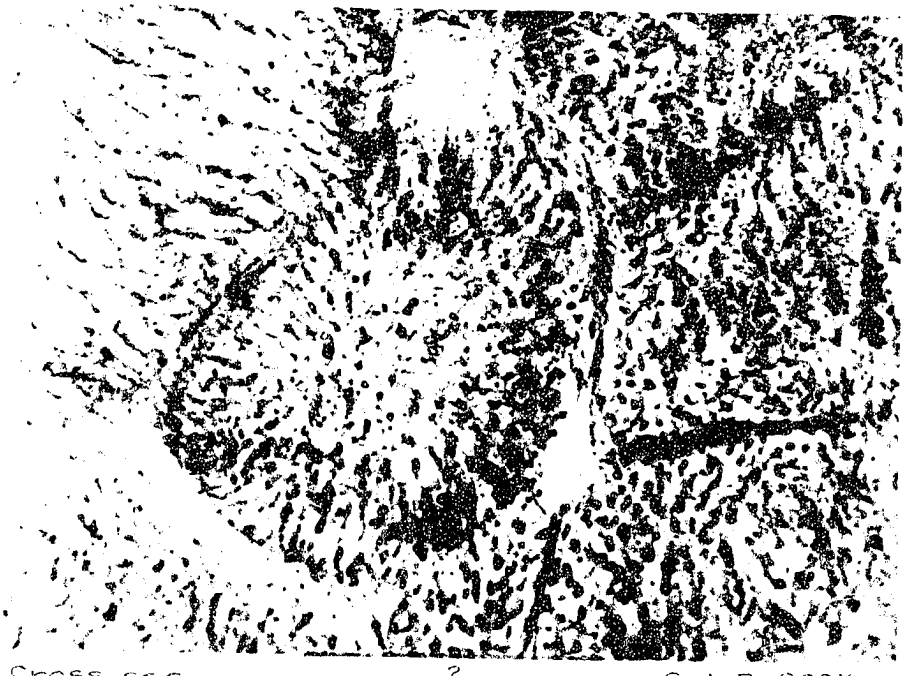
STEER No. 7

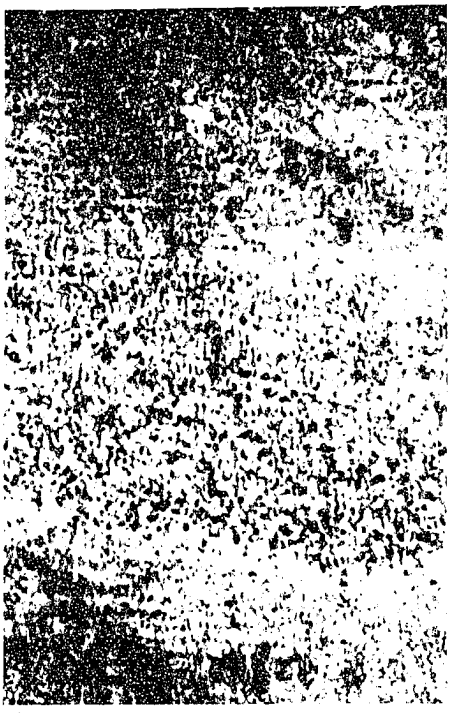


Cross sec. 2 Sch. R. 800X

HEIFER No. 8

Plate VI

The Liposome Content of a Steer and a Heifer Fed 150 Days but with a Difference of 10.81 Percent in Carcass Fat.



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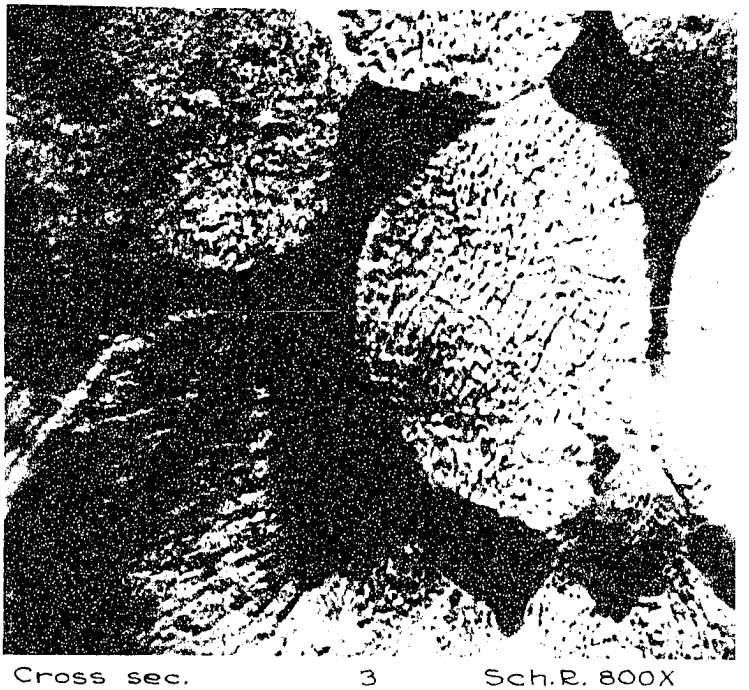
Cross sec. Sch.R. 200X
2

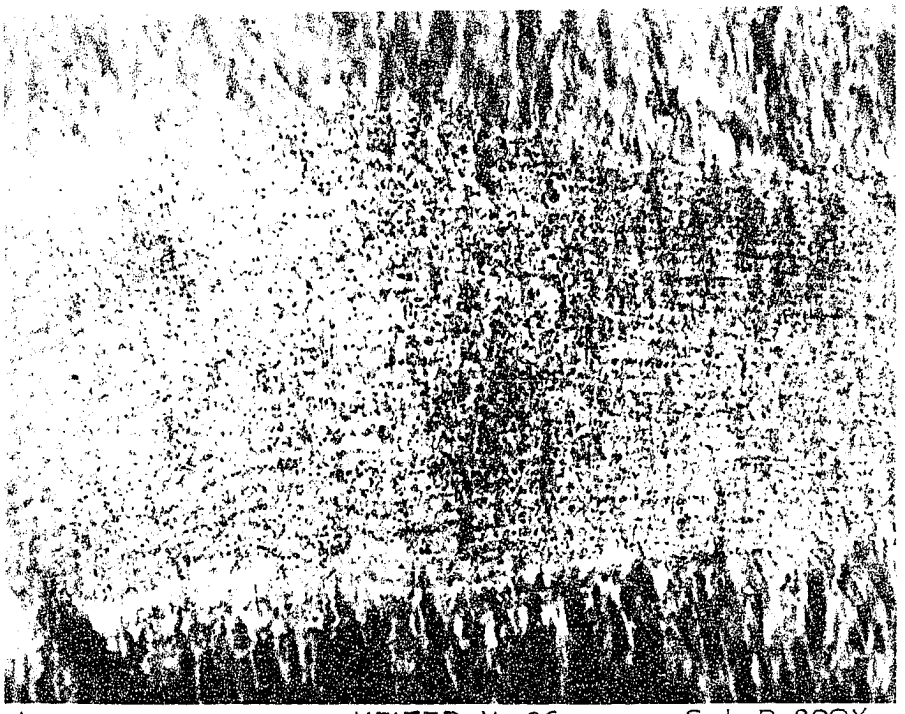


Cross sec. 3 Sch.R. 800X

STEER No.9

Plate VII

Inter-intrafibrillar Fat in a Steer Fed 180 Days.
Carcass Was 36.65 Percent Fat.



Long. sec. HEIFER No.26 Sch. R. 800X
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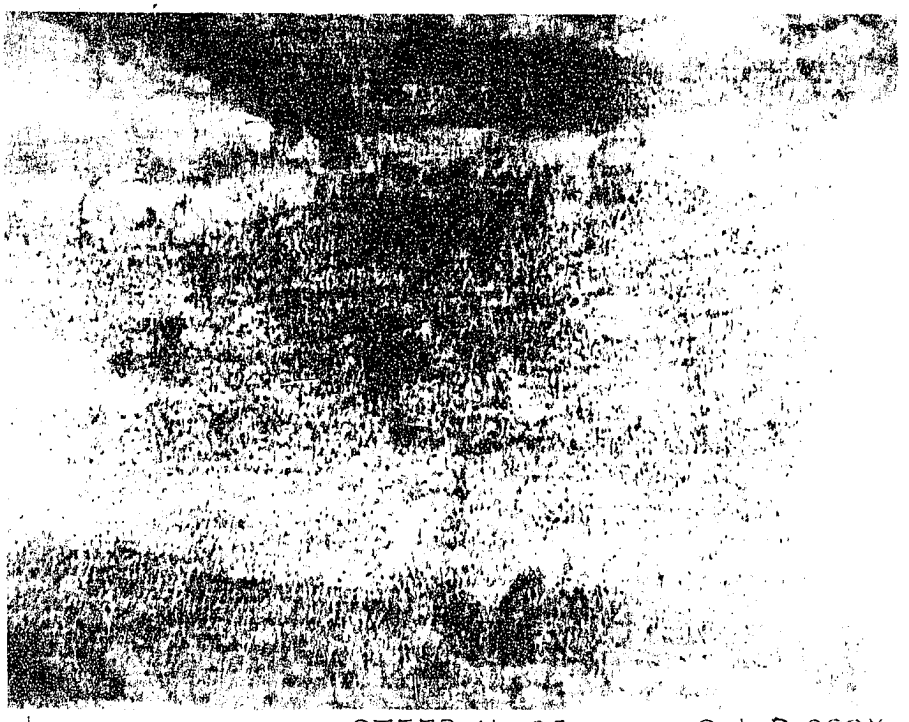
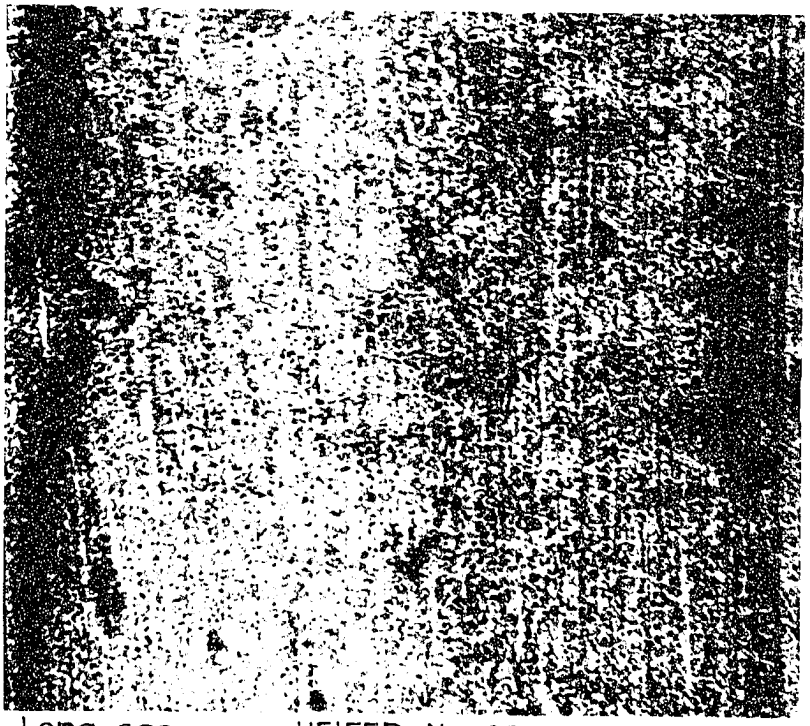


Long. sec. STEER No.25 Sch. R. 800X
2

Plate VIII

Liposomes in Animals Fed 120 Days but Different in Degree of Body Fatness.

Cross sec. HEIFER No.30 Sch.R.800X
1



Long. sec. HEIFER No. 30 Sch.R. 800X
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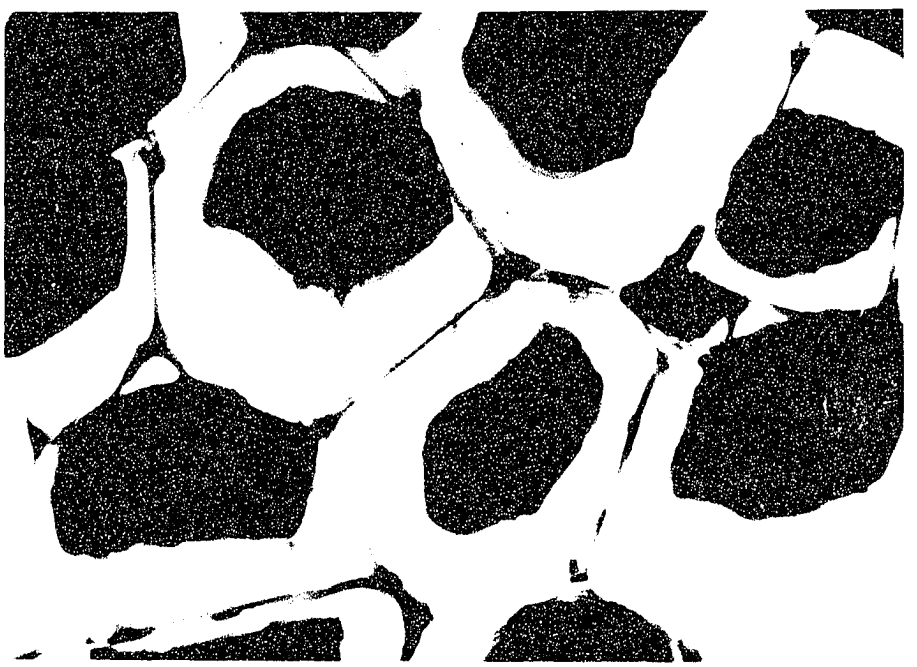
Plate IX

Liposomes in Longissimus Dorsi Muscle. Heifer Fed 180 Days. Carcass Was 35.13 Percent Fat.

Cross sec. 1 H.&E.50X

Cross sec. 2 H.&E.200X



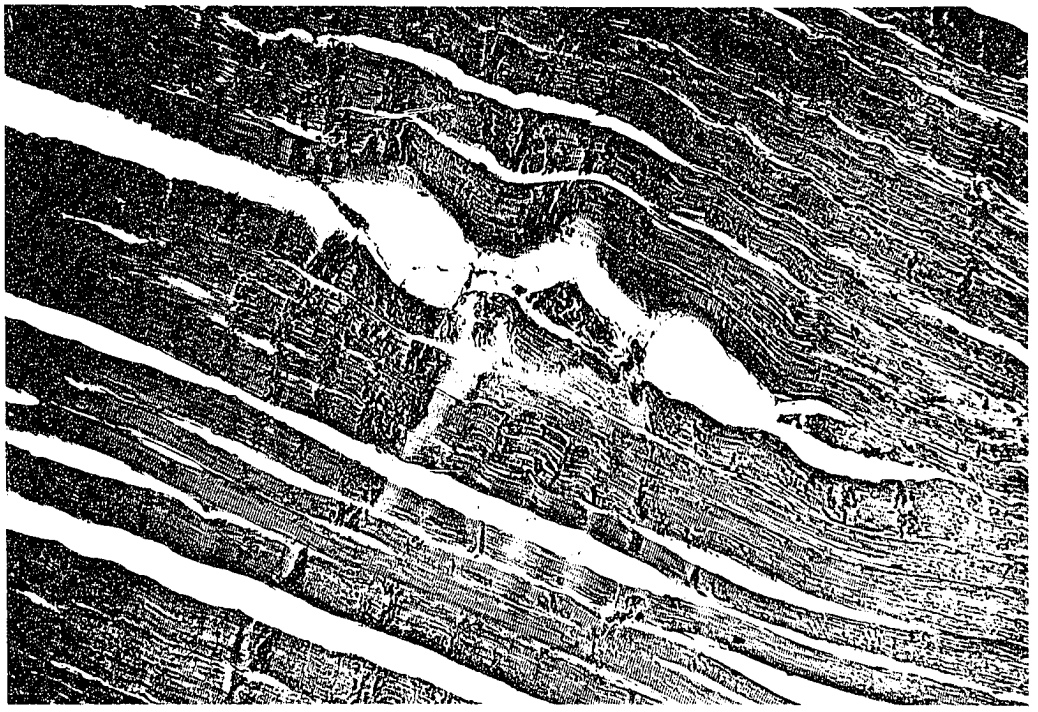
Cross sec. 3 H.&E.800X

HEIFER No. 10

Plate X

Sarcoplasm in Muscle Fibers after Liposomes Are Removed by Staining Technique. Carcass Was 42.87 Percent Fat.

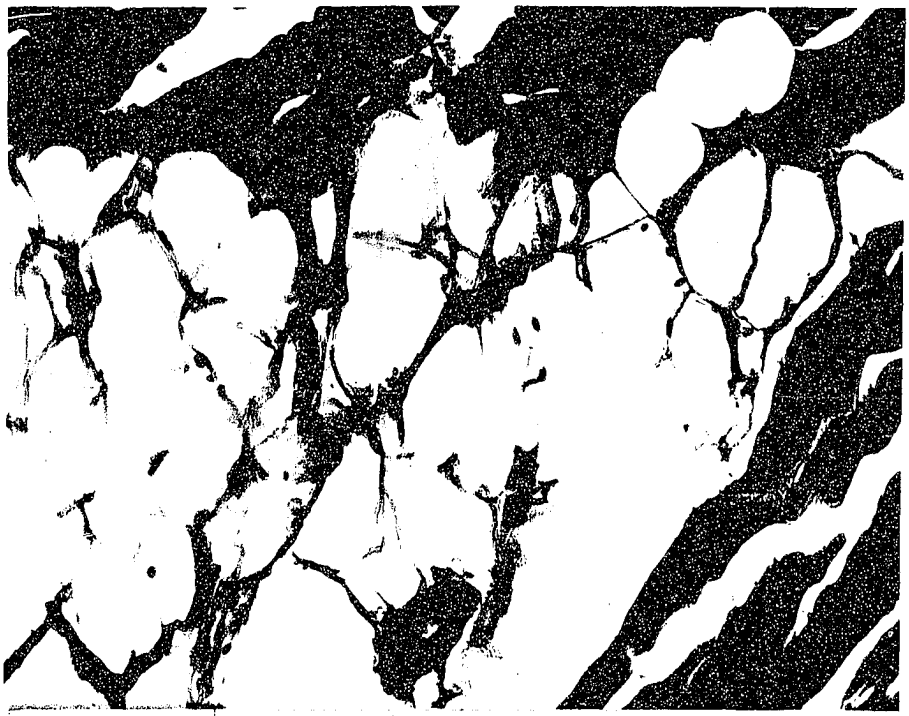
Long. sec. HEIFER No. 10 H.&E. 200X
1



Long. sec. STEER No. 9 H.&E. 200X
2

Plate XI

Interfibrillar Fat in Muscle from Animals in Higher Degree of Obesity.



Atrophy of Muscle Fibers Resulting from Great Adiposity.

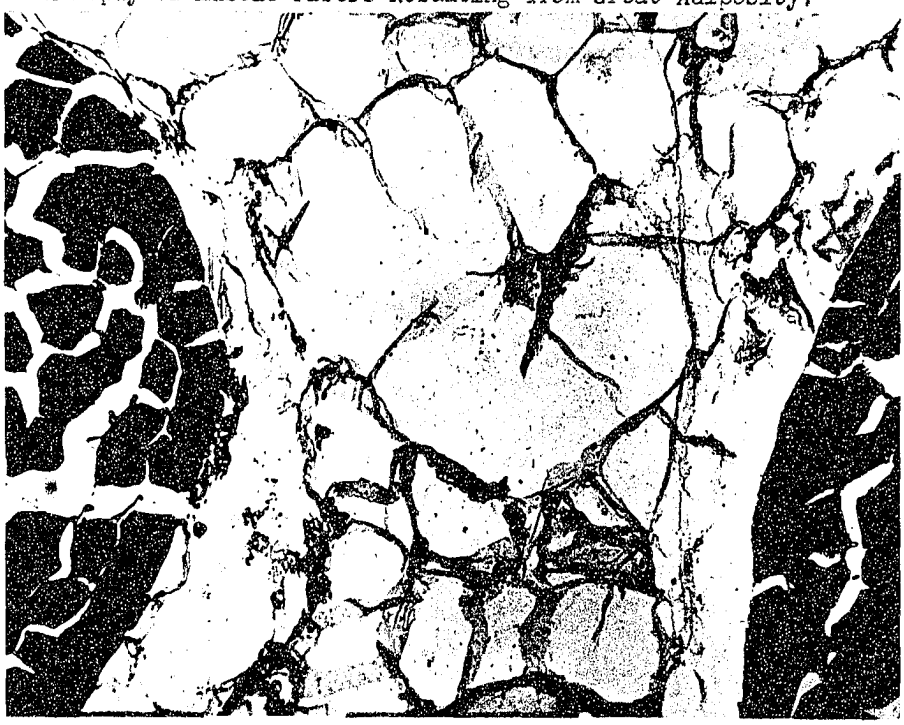


Plate XII

Interfascicular Deposits of Fat.

Color Determinations

Color readings were made with the "A" chart and the rotating disk on a transverse section of the longissimus dorsi muscle between the twelfth and thirteenth vertebrae. The readings by each of the instruments are recorded in table XVII, while the standard for comparison, that is, percentage distribution of red, black, and yellow for the "A" chart, is given in table XVIII.

The "A" chart

According to the "A" chart notation the color of freshly cut young beef was 8; from animals fed 90 days, 7; and from animals fed 120 - 180 days, 6. During 30 minutes exposure to air, the cut surface of muscle from the young animals lightened two color grades, while from older animals it lightened about one color grade. The notations of the "A" chart show the youngest animals to be the darkest with a decided reddening of the meat during the first 90 days, followed by little or no change in color during the next 90 day period.

TABLE XVII

COLOR READINGS OF MEAT ACCORDING TO THE "A" CHART AND THE MUNSELL DISK

Days on feed:	"A" Chart: Freshly cut	"A" Chart: 30 minutes later	Munsell Spinning Color Disk: Freshly Cut: Red	Freshly Cut: Black	Freshly Cut: Yellow	30 Minutes Later: Red	30 Minutes Later: Black	30 Minutes Later: Yellow
0*	8	6	19	47	34	27	40	33
0⊥	8+	6	23	47	30	30	42	28
90	7+	7-	35	46	19	40	40	20
90	8-	7-	29	53	18	40	40	20
120	6	5	45	37	18	49	33	18
120	6	5	46	35	19	48	36	16
150	6	5	45	40	15	47	37	16
150	7-	6	33	42	25	39	39	22
180	6	5	42	44	14	44	44	12
180	6	5	48	39	13	50	39	11

*Steer
⊥ Heifer

TABLE XVIII

Color Values of the Standard "A" Chart

Chart notation	Red R 11/4	Black N/1	Yellow Y.R. 6/5	Hue	Brilliance	Chroma
A 1	79.00	7.00	14			
2	72.50	14.50	13			
3	66.00	22.00	12	6.11	3.70	7.98
4	59.00	30.00	11	6.20	3.53	7.15
5	52.50	37.50	10	6.19	3.32	6.37
6	47.75	43.25	9	6.19	3.14	5.37
7	39.00	53.00	8	6.00	2.97	5.77
8	32.00	61.00	7	6.05	2.73	3.94
9	25.50	68.50	6	6.40	2.77	3.01
10	19.00	76.00	5			

Rotating disks

The difference in color of meat as measured by the rotating disk between animals on feed over a period of 180 days is given in table XVII. According to the readings by the rotating disk, the young animals had the faintest red color to their flesh and the older animals had the darkest color. This is in exact opposition to the readings by the "A" chart. Furthermore, the disk readings indicated differences in color of flesh between animals during the 120 - 180 day period while none were indicated by the "A" chart.

The color analysis by the rotating disk brought out a singular incident in which the increment in red was accompanied by a similar decrement of yellow. The difference between the lean and the fat animals in the amount of black pigment, as shown by the rotating disk, was very small, whereas the standard color values of the "A" chart indicated the quantity of black varied directly with the intensity of the color.

The chart readings of the color constituents of the longissimus dorsi muscle, from cattle slaughtered at each of the five dates, were converted into dimensional terms of hue, brilliance, and chroma, and are given in table XIX.

TABLE XIX

Translation of Munsell Disks Color Readings to Values of Hue, Brilliance and Chroma

Days on feed	Freshly Cut			30 Minutes Later		
	Hue	Brilliance	Chroma	Hue	Brilliance	Chroma
0 *	10.50	3.46	4.13	10.00	3.60	4.95
0 ⊥	9.70	3.30	4.33	8.89	3.50	4.78
90	7.70	3.30	4.99	7.54	3.22	5.60
90	8.00	3.20	4.27	7.54	3.22	5.60
120	7.16	3.47	6.03	7.00	3.54	6.47
120	7.22	3.53	6.20	6.85	3.47	6.24
150	6.86	3.36	5.85	6.89	3.45	6.13
150	8.40	3.45	5.13	7.92	3.50	5.61
180	6.86	3.27	5.46	6.23	3.24	5.56
180	6.56	3.36	6.06	6.57	3.34	6.16

*Steers
⊥Heifers

According to the interpretation of colors in terms of their attributes, the color of the longissimus dorsi muscle from steers slaughtered at the 0 day period showed an R value of 10, and from heifers, the R value was 8.89. The value of "10" in the hue scale is the limit of lightness in red and is midway between red and yellow. Beef having a hue value of 8 to 10 is commonly referred to as having a "pinkish tint", or as being of a "vealy" color.

The color of the muscle in the steers, as noted in the table, changed from a yellow-red, R 10, to nearly a typical red, R 6.23, in the course of 180 days; that in heifers from R 8.89 to R 6.57. (Any red with a hue of R 5 would be a typical red, according to the Munsell color scale.)

Results of these color studies show that, with animals approximately six months of age when put on a fattening ration, the intensity of color develops more rapidly in the first than in the second 90 day period. Based on readings made 30 minutes after the muscle was cut, the intensity of red in the back muscle from steers increased 2.46 optical degrees and heifers increased 1.35 optical degrees during the first 90 day period, and .97 and 1.31 respectively during the second 90 days that the cattle were on test. There were only two periods in which the difference between steers and heifers in color of the meat exceeded one optical degree; the 0 day period when the muscle of heifers was 1.11 degrees darker than that of the steers, and at the 150 day period when that of the heifers was 1.03 degrees lighter than the muscle of steers. At other dates the muscle in heifers was very slightly lighter in color than that of steers.

Color analysis with the photoelectric spectrophotometer

The spectrophotometrical records showed the blue and red to be the predominating colors of muscle in both steers and heifers and showed very little response from the violet, green, and yellow bands of the spectrum. The flesh of steers showed greater energy response for color than heifers at practically every wave length, but the greatest difference between steers and heifers in the color of the flesh was in the red band.*

The energy reflection factors, (that is, the ratios of the intensities of light reflected by the muscle substance to that reflected by the standard magnesium carbonate block) were calculated and are recorded in tables XX and XXI. The difference between steers and heifers in the value of the ordinates of energy reflection factors through the spectrum is much more illuminating when viewed in graphic form, Fig. II. The curves appear in pairs, since the samples were tested in pairs, to carry out the comparative study of sex for each plane of obesity. The numbers on the graph refer to the animal and the letter identifies the sex. The degree of fatness is implied from the number of days each animal was fed prior to slaughter. The color analyzer was not obtained until the work in the second year was well under way; consequently samples from all the animals were not available for analysis.

Since the values of the ordinates for steers and heifers slaughtered at a given date varied in the same direction, the variation between sex

*Photographic records of the intensity of light reflected versus wave length are shown in illustrations I and II, pp. 99-100.

TABLE XX

ENERGY REFLECTION FACTOR OF MUSCLE TO STANDARD WHITE THROUGHOUT THE SPECTRAL COLOR BAND

First Series

Animal:	Wave Length (Millimicrons)													
no.	400	425	450	475	500	525	550	575	600	625	650	675	700	Av.
13S	.034	.024	.030	.084	.114	.081	.063	.060	.115	.180	.205	.216	.226	.110
14H	.045	.012	.018	.086	.103	.068	.051	.048	.118	.185	.212	.224	.232	.108
15S	.025	.015	.028	.100	.113	.090	.063	.059	.127	.191	.209	.220	.234	.114
16H	.024	.013	.021	.057	.101	.075	.042	.045	.113	.171	.189	.207	.212	.098
17S	.026	.014	.015	.078	.112	.081	.058	.058	.122	.195	.216	.227	.236	.111
18H	.013	.007	.015	.047	.083	.067	.045	.044	.102	.158	.169	.178	.192	.086
19S	.015	.008	.014	.056	.082	.060	.047	.047	.108	.179	.206	.220	.230	.098
20H	.014	.008	.021	.069	.081	.065	.046	.046	.106	.176	.199	.214	.226	.098

S Steers
H Heifers

TABLE XXI

ENERGY REFLECTION FACTOR OF MUSCLE TO STANDARD WHITE THROUGHOUT THE SPECTRAL COLOR BAND

Second Series

Animal: Wave Lengths (Millimicrons)														
no.	400	425	450	475	500	525	550	575	600	625	650	675	700	Av.
21S	.036	.020	.016	.100	.104	.109	.067	.057	.096	.169	.210	.220	.224	.110
22H	.043	.020	.010	.100	.149	.103	.066	.056	.098	.173	.238	.257	.275	.122
23S	.036	.017	.015	.053	.086	.086	.043	.048	.068	.137	.205	.223	.230	.095
24H	.017	.008	.007	.047	.089	.060	.039	.032	.048	.121	.159	.183	.210	.078
25S	.047	.023	.014	.094	.127	.099	.078	.071	.144	.194	.244	.266	.278	.129
26H	.063	.030	.028	.070	.100	.090	.070	.069	.083	.144	.187	.196	.209	.103
27S	.080	.043	.040	.087	.100	.103	.077	.074	.088	.157	.206	.233	.228	.117
28H	.077	.044	.021	.070	.103	.076	.047	.045	.060	.116	.164	.183	.185	.092
29S	.075	.033	.026	.081	.138	.145	.103	.119	.171	.270	.323	.350	.352	.168
30H	.034	.017	.013	.054	.105	.094	.071	.074	.109	.176	.231	.255	.262	.114

S Steers
H Heifers

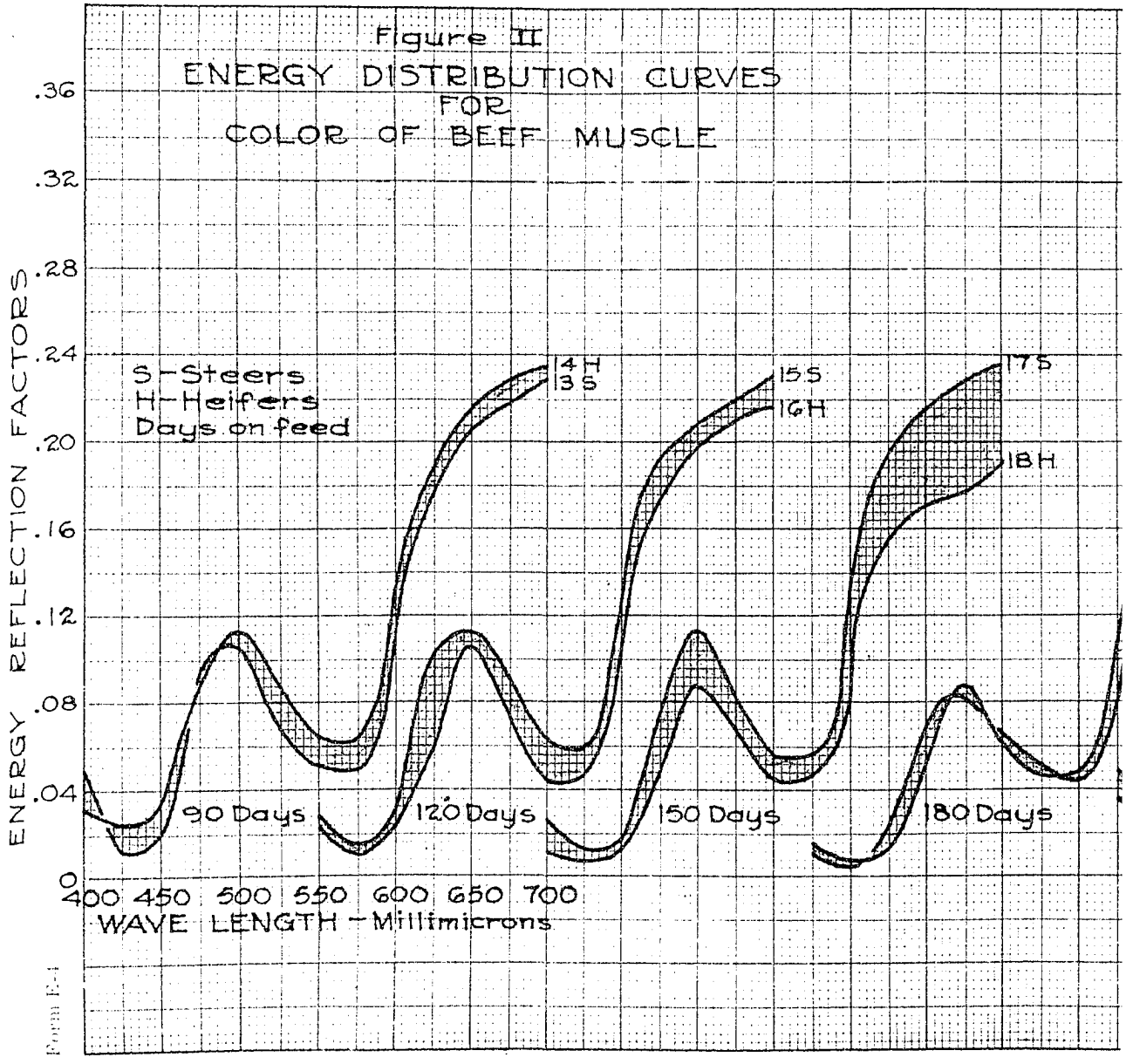
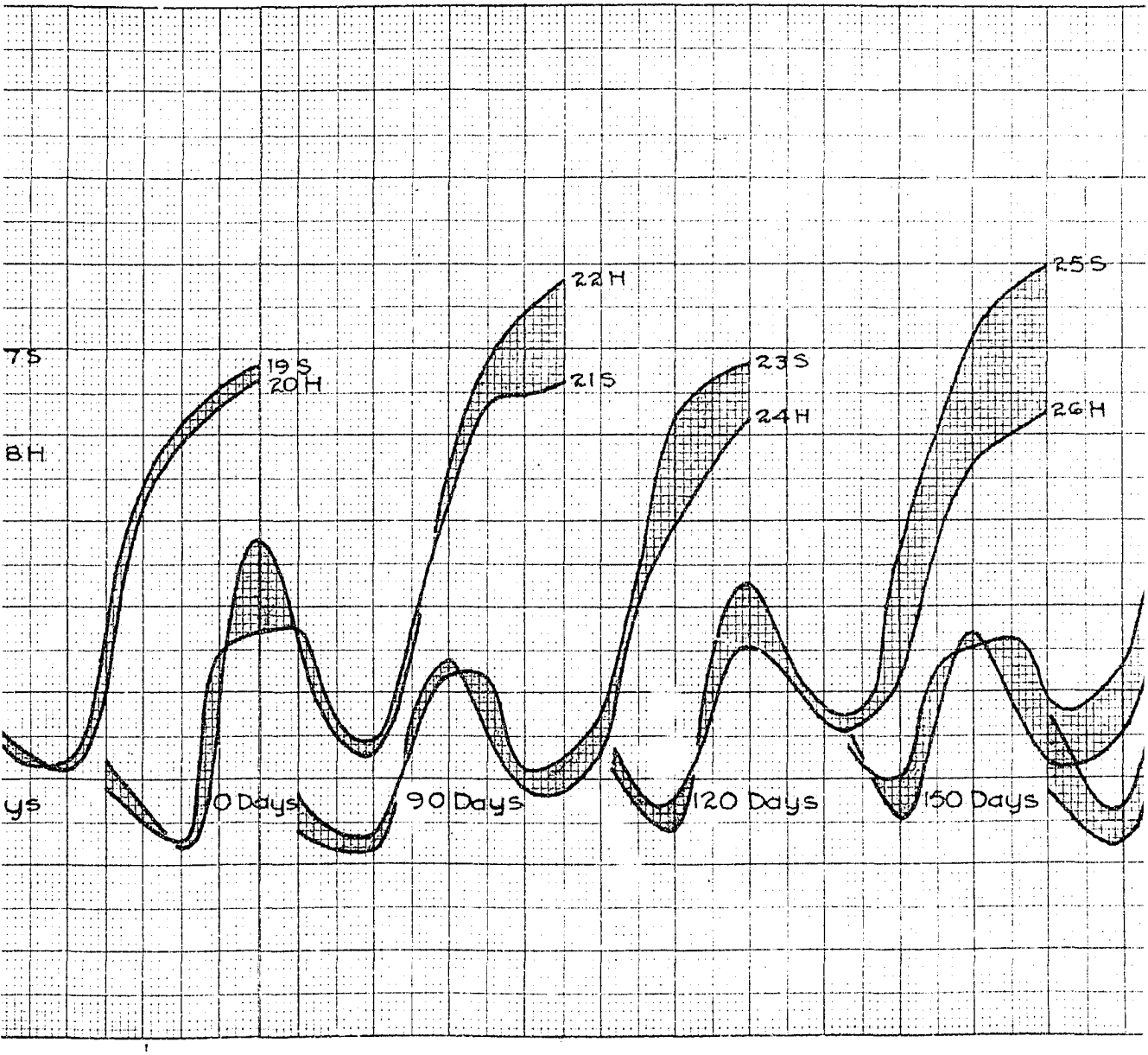
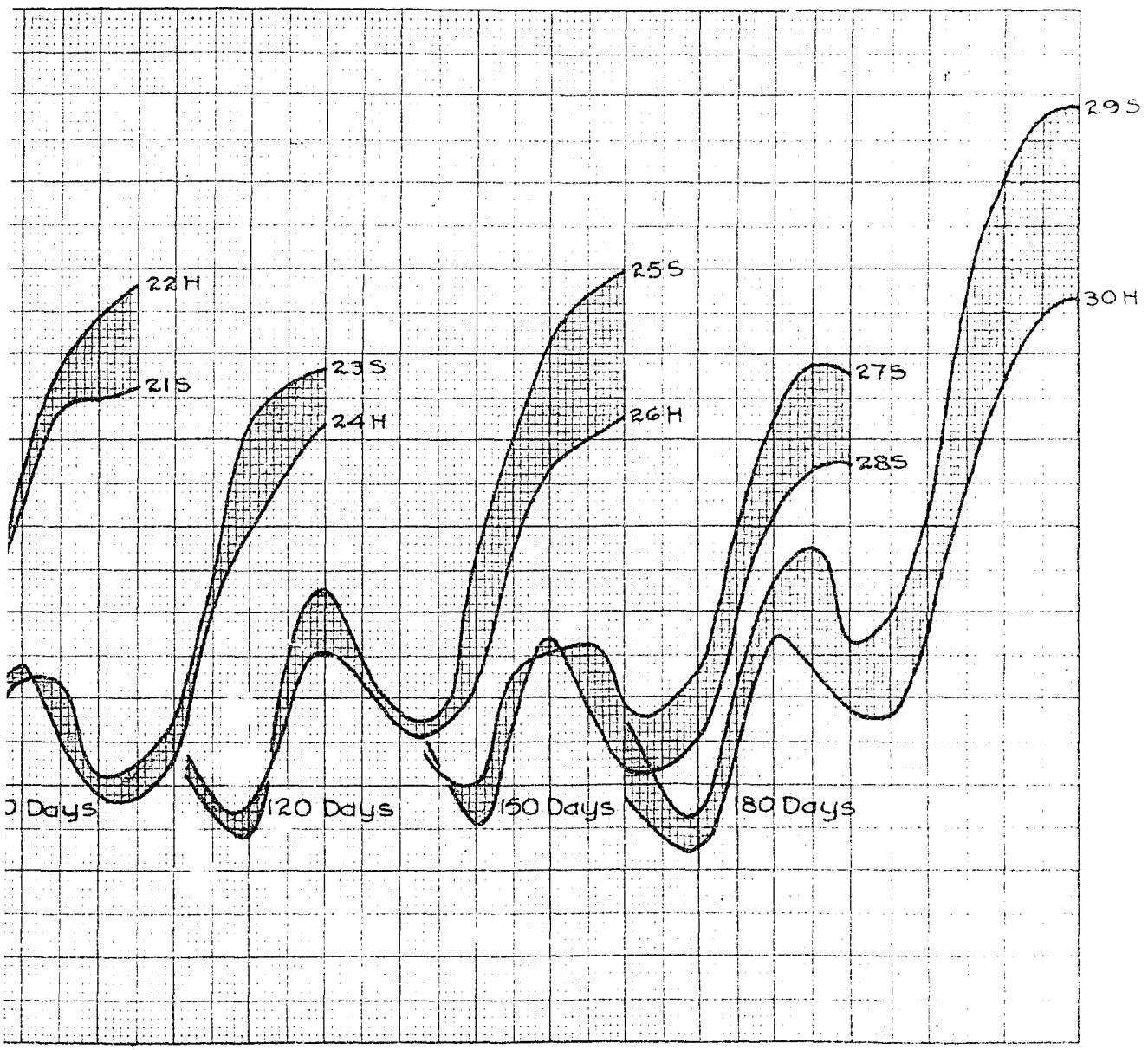


Figure II
ENERGY DISTRIBUTION CURVES
FOR
COLOR OF BEEF MUSCLE
ENERGY REFLECTION FACTORS
.36
.32
.28
.24
.20
.16
.12
.08
.04
0
S-Steers
H-Heifers
Days on feed
4H
3S
15S
16H
17S
18H
90 Days
120 Days
150 Days
180 Days
400 450 500 550 600 650 700
WAVE LENGTH - Millimicrons


7S
8H
ys
19S
20H
22H
21S
23S
24H
25S
26H
0 Days
90 Days
120 Days
150 Days


22H
21S
23S
24H
25S
26H
27S
28S
29S
30H
0 Days
120 Days
150 Days
180 Days

and between dates was calculated from the average ordinates of steers and of heifers.

During the first series, table XX, the average reflection factor of the flesh from steers was 14.50 percent greater than that from heifers at 120 days; 22 percent greater at 150 days, and 0 percent greater at 180 days. During the second series, table XXI, the average reflection factor of the flesh from steers was 20 percent greater than that from heifers at 120 days; 22 percent greater at 150 days, and 32 percent greater at 180 days.

Since the difference between the average reflection factor of steers and heifers seemed rather large, a comparison was made of the reflection factors from the blue and red bands of steer and heifer flesh to determine if there was any difference between these colors in the ratios of response. It was found, table XXII, that steers had a slightly higher ratio of blue to red in muscle than heifers in the first series, while the exact reverse was found in the second series. It was strongly indicated from these data that the energy response in the blue and the red bands was not correlated with age or obesity.

Color of fat. Very little difference in the color of renal fat was recorded between highly and thinly fleshed animals or between steers and heifers, table XXIII. All fats gave a high energy response at a wave length of 525 millimicrons. The response decreased through the green band but increased rapidly through the yellow, reaching the maximum response between the orange and red bands of the spectrum. These changes in the energy response for the different color bands while rather slight, indicate that fat from bovines, though it appears white or slightly tinted, contains substances with color pigments.

TABLE XXII

COMPARISON OF FAT CONTENT AND RATIO OF BLUE TO RED ORDINATES OF THE SPECTRAL BANDS

Animal number	Empty body weight	Fat percent in carcass	Maximum blue ordinate	Maximum red ordinate	Ratio of blue to red
13S	425	21.62	.114	.226	.504
14H	425	21.89	.103	.232	.444
15S	529	26.45	.113	.234	.483
16H	541	35.20	.101	.212	.476
17S	590	24.84	.112	.236	.474
18H	537	28.41	.083	.193	.430
19S	715	30.14	.083	.230	.361
20H	637	37.73	.081	.226	.359
23S	478	19.67	.086	.230	.374
24H	529	27.00	.089	.210	.424
25S	573	27.58	.127	.278	.457
26H	552	33.97	.100	.209	.478
27S	659	26.77	.100	.228	.439
28H	651	30.46	.103	.185	.557
29S	728	32.17	.138	.352	.392
30H	739	35.13	.105	.266	.395

S Steer
H Heifer

TABLE XXIII

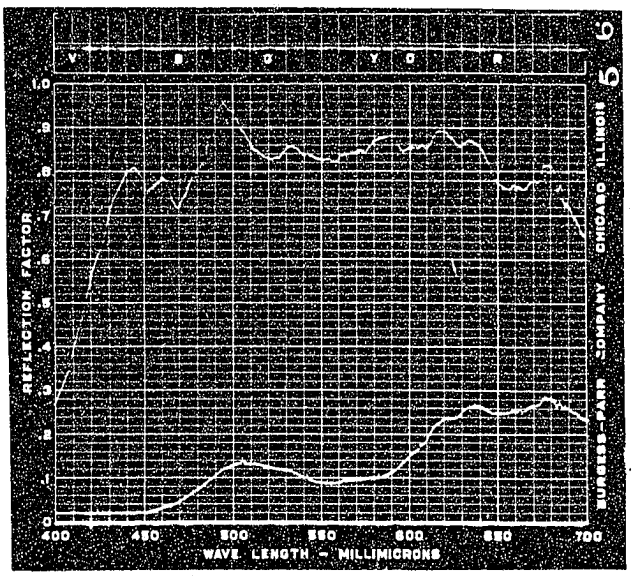
ENERGY REFLECTION FACTOR OF FAT TO STANDARD WHITE THROUGHOUT THE SPECTRAL COLOR BAND

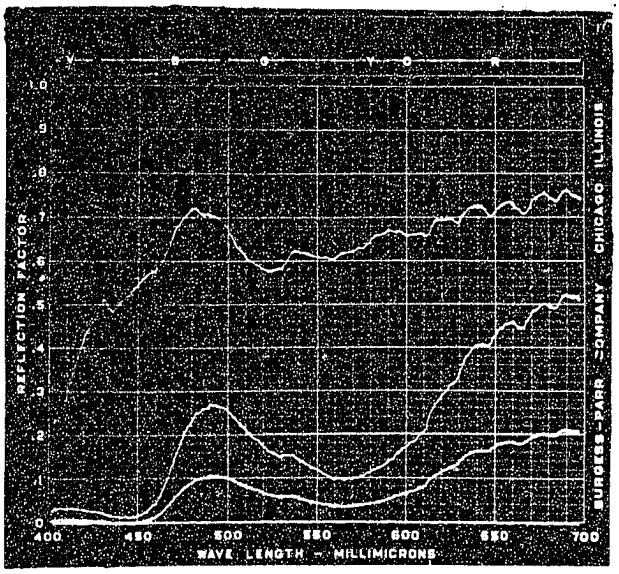
Animal:	Wave Length (Millimicrons)													
no.	400	425	450	475	500	525	550	575	600	625	650	675	700	Av.
15S	.488	.366	.500	.533	.569	.623	.613	.588	.669	.672	.671	.681	.692	.590
16H	.381	.329	.409	.446	.462	.528	.510	.506	.585	.581	.571	.565	.575	.496
17S	.514	.433	.533	.643	.651	.642	.622	.622	.742	.738	.770	.763	.737	.647
18H	.486	.400	.483	.518	.540	.612	.585	.578	.667	.677	.672	.678	.684	.583
19S	.459	.371	.474	.507	.518	.604	.591	.602	.674	.696	.674	.685	.686	.580
20H	.329	.286	.400	.440	.476	.534	.500	.500	.578	.596	.580	.568	.545	.487
21S	.259	.210	.279	.338	.351	.419	.392	.413	.507	.545	.557	.554	.549	.413
22H	.435	.316	.370	.403	.454	.566	.542	.556	.621	.650	.653	.662	.662	.530
23S	.469	.400	.508	.569	.618	.685	.633	.656	.703	.771	.756	.764	.762	.638
24H	.448	.350	.428	.506	.557	.630	.588	.619	.658	.700	.696	.707	.701	.584
25S	.300	.217	.282	.345	.400	.546	.397	.425	.464	.522	.512	.512	.526	.419
26H	Sample discarded because of mechanical difficulties													
27S	.242	.197	.227	.233	.238	.272	.266	.273	.292	.298	.301	.282	.289	.262
28H	.206	.169	.202	.210	.224	.233	.215	.219	.233	.247	.238	.238	.237	.221
29S	.500	.400	.421	.432	.484	.550	.545	.549	.567	.571	.562	.548	.544	.513
30H	.536	.417	.472	.500	.538	.613	.593	.596	.640	.651	.641	.638	.646	.575

S Steers
H Heifers

ILLUSTRATION I

PHOTOELECTRIC SPECTROPHOTOMETRICAL
COLOR OF BOVINE MUSCLE

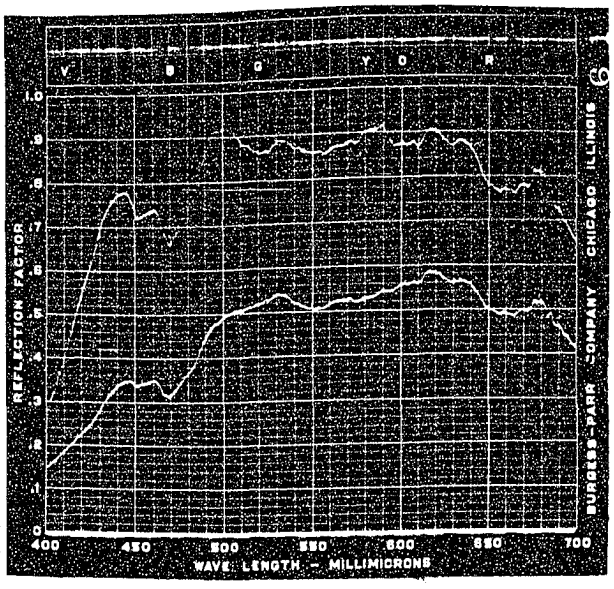


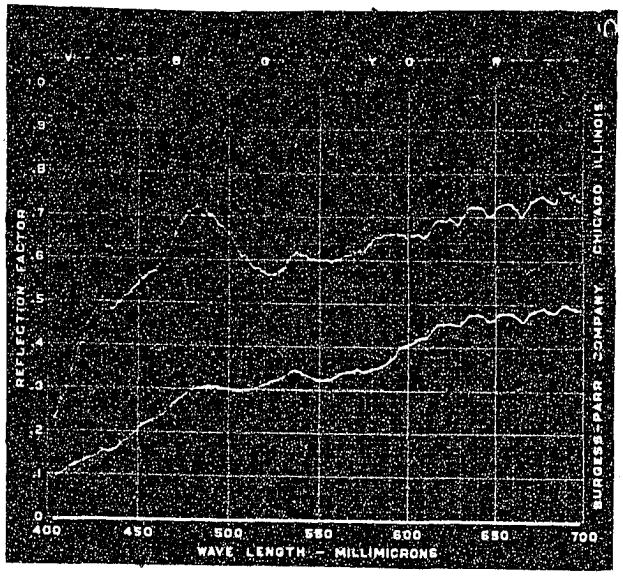


TOP LINE IN EACH RECORD IS THE CURVE TRACED FROM THE STANDARD WHITE. BOTTOM LINE IS THE LIGHT RESPONSE FROM THE RAW MEAT SAMPLE. THE MIDDLE LINE IS THE INTENSITY OF LIGHT MULTIPLIED BY $2\frac{1}{2}$ TIMES.

ILLUSTRATION II

PHOTOELECTRIC SPECTROPHOTOMETRICAL
COLOR OF BOVINE FAT





COLOR ANALYSIS OF FAT (BOTTOM CURVE)
AS COMPARED TO THE STANDARD WHITE

External fat had a much lower spectral energy response, but in other respects the changes in energy reflection factors coincided rather closely with those from renal fats.

Culinary and Palatability Tests

The culinary and palatability tests were made on the standing ribs of beef.

The cooking losses from steer roasts aged 10 days and 30 days are given in table XXIV; those from heifer roasts in table XXV.

The total cooking loss* from roasts aged 10 days irrespective of degree of fatness or sex was greater than that from roasts aged 30 days. As shown from the data in tables XXIV and XXV the major difference in loss between roasts aged 10 days and those aged 30 days was in the loss of volatile substances, and caused by the occurrence of greater dehydration in the longer aged roasts.

The total loss from roasts weighing, roughly, three pounds and taken from the young, thinly fleshed animals slaughtered at the 0 day period, was about the same as that from nine pound roasts taken from older and fatter animals slaughtered at the 180 day period. Obviously the constituents which composed the loss were widely different. Whereas the loss from the small roast was almost entirely volatile, that from the larger

*The total cooking loss, made up of volatile substances and drippings, is the difference between the weights of the roasts before and after cooking. The dripping loss is the weight of the fat and meat juices which escape from the roast and accumulate in the pan. Volatile loss is the difference between the total loss and the drippings.

TABLE XXIV

LOSSES DURING COOKING FROM RIB ROASTS

Steers

Animal no.	Weight lbs. Aged 10 days	Weight lbs. Aged 30 days	Cooking Losses Roast Aged 10 Days: Volatile %	Drip %	Total %	Cooking Losses Roast Aged 30 Days: Volatile %	Drip %	Total %	Minutes per Pound to Cook Aged 10 days	Minutes per Pound to Cook Aged 30 days
2S	2.37	3.08	10.30	.56	10.86	7.83	.57	8.44	25.3	20.4
11S	2.48	*	9.51	.71	10.22	*	*	*	24.2	*
21S	2.50	3.09	9.95	.35	10.30	9.64	.57	10.21	22.4	23.6
Av.	2.45	3.08	9.92	.54	10.46	8.73	.57	9.32	23.9	22.0
3S	4.76	7.13	7.81	1.15	8.96	9.43	1.33	10.76	24.3	20.3
13S	4.95	5.24	7.20	1.24	8.44	9.38	1.60	10.98	22.2	25.4
23S	5.27	5.50	6.94	1.67	8.61	6.43	1.77	8.20	20.5	20.9
Av.	4.99	5.99	7.31	1.35	8.67	8.41	1.57	9.98	22.3	22.2
5S	6.01	7.68	7.36	3.08	10.44	5.80	2.01	7.81	23.0	20.6
15S	5.98	6.48	7.30	3.24	10.54	8.30	2.51	10.81	26.2	18.5
25S	6.21	7.44	6.46	2.38	8.84	3.76	5.24	9.00	20.6	19.2
Av.	6.06	7.20	7.04	2.90	9.94	5.95	3.25	9.21	23.3	19.4
7S	7.19	8.87	7.12	3.21	10.33	5.17	2.13	7.30	20.6	19.7
17S	6.49	7.88	7.31	2.56	9.86	5.43	2.07	7.50	19.4	19.3
27S	7.60	8.47	5.71	2.83	8.54	5.60	2.31	7.91	19.0	18.9
Av.	7.09	8.41	6.71	2.87	9.58	5.40	2.17	7.57	19.7	19.3
9S	8.33	9.53	6.00	4.79	10.79	5.90	4.14	10.04	20.4	19.9
19S	8.20	9.39	7.26	3.44	10.70	5.42	3.68	9.11	18.9	17.1
29S	8.77	10.23	5.40	3.79	9.19	6.98	4.26	11.24	18.1	18.5
Av.	8.40	9.72	6.22	4.01	10.23	6.10	4.03	10.13	19.1	18.5

* Roast discarded because of excessive deterioration

S Steers

TABLE XXV

LOSSES DURING COOKING FROM RIB ROASTS

Heifers

Animal no.	Weight lbs. Aged 10 days	Weight lbs. Aged 30 days	Cooking Losses Roast Aged 10 Days: Volatile %	Drip %	Total %	Cooking Losses Roast Aged 30 Days: Volatile %	Drip %	Total %	Minutes per Pound to Cook Aged 10 days	Aged 30 days
1H	2.34	3.30	9.67	.38	10.05	7.40	.40	7.80	23.5	22.1
12H	2.04	*	9.83	.21	10.04	*	*	*	22.0	*
22H	3.47	4.38	8.38	2.22	10.60	8.65	.91	9.56	23.0	26.0
Av.	2.62	3.84	9.29	.94	10.23	8.03	.65	8.68	22.8	24.0
4H	4.42	5.55	7.47	2.19	9.66	6.03	1.20	7.23	24.8	22.0
14H	4.53	5.16	7.23	1.50	8.73	9.35	2.43	11.78	22.5	25.2
24H	5.73	6.40	6.00	2.50	8.50	7.17	2.60	9.77	23.0	22.6
Av.	4.89	5.70	6.90	2.06	8.96	7.52	2.08	9.59	23.4	23.3
6H	6.44	7.62	6.81	4.34	11.16	5.20	2.95	8.15	23.3	19.7
16H	6.29	7.47	9.50	2.63	12.12	6.14	3.42	9.56	23.8	18.1
26H	5.93	7.44	6.10	4.69	10.79	3.47	5.15	8.62	21.9	16.4
Av.	6.22	7.51	7.47	3.89	11.36	4.94	3.84	8.78	23.0	18.1
8H	6.76	8.20	5.14	4.49	9.63	3.65	2.90	6.60	20.0	19.5
18H	5.33	6.74	7.19	2.97	10.16	6.18	2.51	8.69	19.3	22.3
28H	8.00	8.07	4.96	3.83	8.79	4.61	3.55	8.16	18.1	17.3
Av.	6.70	7.67	5.76	3.76	9.53	4.81	2.99	7.82	19.1	19.7
10H	9.59	9.56	4.99	6.27	11.26	3.82	4.03	7.85	20.3	18.9
20H	7.53	8.08	6.69	4.68	11.37	5.53	3.24	8.78	19.3	19.2
30H	8.69	10.25	5.00	5.27	10.27	5.67	5.17	10.84	20.4	19.0
Av.	8.60	9.30	5.56	5.41	10.97	5.01	4.15	9.16	20.0	19.0

* Roast discarded because of excessive deterioration

H Heifers

and fatter roast was distributed more nearly equally between volatile and dripping loss.

Cooking losses of roasts from steers and heifers slaughtered on the same date were similar in quantity but different in kind. It is shown in table XXVI that the volatile loss of roasts from steers was greater at

TABLE XXVI

Fatness of Ribs from Steers and Heifers, and Cooking Losses of Rib Roasts

Days on feed	Percent fat prime ribs	10 Days			30 Days		
		Volatile	Drip.	Total	Volatile	Drip.	Total
0*	10.24	9.92	.54	10.46	8.73	.57	9.30
0⊥	10.92	9.29	.94	10.23	8.03	.65	8.68
90	21.50	7.31	1.35	8.67	8.41	1.57	9.98
90	21.17	6.90	2.06	8.96	7.51	2.08	9.59
120	26.87	7.04	2.90	9.94	5.95	3.26	9.21
120	35.41	7.47	3.89	11.36	4.94	3.84	8.78
150	28.52	6.71	2.87	9.58	5.40	2.17	7.57
150	34.81	5.76	3.76	9.53	4.81	2.99	7.82
180	35.28	6.22	4.01	10.23	6.10	4.03	10.13
180	41.56	5.56	5.41	10.97	5.01	4.15	9.16
Av.							
Steers	24.50	7.44	2.33	9.77	6.91	2.33	9.24
Heifers	28.78	6.99	3.21	10.21	6.06	2.74	8.80

*Steer
⊥Heifer

each cooking date than that from heifers, while the greater dripping loss was noted in the roasts from heifers. It is also noted in the table that, with one exception, the prime ribs from heifers were fatter at each

slaughter date than those from steers. The average fat content of prime ribs from heifers was 28.78 percent and the average dripping loss 3.21 percent, whereas the ribs from steers had a fat content of 24.50 percent, and a dripping loss of 2.33 percent.

Cooking time

There was only a small difference between roasts in respect to the cooking time required per pound despite the wide difference between the weights of roasts from thinly fleshed and those from fatter animals.

The time for roasting ribs from heifers, usually fatter and better marbled, did not consistently differ from that required for ribs from steers. The average time required to roast ribs from steers and heifers at each cooking period was almost identical with that from heifers.

Palatability scores

A "cooked-meat-grading chart", illus. III, was used for recording the palatability scores of the samples. The scores for the roasts aged 10 days and those aged 30 days from steers and heifers slaughtered at five different periods are summarized in table XXVII.

ILLUSTRATION III

MEAT COOKING RECORD

GRADING CHART FOR COOKED MEAT

SHEET NO. 7 Cooking Laboratory No.____ Sample No.____ Kind____ Date____

FACTOR	PHASE	7	6	5	4	3	2	1	REMARKS
Aroma	Intensity	Very pronounced	Pronounced	Moderately pronounced	Slightly pronounced	Perceptible	Slightly perceptible	Imperceptible	What aroma____
	Desirability	Very desirable	Desirable	Moderately desirable	Slightly desirable	Neutral	Slightly undesirable	Undesirable	Normal or abnormal?__
Texture	Intensity	Very fine	Fine	Moderately fine	Slightly coarse	Coarse	Very coarse	Extrenely coarse	
Flavor of Fat	Intensity	Very pronounced	Pronounced	Moderately pronounced	Slightly pronounced	Perceptible	Slightly perceptible	Imperceptible	What flavor?____
	Desirability	Very desirable	Desirable	Moderately desirable	Slightly desirable	Neutral	Slightly undesirable	Undesirable	Normal or abnormal?__
Flavor of Lean	Intensity	Very pronounced	Pronounced	Moderately pronounced	Slightly pronounced	Perceptible	Slightly perceptible	Imperceptible	What flavor?____
	Desirability	Very desirable	Desirable	Moderately desirable	Slightly desirable	Neutral	Slightly undesirable	Undesirable	Normal or abnormal?__
Tenderness	Intensity	Very tender	Tender	Moderately tender	Slightly tough	Tough	Very tough	Extremely tough	
Quality of Juice	Intensity	Very rich	Rich	Moderately rich	Slightly rich	Perceptible	Slightly perceptible	Imperceptible	
	Desirability	Very desirable	Desirable	Moderately desirable	Slightly desirable	Neutral	Slightly undesirable	Undesirable	
Quantity of Juice	Intensity	Very large	Large	Moderately large	Slightly large	Small	Very small	Negligible	
	Desirability	Very desirable	Desirable	Moderately desirable	Slightly desirable	Neutral	Slightly undesirable	Undesirable	

COLOR OF LEAN

1.Light red. 4.Pinkish brown.
2.Dark pink. 5.Light brown.
3.Light pink. 6.Dark brown.

COLOR OF FAT

1.White. 4.Yellowish brown.
2.Creamy white. 5.Yellow.
3.Grayish cream. 6.Amber.

NOTE: Encircle the words which describe intensity, mark desirability and color with a check.

_____
(Signature of judge)

TABLE XXVII

SUMMARY OF PALATABILITY SCORES* ON COOKED ROASTS FROM STEERS AND HEIFERS

Days on feed	Aroma: In-tensity	Aroma: Desirability	Texture	Flavor: Fat: In-tensity	Flavor: Fat: Desirability	Flavor: Lean: In-tensity	Flavor: Lean: Desirability	Tenderness	Juiciness: Quality	Juiciness: Quantity	Means
Roasts from Steers - Aged 10 Days											
0	4.3	4.5	5.1	4.0	4.0	4.2	4.2	4.2	3.3	2.9	4.07
90	5.1	5.3	5.2	4.8	5.0	4.4	5.3	5.7	4.5	4.3	4.96
120	4.6	5.1	4.9	4.6	4.8	4.4	5.1	5.7	4.8	4.9	4.89
150	4.5	5.3	5.7	5.1	5.4	5.2	6.1	6.3	5.7	5.7	5.50
180	5.2	5.5	5.5	5.2	5.9	5.7	6.0	6.1	5.8	5.7	5.66
Av.	4.74	5.14	5.28	4.74	5.02	4.78	5.34	5.6	4.82	4.7	5.01
Roasts from Heifers - Aged 10 Days											
0	4.4	4.5	4.9	4.0	4.3	4.5	4.1	4.1	3.4	3.4	4.16
90	5.1	5.5	5.4	4.7	5.3	4.9	5.4	5.8	4.4	4.8	5.13
120	4.6	4.9	5.3	4.7	5.1	4.7	5.5	5.6	5.1	5.1	5.06
150	4.9	5.5	5.6	5.4	5.5	5.0	6.2	6.0	5.9	5.2	5.52
180	5.0	5.5	5.3	5.4	5.9	5.4	5.9	6.3	6.0	5.7	5.64
Av.	4.8	5.18	5.3	4.82	5.22	4.9	5.42	5.56	4.96	4.84	5.10
Roasts from Steers - Aged 30 Days											
0	4.2	4.2	5.5	4.0	4.2	4.3	3.8	4.8	3.4	3.2	4.16
90	5.0	4.6	5.2	4.4	4.3	4.8	5.0	5.7	4.9	5.0	4.89
120	5.1	5.3	5.2	4.6	5.1	4.9	5.9	5.9	5.0	5.7	5.28
150	5.1	5.8	5.9	4.9	5.9	5.2	6.2	6.2	5.8	6.1	5.71
180	5.3	6.2	5.8	5.4	5.6	5.7	5.9	6.1	6.1	6.2	5.83
Av.	4.94	5.22	5.52	4.66	5.02	4.98	5.36	5.74	5.04	5.24	5.17
Roasts from Heifers - Aged 30 Days											
0	4.3	3.9	5.5	4.2	4.2	4.7	3.7	4.7	4.2	4.2	4.36
90	4.9	4.8	5.3	4.2	4.6	4.6	4.7	5.7	4.9	5.3	4.90
120	5.4	5.6	5.4	4.7	5.5	5.1	6.0	5.6	5.3	5.8	5.44
150	5.1	5.8	5.8	5.0	5.9	5.2	6.3	6.3	5.7	5.6	5.67
180	5.4	6.1	5.7	5.6	6.1	5.5	5.9	6.6	6.1	6.1	5.91
Av.	5.02	5.24	5.54	4.74	5.26	5.02	5.32	5.8	5.24	5.4	5.26

* A perfect score is 7

The scoring committee was unanimous in its opinion that the palatability of the roast improved as the animals became older and fatter.

The most striking change in the roasts recorded by the committee was the increase in the juiciness of the flesh as the animals became fatter. The score for quality and quantity of juice in roasts markedly increased in both sexes and the score for quantity of juice in roasts from heifers was slightly higher at each interval than that from steers.

Texture, according to the scores, showed less change throughout the period than any other factor considered with palatability.

All other factors of palatability increased in value as the animals became older and fatter.

Aging the roasts from cattle fed 90 days or less proved to be a detriment to the flavor of both fat and lean, while aging roasts from the fatter cattle enhanced their palatability, particularly noted by increases in the juiciness of the flesh and improvement in the aroma.

A comparison was made between sexes, of roasts aged 10 days and 30 days, based on the average score of five factors considered as the most important in determining palatability. The factors were desirability of aroma, of fat, of lean, of tenderness, and of quality of juice. The average score of these factors for roasts aged 10 days, was 5.18 from steers, and 5.27 from heifers. The average score on roasts aged 30 days was 5.28 from steers, and 5.37 from heifers. Since the palatability of the roasts was so nearly the same, the utmost statement supported by the data regarding the differences between sexes is that the judges slightly preferred roasts from heifers.

Tenderness

Tenderness of the meat was determined by measuring the pressure required to shear the uncooked meat, and by a palatability test which included a value for tenderness. The results of these two tests, summarized with respect to sex, and to fatness of animals designated by days on feed, are shown in table XXVIII.

TABLE XXVIII

Shearing Strength of Raw Muscle as Compared with Tenderness Score of Cooked Roasts

	Days on Feed				
	0	90	120	150	180
	Pounds Required to Shear				
Steers	32.72	28.26	36.16	29.60	31.33
Heifers	39.04	30.90	29.06	24.97	30.87
	Committee Score				
	Roasts Aged 10 Days				
Steers	4.2	5.7	5.7	6.3	6.1
Heifers	4.1	5.8	5.6	6.0	6.3
	Roasts Aged 30 Days				
Steers	4.8	5.7	5.9	6.2	6.1
Heifers	4.7	5.7	5.6	6.3	6.6

The shearing strength of raw muscle varied widely between the sexes and between degrees of fatness of the animals. According to this test tenderness was not materially increased in either of the sexes, even in ex-

tended fattening periods of the animals.

The scores by the committee indicated, that with increased age and fatness of the animals, the tenderness of the cooked meat, from roasts stored 10 days, increased 45 to 54 percent; from roasts stored 30 days, the tenderness increased 27 to 40 percent. The meat from heifers showed the greater increase in tenderness in both cases. There was no appreciable difference between steers and heifers within dates in the increase in tenderness due to aging of the meat prior to roasting.

DISCUSSION OF RESULTS

Live Weights of Steers and Heifers in the Slaughter Test

Two lots of both steer and heifer calves were fed during each of the three years that this study was in progress. Each lot contained eight or more calves. One lot of steers and one lot of heifers were designated at the beginning of the feeding period each year as the lots from which five steers and five heifers were to be selected for slaughter. The selection of animals from the lots for slaughter was mainly with respect to size and degree of fatness. The animal which represented, as nearly as could be determined, the average of the lot was selected at each slaughtering period. The weights of animals slaughtered often varied markedly from the average of the lot, which strongly indicated that weight was not given much consideration in selecting the average animal.

The variation in weight between individuals within lots is rather clearly indicated in table I. The average initial weight of steer calves placed on feed was 417 pounds and coincidentally the average initial weight of steer calves slaughtered was also 417 pounds.

The average weight of heifer calves placed on feed was 405 pounds, while the average initial weight of those ultimately slaughtered in the test was 395 pounds. In a total of 15 slaughtered periods the weights of steers exceeded those of heifers eleven times. The data in table I reveal that the animals selected for slaughter varied widely in their

initial weights. Invariably the initial weights of animals that were slaughtered after 0 day and after 90 days on feed were less than those which were slaughtered after 150 and 180 days on feed. However, the similarity of the methods followed in selecting animals for slaughter in both sexes is indicated by the small difference in the average initial and final weights between steers and heifers.

The differences between years in the ratio of final weight to initial weight of individuals slaughtered and of final weights to average lot weights of cattle are of such character as to preclude any general explanation as to their causes. The decision as to the individual from each lot to slaughter at each date was based primarily upon inherent characteristics of the group. The fact that lots of cattle do not respond alike to treatment is evidence of the inability accurately predict animal performance.

Dressing Percentage

Dressing percentage, or the proportion of the chilled carcass to the live weight, varies even in animals of similar age, weight, and degree of fatness because of differences in alimentary content, or "fill", and of the internal fat content.

The influence of "fill" was minimized in this study when all animals marked for slaughter were removed from feed 24 hours prior to slaughter, but all had access to water. There is the possibility, however, that one animal had eaten more just before it had been taken off feed, and consequently it might have drunk more water, resulting in less shrinkage

to the tissue while fasting. To remove completely the influence of "fill", the yields of carcass were calculated on the basis of empty body weights. This body weight was obtained by subtracting the weight of the alimentary content from the live weight of the animal.

Internal Fats

Mesenteric fats, considered a part of the offal, are removed from the body in dressing cattle, and obviously any development of these fats will tend to reduce the percentage of carcass. The percentages of mesenteric fats of steers and heifers at the different slaughter periods are shown in table IV. Fats designated as miscellaneous included the pericardium and the trimmings from the internal organs after the omentum and ruffle were removed.

As was to be expected, the internal fats increased as the animals became heavier, regardless of sex, and in this study considerable variation between the live weight and the fat content in the splanchnic area was noted in both steers and heifers.

Because heifers had a greater percentage of internal fats it would appear that they would have a lower yield of carcass than steers. This point of view is supported by three other observations; the similarity of daily gains made in the feed lot by steers and heifers; the similarity of ratios between empty body weights and live weights, and the lighter weights of the heifers as compared with steers at each slaughter date. Despite all this evidence which implies that the steers should have the higher dressing percentage, the heifers had the higher average dressing

percentage at every slaughter date. Therefore, the logical deduction is that the dressing percentage is determined by many factors, and that internal fat is only one. The biological functions of the organs of the body determine the magnitude of the dressing percentage of an animal. The interaction of these functions varies between ages, degrees of fatness, sexes, environmental conditions, and possibly in other ways. Compared with the internal fat of steers the preponderance of internal fat in heifers was more than counterbalanced by developments in the skeletal area of the body. This substantiates the opinion of cattle producers that the females mature more rapidly and at an earlier age than the males.

Cutting tests revealed some rather distinct differences between steers and heifers in the development of carcasses. The primal cuts from steers were approximately 1¼ percent less than from heifers at the beginning and 2 percent more at the end of the feeding period. The difference between sexes in primal cuts may be of much more importance than indicated by a difference of 2 percent in the yields. Due to consumer demand the primal cuts are sold 25 to 30 percent above and all other cuts 33 1/3 to 50 percent below the average carcass price. Therefore a difference between two carcasses of 2 percent in yield of primal cuts is equivalent to 0.3 cents per pound for 16 cent carcasses and 0.5 cents per pound for 21 cent carcasses. To some this may appear as trivial, but buyers and sellers of carcass beef transact their business on a 0.25 cent spread in price. Both steers and heifers showed a general decline in the ratio of primal cuts to other parts of the carcass during the feeding period, and the body development in heifers resulted in a

greater decline than in steers. Considering these reductions from another viewpoint, the less demanded cuts were increased 5.57 percent in steers and 8.71 percent in heifers by the 180th day. These differences between sexes in body development support the contention of many cattle feeders that heifers fatten faster and finish at lighter weights than steers.

Since no outstanding differences between sexes in the weights of the primal cuts were found, a physical analysis was made of all the cuts to determine the difference in the distribution of lean, fat, and bone in the wholesale cuts of steers and heifers.

Physical Composition of Beef Carcasses

The quality of beef, as has been pointed out, involves not only the character of tissue substances but also the quantity and distribution of the constituent parts which compose the flesh. It has been shown that the size and shape of a particular wholesale cut of beef will vary within the sex as well as between sexes, which suggests that cuts may differ also in the distribution of the quantity of tissue substances that compose the pieces.

The steers increased their fat content approximately 7 percent, while the heifers increased their fat content more than 10 percent during the 90 - 120 day interval. This difference between sexes in the rate at which the fat is deposited with respect to total constituents in the carcass is in substantial agreement with the opinion of cattle feeders - that is, heifers fatten much more rapidly than steers during the first 120 days

that the animals are on feed.

In view of the rapid fattening tendencies of steers and heifers during the 90 - 120 day and the 150 - 180 day periods, the marked recession in the trend of tissue development, as shown in the data between 120 days and 150 days, appears illogical. Such drastic changes might be attributed to failure on the part of the committee to recognize animals representing average performance in the feed lot. There is some evidence in the data to support this, but it is not the whole explanation. Comparing the live weights of animals slaughtered at each date, as shown in table I, it is noted that the weights increased from 60 pounds and 100 pounds per month, which corresponds quite closely with the average daily gains of all animals in the feed lot. Furthermore, as shown in table XI, the pounds of fat in carcasses were increased at each succeeding slaughter period. The gain in body weight and fatness is offered as conclusive evidence that the animals selected were representatives of the group at the date of slaughter.

Concerning the animals slaughtered at 120 days and 150 days, it is shown in tables V and VI that in two out of three years, steers as well as heifers showed a higher percentage of fat on the 120th day than on the 150th day. The difference in percentages of total fat between dates in both steers and heifers can be readily calculated from data in table XI. The difference in percentage of fat content of steer carcasses at 150 days as compared with that at 120 days was as follows: first year, plus 4.6; second year, minus 1.5; third year minus 0.85, and of heifer carcasses: first year, plus 8.6; second year, minus 6.6; third year, minus 3.5 These percentages might be taken to indicate that cattle slaughtered the

first year were either larger on both of these dates, or that differences in weight between dates were greater than those in animals slaughtered at the same period during succeeding years. On the contrary, the live weights of the cattle and the carcass weights for the first year were of such magnitude as to fall between those slaughtered in other years at both the 120 day and 150 day periods.

No investigations were made of the ancestry of the calves, except to note that they were Hereford grades. It is recalled that the calves used in the first year's study were not from the same herd of cattle or even from the same section of the plains region as those used during the second and third years. Although the calves looked much alike in conformation it is highly probable that the genetical background varied in many respects, and therein may lie the solution to the differences between calves in rate of fattening. Whether the changes in the trend of tissue development observed during the 120 - 150 day period was due to misinterpretation of animal performance in the feed lot, or to innate characteristics of cattle, must be left for future work to decide.

Ratio of lean and fat to bone

A knowledge of the proportion of wholesale cuts and of their constituent parts to the carcass does not furnish a complete account of the edible part of the cut. The edible part is determined by the ratio of the lean and fat to the bone and tendons.

Meat retailers as a whole are of the opinion that steers have less waste fat and a greater proportion of primal cuts to carcass than heifers.

Results of cutting test in this study are in accord with this opinion although the difference between the two sexes is not nearly as great as is generally indicated.

From a consumer's viewpoint the proportion of edible to non-edible part in any retail cut is of much importance. These studies show that for cattle weighing 900 pounds or less the proportion of edible to non-edible part in the primal cuts is greater in heifer than in steer beef. It was shown by physical analysis that the ratio of lean and of fat to bone was higher in the primal cuts as well as in the carcass as a whole, from heifers than that from steers. Explanation for this lies in the fact that the skeleton was smaller in heifers than in steers.

Although the ratio of edible to non-edible parts was higher in heifer than in steer beef it is not logical to assume that retail cuts from heifers should always be preferable to those from steers. Much depends upon the quantity of fat required to bring out the quality and palatability of the meat. There is no unanimity of opinion on this point, for a given quantity of fat may be considered necessary by one consumer and excessive by another. Hence the extent to which quality of beef can be improved by increasing the fat content is purely a matter of personal opinion. Likewise judgment as to the redundance of fat rests with the individual.

The principal differences between sexes brought out by physical analysis of the carcasses were that heifers fed 120 days were comparable to steers fed 180 days in total fat content of the carcasses, and heifers fed 150 days were comparable to steers fed 180 days in fatness of primal cuts. This observation is of particular interest since cattle feeders

in general maintain that heifers are commonly about 30 days in advance in degree of finish of steers of similar weight and age.

Histological Studies

The quantity and the distribution of fat in the body are of great economic importance, because of their influence upon the value of the carcass; for a pound of fat deposited between the muscles, or of the marbling fat is of much greater value than the same amount deposited in the renal or in the subcutaneous area. Of even more economic value in improving the quality and tenderness of the muscle are the intramuscular fats, generally referred to as the marbling of the meat, and the liposomes, or the intracellular fats. No analyses were made to determine the quantity of marbling fat, since no way by which it could be segregated physically from other fats was known, but a study was undertaken to determine, by histological methods, the size and abundance of liposomes in muscle cells. Because of the characteristics of these microscopic fat bodies, it was impossible to study them in every skeletal muscle; therefore, a section of the longissimus dorsi muscle was selected as representative of the fat accumulations in the more important meat areas of the bovine carcass.

There was little to indicate the probable location of liposomes within the sarcoplasm of the muscle of the calves, but as the animals became fatter these droplets became more numerous and larger in size. The liposomes then began to occupy a more or less definite position within the fiber. In highly fattened beef the liposomes appeared in rows of bead-

like formation along the outer surfaces of the fibrilae or between them. At no time did they appear to have an inclusive substance which could be seen to serve as a cell membrane.

It was definitely shown that liposomes were not distributed equally among all fibers of a given fasciculus. They seemed to accumulate in a fiber or in a small group of fibers, while adjacent fibers contained comparatively few. Furthermore, the fibers which had the greater preponderance of these droplets did not appear to occupy any definite position within the fasciculi.

Since there seemed to be no unanimity of opinion among investigators regarding the relationship between the liposome content and the general plane of adiposity of animals, a preliminary study was made, by using rats, to determine the changes in the liposome content of a muscle due to age, degree of fatness, and sex.

Fats in the bodies of mature and half grown rats were exhausted by inanition, then rapidly replenished by feeding butter stained with Scharlach R. During the onset of inanity, the quantity of fat in muscle fibers markedly diminished and in some instances completely disappeared. When the starved rats were fed the stained butter, the size and number of liposomes were increased within a few days to that observed in normally fleshed rat muscle. In the fed rats the fat in all of the adipose tissue assumed a pink color similar to that of stained butter and was in contrast to the white fat normally found in the adipose tissue. Faint traces of the color resembling the stained butter were observed in the liposomes of the sarcoplasm following ingestion of the butter fat by the animal.

The stained butter was fed to normally fleshed rats, with the result that a pink color in the renal and omental fats developed within seven to nine days.

The results of the study with rats indicate that the liposome content of the muscle fiber is closely associated with the state of general obesity in the animal.

Microscopic examinations revealed that fat accumulates in the innermost parts of the bovine muscle. Furthermore, they revealed the extent to which fat develops inside the fasciculi at various stages of adiposity. Such deposits of fat undoubtedly must constitute a very large proportion of the total aggregate of fat in the body and contribute markedly toward the improvement in the quality of meat.

The study with rats brought out a salient feature, which, from a fundamental point of view, may be extremely noteworthy. The development of liposomes within the sarcoplasm appears to be a normal function of the cell, and there is sufficient evidence to suggest a role for them in terms of a nutritive material upon which muscle metabolism may depend. The passing of the liposomes, as in inanition, and their reappearance with obesity would appear further to support the phyothesis that these bodies are of nutritive significance to the muscle fiber. If it is accepted that liposomes are, by nature of their histological properties, a true fat, it appears reasonable to assume then that they would make the same contribution to improving the palatability of meat as would a similar quantity of fat located contiguous to the muscle bundles. These fat-bodies should make even a greater contribution to the quality of meat than intercellular fat because of their more intrinsic relation with the protoplasmic sub-

stance.

Observations with rats suggest that the formation of the liposomes is very closely allied with the development of adipose tissue, since increases of fat in the adipose tissue were accompanied by increases in liposomes. However, the liposomic content is not in a definite ratio to the total fatty tissue, as marked variation was observed in the number of liposomes in muscle from cattle with similar degrees of fatness. On the other hand some of the thinner fleshed animals with a low visible fat content exhibited an extensive liposomic development. As the animals increased in fatness, the muscle fibers appeared to reach a state of saturation for liposomes, but there was no evidence which pointed to saturation of the adipose tissue in the body.

The macroscopic fat from steers and heifers slaughtered on the same date, although not significantly greater, consistently favored the heifers with respect to the proportion of fat to other tissues in the carcass. It was also noted that the liposomes were usually more prevalent in the muscle of heifers. When comparisons were made of the liposomic content between steers and heifers having approximately the same fat content regardless of date slaughtered, it was observed that the size and abundance of liposomes were very similar. This points to the deduction that the intracellular fat development is more closely correlated with general obesity of the animal than with any sex characteristic.

Color of Beef

While some difference in color due to age was recorded by the "A"

chart, the color notations on the chart did not correspond exactly to that observed in the meat. This was not surprising since the "A" chart was a standard specifically designed to measure the color of mature beef; therefore, it would hardly suffice for determining color of meat from the young animals used at the 0 day periods in this study.

The rotating disks afforded a more accurate measure of color than the "A" chart, since very slight deviations in the color of meat could be recorded by adjusting the color disks. A marked difference between some of the readings by the "A" chart and that of the rotating disk was observed. The quantities of red, black, and yellow in the rotating disk required to match the color of meat from young animals did not correspond with the color value of the "A" chart readings of muscle from calves but the two devices were quite comparable in indicating the color of the meat of older animals.

The discrepancy between the readings by the "A" chart and by the rotating disk was attributed in large measure to the adaptability of the "A" chart to colors of beef from mature animals, whereas the majority of animals used in this study were immature.

A gradual though not a consistent increment of red was noted in the flesh during the fattening period. The muscle in animals used in this study darkened decidedly in the course of 180 days. On the other hand the deposits of fat in the musculature reduced the intensity of the red color in the lean. In animals with large quantities of intramuscular fat, the color of lean was lighter red than that of lean containing little or no fat. According to the color readings with the rotating disk, flesh con-

taining considerable marbling and a high liposomic content had a greater percentage of yellow and a smaller percentage of red than the flesh differently constituted. Thus the quantity and diffusion of fat in muscle from the older animals appeared to offset the increased reddening of the flesh due to age.

The exact increase in intensity of color of flesh for any particular period is said to be influenced by such factors as age, breed, feed, and sex. Females are said to mature earlier than males, which implies that heifers may have darker muscles than steers, but in these investigations some evidence was found that the color of the flesh was slightly lighter in heifers than in steers of a similar age. However, the great variance in color of flesh from heifers indicated other factors than age were concerned with color. The greater difference in fat content between heifers and steers, over a period of 180 days, pointed to the possibility that fat in muscle may influence the intensity of the red color. Accordingly, the color readings were compared with the microscopic observations of muscle tissue.

The relationship between the color of meat and the fatty deposits in muscle is considered of great significance since sections from the longissimus dorsi muscle were observed in both studies. In animals slaughtered on the same date, the muscle containing the greater liposomic content had the lighter color, or, to state it otherwise, had the lowest hue value. An outstanding illustration of this is shown in plates V and VI, in which the muscle fiber of the heifer had a very extensive liposomic development and the color hue was the lightest flesh of any animal slaughtered during

the last 90 days of the experiment. Extensive development of liposomes was observed in two other animals fed 180 days. As observed by the eye, the flesh of the steer appeared darker than that of the heifer, though according to the hue values of these two animals the flesh of the heifer had a slightly lighter color of red than that of the steer. The higher chroma value with slightly greater brilliance was sufficient to reduce the influence of hue so as to cause the flesh of the heifer actually to appear lighter. A comparison was made between the color of muscle from two other animals with similar total fat content, and it was noted that the one with the greater liposomic development had the lighter color of flesh.

A comparison was made between the color of muscle from animals of the same sex but of various ages, and between color of muscle and total fat and liposomic content. It was noted that by increasing the age of the animal, but not the liposomes, the intensity of the red in the muscle increased; that by increasing the liposomes but not the age of the animal, the intensity of color decreased - that is, the muscle became lighter in color. On the basis of these observations it appeared highly probable that the intensity of color was positively correlated with the age of animal and negatively correlated with the microscopic fat deposits for a given age of animal.

When the color of muscle from steers and heifers of the same age and the same degree of liposomic development was compared, the flesh of the heifer was usually found to be the darker. Only in those instances when heifers were much fatter and had greater liposomic fat were the muscles lighter in color than those of steers.

It is shown in table XIX that the color of muscle in heifers at the 0 day period was approximately one optical degree darker than that of steers. It is recalled that these animals were about six months of age and considered thin in flesh. Disregarding the influence of fat upon the color of muscle it was found that the steers and heifers each increased the intensity of the color in the protoplasm about one optical degree per month and the heifers were still one optical degree darker in the flesh than the steers at the close of the fattening period. But due to the female characteristic of rapid fattening, this difference in color between steers and heifers was removed within 60 - 90 days, and thenceforth during the fattening process the accumulation of fat in the bodies of heifers was enough greater than that in steers to obliterate most of the difference between sexes in color of the flesh.

The color of the fat in all of the animals was considered as white, although a slight yellow tint was discernible in most of the animals. These deductions are based wholly upon eye observations, as the rotating disk was not equipped to analyze color of fat.

The Color Analyzer

The most accurate analysis of color is through the use of a spectrophotometer which measures the stimulus of the various colors of a substance as compared to that of a standard at each wave length throughout the spectrum. From these measurements it is then possible accurately to determine the reflection factor of color for any wave length as a ratio to that of a standard. For the purpose of this study it was assumed that the standard,

magnesium carbonate, gave a perfect white reflection at all wave lengths regardless of where its ordinates intercepted the intervals of wave lengths. Since at any wave length exactly the same amount of light would fall upon the sample to be analyzed as upon the standard, the ratio of response would give the energy reflection factor. On the basis of this hypothesis calculations were carried through, using values obtained at each 25 millimicron interval between 400 and 700 millimicrons.

It was shown by spectrophotometrical tests that the intensity of red, as indicated by the energy reflection factors, was greater in the muscle of steers than of heifers. Comparing the data acquired by color analyzer with the microscopic observations it appears that the most probable substance which gives rise to fluctuating changes in color in normal bovine muscle is fat. This thorough-going test, while limited to a few observations, confirms the results of other tests on color of meat, and conclusively shows that the color of meat is greatly influenced by the deposition of intramuscular fat. Furthermore, these tests show that the similarity of color of meat from heifers to that from steers is due in a large measure to the preponderance of fat disseminated through the musculature of the heifer.

Culinary Tests

The culminating and most important test to determine quality and palatability of meat is that given by connoisseurs of foods. Meat submitted for test is presumed to be cooked in such manner as to bring out its most palatable characteristics.

During cooking many of the constituents of meat are altered; the fats are melted and variable quantities escape from the tissues; the protoplasm of the cells coagulate, but some of the liquid substance is released from the muscle cells and accumulates with the fat to form the drippings. Much of the protoplasm, being a colloidal substance, is impounded by the connective tissue of the muscle to give the cooked meat the character of juiciness. Juiciness and tenderness are thought to be correlated with the aging or ripening factor; consequently a portion of each cut designated for the culinary and palatability test was aged 30 days before it was cooked.

All uncooked roasts lost weight during the storage period, but the shrinkage varied between roasts due to difference in size of piece and degree of fatness as well as to variation in the humidity of the coolers.

The total cooking loss, made up of volatile and drippings, is the difference between the weights of the roasts before and after cooking. The dripping loss is the weight of the fat and meat juices which escape from the roast and accumulate in the pan. Volatile loss is the difference between the total loss and the drippings.

A comparison of the total fat content of the standing ribs with the cooking loss, as is shown in table XXVI, strongly indicates that irrespective of sex, the dripping loss is highly correlated with fatness of the rib cut.

The drippings were composed partly of melted fat and partly of protoplasmic substances from the muscle; but since the drippings were not fractionated, it is not possible to state the proportionate part contributed by each.

The volatile loss, as is shown in table XXVI, decreased at each succeeding cooking period and the steers and heifers showed approximately the same percentage decrease. This loss was due almost wholly to evaporation of moisture, and its decrease during the 180 day period was attributed to the increase in size, and in fatness of the roasts, and in degree of maturity of muscle cells. Increases in size of the roasts reduced the proportion of outside surface to volume; increases in fatness added to the inhibition of moisture to escape; and maturation of the muscle reduced the readily evaporative portion of the cellular substance.

It is noted in tables XXIV and XXV, that the weights of roasts from steers and heifers were approximately the same at each cooking date, but that the volatile loss was greater in roasts from steers than in those from heifers. While no moisture determinations were made on any of the roasts, there is little reason to suspect any difference in moisture content in the protoplasm due to sex. However, a greater volume of fat was stored in the roasts from heifers, and therein probably lies the explanation for the smaller volatile and the greater dripping loss from heifers than those from steers at the different cooking periods.

Cooking time

There was only a small difference between roasts in respect to the cooking time required per pound despite the wide difference between the weights of roasts from thinly fleshed and those from fatter animals. This may lead to the supposition that larger and fatter roasts cooked more quickly than those containing less fat. The larger roasts actually re-

quired a longer time to cook, but increases in weight of roasts did not result in corresponding increases in time required for cooking. Since the distance which the heat must travel in a roast is not a constant ratio to the weight, but one of diminishing proportions with weight increase, it becomes obvious that the unit of time of cooking decreases with increased weight of pieces.

Though ribs from heifers were usually fatter and better marbled, the time for roasting did not consistently vary from that required for ribs from steers, and the average time required to cook roasts from each was almost identical.

Palatability scores

All roasts were carved and scored by a committee of at least five members. The meat sample consisted of a cut of the longissimus muscle, three-eighths to one-fourth inch thick, with the fat contiguous to it. Only slices of the inside, or unbrowned, portion of the roasts were served for scoring.

Variations in scores between members of the committee would be a natural presumption, but a scrutiny of individual records revealed that the variation was extremely consistent. It was evident that some members consistently had a higher appreciation of the factoral values listed on the score card. Others were equally consistent in recording lower response to these values.

The score for texture is primarily a registry of the size of muscle bundles or fasciculi sensed in the meat. The tendency for the muscle to

show a finer texture as the animals increased in age and adiposity is explained on the premise that the addition of fat in the perimysium released the tension between fasciculi thereby giving opportunity for the individual muscle bundles, rather than groups of bundles, to be identified as the unit of texture.

Tenderness Tests

Tenderness is accepted by the majority of meat consumers as one of the more essential requisites of good meat. It was clearly shown in previous tests, table XXVII, that as the animals became older and fatter the meat increased in degree of tenderness. Since it is well known that age, apart from any other factor, impairs the tenderness of meat, it would be concluded that the quantity of fat was a primary factor in determining degree of tenderness. If this were true, then fat introduced mechanically into the lean tissue might be expected to increase tenderness. But such trials as have been made have produced no positive results.

Comparing animals that were fed 120 days and longer, it is recalled that the prime ribs from heifers contained a higher percentage of fat than those from steers. It was also observed, though not recorded in the data, that the superficial covering of fat on the ribs of heifers was thicker than that on the ribs from steers. But in the palatability tests on cooked roasts from these animals, only a slight difference in tenderness was noted between sexes. It is of interest that roasts showing similar quantities of fat but differing in quantity of intramuscular fat, revealed by histological examination, differed in degree of tenderness; those having the

greater amount of intramuscular fat were more tender. It appears, therefore, that the placement of fat is of more importance than the mere presence of a mass of fat within the lean tissue in developing tenderness.

Mechanical Tests for Tenderness

Attempts were made to determine the tenderness of meat by measuring the shearing strength of the uncooked muscle. A total of twenty-seven determinations was made on the longissimus muscle from three steers and three heifers at each of the feeding periods.

It was clearly seen from the data, table XXVIII, that the shearing strength of the muscle tissue was not correlated with the tenderness score from the palatability test. Tenderness of the cooked meat increased as the roasts increased in degree of fatness, but the results shown by the shearing apparatus indicated no such tendency. The committee that scored the roasts did not recognize a difference between sexes in degree of tenderness worthy of mention, but the shearing strength of samples from steers was much greater than that from heifers at the 120 day and 150 day feeding periods.

Since the ribs cut from heifers contained more fat than those from steers at these dates, one would presuppose that the difference in shearing strength was due to differences in degrees of fatness of the muscle. This was not confirmed by mechanical tests, however, on raw muscle from ribs of animals slaughtered at the 180 day period which had a marked difference between sexes in degrees of fatness, yet the muscle sheared with about equal ease.

The disparity of the results with the shearing apparatus was noted very soon after the study was under way. An inquiry into the cause was made but no definite conclusions were reached. It was found, however, that any one of a number of conditions could be responsible for the discrepancy of results. The most likely was error in sampling the raw muscle. Examinations of portions of the same muscle having 10 - 15 pounds difference in shearing force indicated that the aponeurosis was more deeply invested in the muscle of some samples than in others. This condition was not readily detected by external examination of the muscle sample. It was found from other trials that even a small fragment of this band materially increased the pull necessary to shear the sample.

Differences in firmness of flesh and in the distribution of fat within the muscle area are other probable causes for variation in shearing results, but these probabilities could not be verified during this study.

Members of the palatability committee were observed using only the center portions of muscles for the tenderness test; hence their opinions of tenderness were based on the resiliency of the sarcolemma and the endomysium rather than on muscle and soft contiguous parts which were included in the shearing tests. When the shearing tests of a sample taken from the center of the muscle were compared with tenderness score reported by the committee, the results were in close agreement. It was concluded from this that in many cases the shearing apparatus was recording shearing strength of components in the muscle not included in the test by the committee; therefore, differences in results between the two methods are irrelevant.

GENERAL SUMMARY AND DEDUCTIONS

The purpose of the investigation was to study the effect of sex on the quality and palatability of beef produced by choice feeder calves.

A group of steer and heifer calves were fed 180 days in three different years. Each year a representative animal from each group selected at 0 - 90 - 120 - 150 and 180 day feeding periods was slaughtered. A total of 15 steer and 15 heifer carcasses was studied.

Physical analyses were made in which the carcasses were divided into standard wholesale cuts and one side of each carcass was separated into its constituent parts - lean, fat, bone, and tendon.

Color determinations were made on the lean and fat by two mechanical devices - the Munsell spinning disk, which determined the color by arranging segments of color standard so that when rotated the standard color corresponded to that of the meat, and the Razek-Mulder photoelectric color analyzer, which determined the response of sensitivity of color at each wave length throughout the spectrum for lean and fat from steers and heifers at different planes of adiposity.

Microscopic studies were conducted to determine the occurrence of liposomes in the longissimus dorsi muscle from steers and heifers at the different degrees of obesity, and to determine the histologic relationships between the intramuscular and intermuscular fat in steers and heifers at the different feeding periods.

A comparison was made between the sexes in the distribution of the white fibrous and yellow elastic connective tissue, and in the diameters

of muscle cells from animals which varied in age and degrees of fatness.

Cooking and palatability tests were made on rib roasts aged 10 and 30 days from steers and heifers with different degrees of fatness. Dripping and volatile loss, as well as time required for cooking, was recorded. The roasts were scored for palatability.

Tenderness tests of the longissimus dorsi muscle were made on each roast by a mechanical shearing device and by the palatability committee to determine differences between the sexes.

The larger differences between carcasses of steers and heifers with regard to wholesale cuts, and the proportion of lean, fat, and bone have been cited. It is observed from the data that there are variations in initial and final weights of the steers and heifers in the yield of wholesale cuts, in the yield of primal cuts, in the lean, fat, and bone, and in the edible meat obtained from carcasses of animals slaughtered at different ages and degrees of fatness. These variations were considered in comparing quality and palatability of meat from steers and heifers, and the findings were as follows:

(1) Comparing sexes as to final liveweight by the method of analysis of variance, it was found that the weights of steers did not differ significantly from those of the heifers. In the first two years the steers were heavier than the heifers, while in the third year the reverse was true, as shown in table I. Since the steers and heifers differed in initial weight, the final weight was adjusted by covariance for initial weight. With the adjustment the differences in final weight were still not significant.

(2) The percentage yield of carcass, whether calculated on the basis of live weights or on empty body weights, was greater in heifers

than in steers, notwithstanding the fact that when both had been fed 90 days or longer the heifers had a greater quantity of visceral fats than steers. This strongly indicates that the skeletal constituents, such as muscle, fat, and bone develop faster in young heifers than in young steers.

(3) An analysis of the total weights of primal cuts of steers and heifers indicated that the total yield of primal cuts from steers does not differ significantly from that of heifers when cattle under 900 pounds liveweight are considered. However, carcasses from steers may be expected to have a slightly larger percentage of round and shoulder than those from heifers. Of the less demanded cuts the percentage of flank and of kidney fat was smaller and that of shank was greater in steers than in heifers. The difference between ratios of other cuts was not attributed to sex.

(4) Heifers fattened much faster than steers during the earlier part of the feeding period. Carcasses from heifers fed 120 days contained as much fat as did those from steers fed 180 days. This indicates that heifer calves reach market maturity 30 days to 60 days ahead of steer calves similarly fed.

(5) The percentage of fat in the primal cuts increased faster in heifers than in steers during the first 120 days. After that time the increase was slower. Of the primal cuts from cattle slaughtered at different times, the prime ribs and loins had the greatest deposits of fat, and in this respect heifers had greater accumulations than steers. From the standpoint of fatness, the loins, ribs, and chucks from heifers, fed 120 days, were as desirable as those from steers fed

180 days.

It is noteworthy that the intercellular fat also increased as the adipose tissue developed, and liposomic deposits were greater in muscle of heifers than those of steers of similar time on feed. However, the difference between the sexes in quantity of fat contributed in this form was too small to be of practical consequence from the standpoint of quality of the flesh.

(6) The percentage of lean gradually decreased in both sexes as the feeding period was lengthened. When the percentage of lean was calculated upon the basis of the fat-free carcass, there was no difference due to sex. From these results the deduction is made that steer and heifer calves weighing 350 pounds to 400 pounds, full fed on a standard fattening ration within the limits of this experiment, will develop muscular tissue at about the same rate, and that sex in feeder cattle of this age and weight is not a factor of significance with regard to muscular development.

(7) It is generally conceded that there is little difference in quantity of bone from carcasses of animals of the age and weight included in this study, regardless of sex. This opinion was supported by the findings in the present investigation.

(8) The color of meat was influenced by age and finish of the animals, but the difference between the sexes in color of lean and of fat when measured by precise methods was less than one color grade; consequently, the difference between the sexes was not significant.

(9) The formation of liposomes, seemingly a function of the muscle cells exercised only in advanced stages of organic obesity, was much more

extensive in the cells of the longissimus dorsi muscle of heifers than that of steers of similar time on feed. It was also observed that the roasts from prime ribs of heifers scored slightly higher in quantity of juice than those from ribs of steers. It was concluded, therefore, that the microscopic fatty bodies contributed to this factor of quality in roasts, but the constitution of roasts was such that differences in the internal fatty deposits, or in the juiciness of the meat could not be confirmed as differences due to sex.

(10) The total cooking loss of rib roasts from steers and heifers slaughtered at the same time was practically the same. The degree of fatness of the ribs had only a slight effect upon the total amount of loss. The loss due to evaporation decreased and the drippings increased as the fat in the roasts increased, but in percentage of loss there was no difference due to sex.

(11) The committee did not detect any particular difference in the palatability of roasted meat that could be attributed to sex.

(12) The tenderness score on roasted beef by the committee did not correlate with the results from tests made by the shearing machine. With the shearing machine more variability was found within than between animals in the number of pounds required to shear the muscle; thus differences in tenderness due to sexes were not indicated by this test.

This study has included the analysis of far more animals than the number included in any similar study thus far reported in the literature, and since these results are in agreement with those reported by other investigators, the findings in this study are considered as contributory to the knowledge as regards the physical characters of carcasses from

beef steers and beef heifers.

The general conclusion seems warranted, therefore, on the basis of the information available from the data, that such differences as did occur between steers and heifers with respect to carcass development, to histological structure, color of flesh, response to cooking or palatability, were not attributed to sex.

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LITERATURE CITED

1. Albrecht, Eugene. Neue Beiträge zur Pathologie der Zelle. Deutsche path. Gesellschaft. 5:7. 1902.

2. Bell, E. T. On the occurrence of fat in the epithelium, cartilage and muscle fibers of the ox. Amer. Jour. Anat. 9:401-438. 1909.

3. _____. The staining of fats in epithelium and muscle fibers. Anat. Record 4:199-212. 1910.

4. _____. The interstitial granules (liposomes) in fatty metamorphosis of striated muscle. Jour. Path. and Bact. 17:147-159. 1911.

5. Bevier, I. and Sprague, E. C. Roasting of beef. Ill. Agr. Exp. Sta. Cir. 71:30. 1903.

6. Black, W. H., Warner, K. F. and Wilson, C. V. Beef production and quality as affected by grade of steer and feeding grain supplement on grass. U. S. Dept. Agr. Tech. Bul. 217. 1931.

7. Bull, Sleeter, Olson, F. C. and Longwell, J. H. Effects of sex, length of feeding and ration of ear-corn silage on the quality of baby beef. Ill. Agr. Exp. Sta. Bul. 355. 1929.

8. Bull, Sleeter. Moderate exercise does not make tough beefsteak. Ill. Agr. Exp. Sta. 1929-1930 Rpt. pp. 75-77. 1930.

9. Bullard, H. H. Interstitial granules and fat droplets of striated muscle. Am. Jour. Anat. 14:1-46. 1912.

10. _____. The microscopic demonstration of fats in tissue sections. Jour. Med. Res. 27:55-66. 1912.

11. Davis, W. C. and Whalin, C. V. Market classes and grades of dressed beef. U. S. Dept. Agr. Dept. Bul. 1246:7. 1927.

12. Edinger, A. T. The physical composition of a lean, a half fat and a fat beef carcass and the relative cost of the nutrients contained in each. Mo. Agr. Exp. Sta. Res. Bul. 83. 1925.

13. Erdheim, J. Zur normalen und pathologischen Histologie der Glandula thyreoidea, parathyreoidea und Hypophysis. Beitr. z. path. Anat. u. z. allg. path. Jena. 33:158-236. 1903.

14. Foster, M. T. Carcass comparisons of mature and immature steers. Mo. Agr. Exp. Sta. Res. Bul. 117. 1928.

15. Froboese, C. and Spröhnle, G. Untersuchungen zur Theorie und Technik der Sudanfärbung. Ztschr. f. Zellforsch. u. mikr. Anat. Forsch. 14:13-59. 1928.

16. Grindley, H. S. and Mojonnier, T. Experiments on losses in cooking meat. U. S. Dept. Agr. Office of Exp. Sta. Bul. 141. 1904.

17. Grindley, H. S. and Emmitt, A. D. Studies on the influence of cooking upon the nutritive value of meats at the University of Illinois. U. S. Dept. Agr. Office Exp. Sta. Bul. 162. 1905.

18. Haines, F. and Rosenbaum, J. A histological and chemical study of fatty matter of normal and cryptorchid testis. Jour. Exp. Med. 13:355-364. 1911.

19. Hall, L. D. Market classes and grades of meat. Ill. Agr. Exp. Sta. Bul. 147:157. 1910.

20. _____, and Emmett, A. D. Relative economy, composition and nutritive values of the various cuts of beef. Ill. Agr. Exp. Sta. Bul. 158:135-233. 1912.

21. Hammond, John. Growth and the development of mutton qualities in sheep. pp. 496-502. Oliver and Boyd, Edinburgh, Scotland. 1932.

22. Helser, M. D., Nelson, P. Mabel and Lowe, Belle. Influence of animal age upon quality and palatability of beef. I. Carcass yields and quality of meat cuts. II. The roast beef - preparation, quality and palatability. Ia. Agr. Exp. Sta. Bul. 272. 1930.

23. _____. Farm meats. p. 104. The Macmillan Company, New York, N. Y. 1923.

24. Herxheimer, G. Zur Fettfärbung. Central f. Allg. Path. u. path. Anat. 114:841. 1903.

25. Kaufmann, C. and Lehmann, E. Zur Technik der Sudanfärbung. Ztschr. f. Zellforsch. u. mikr. Anat. Forsch. 16:586-597. 1929.

26. Kemp, G. T. and Hall, L. D. The formation of fat in animals fattened for slaughter. Am. Jour. Physiol. 18:proc. XIX. 1907.

27. Kennedy, W. J., Dinsmore, W., Rutherford, W. J. and Smith, W. W. Experiment in beef production. Beef type versus dairy type. Ia. Agr. Exp. Sta. Bul. 81. 1905.

28. Knoll, P. Ueber Myocarditis und die übrigen Folgen der Vagussection bei Tauben. Zeitschrift f. Heilkunde Bd. 1:255. 1880.

29. Kolliker, A. Zur Kenntnis der quergestreiften Muskelfasern. Ztschr. Wiss. Zool. 47:689-710. 1888.

30. Lehmann, K. B. Studien über die Zähigkeit des Fleisches und ihre Ursachen. Archiv f. Hyg. 63:134-179. (Abs. Exp. Sta. Rec. 19: 1161.) 1907.

31. Leighton, G. R. and Douglas, L. M. The meat industry and inspection. v. 3. London. 1910. Original not seen; quoted by Hammond (21), p. 501.

32. Lush, J. L. Practical methods of estimating the proportion of fat and bone in cattle slaughtered in commercial packing plants. Jour. Agr. Res. 32:727-755. 1926.

33. MacIntosh, D. L. The influence of feed on the color, chemical composition and cooking quality of the meat of grass fed cattle. Kans. Agr. Exp. Sta. Bien. Rpt. 1929-1930. pp. 70-72. 1930.

34. Mitchell, H. H. and Hamilton, T. S. Some factors affecting the connective tissue content of beef muscle. Jour. Nutr. 1:165-178. 1928.

35. Munsell, A. H. A color notation. 4th ed. Chp. VI. Geo. H. Ellis Company, Boston, Mass. 1916.

36. Romeis, B. Weitere Untersuchungen zur Theorie und Technik der Sudanfärbung. Ztschr. f. Zellforsch. u. mikr. Anatforsch. 16:525-584. 1929.

37. Schmid, A. Das Simmentalervieh als neuzeitliche Leistungsrasse. Schweiz. Landwt. Monat. 7:113-128. 1929.

38. Slater, Don J. Market classes and grades of cattle. U. S. Dept. Agr. Bul. 1464:11. 1927.

39. Snedecor, G. W. Calculations and interpretations of analysis of variance and covariance. Collegiate Press, Ames, Ia. 1934.

40. Sprague, E. C. and Grindley, H. S. A precise method of roasting beef. Univ. of Ill. Univ. Studies No. II, No. 4. 1907.

41. Traina, R. Uber das Verhalten des Fettes und der Zellgranula bei chronischem Marasmus und akuten Hungerzuständen. Beitr. z. path. Anat. u. z. Allg. Path. 35:1-92. 1904.

42. Trowbridge, P. F., Moulton, C. R. and Haigh, L. D. The effect of limited food supply on the growth of young beef animals. Mo. Agr. Exp. Sta. Res. Bul. 28. 1918.

43. _____, _____ and _____. Composition of the beef animal and energy cost of fattening. Mo. Agr. Exp. Sta. Res. Bul. 30. 1919.

44. U. S. Bur. An. Ind. An. Husb. Div. A study of the factors which influence the quality and palatability of meat. Issued for the nat'l coop. project on meat investigation Revised Ed. 1927 (mimeo.).

45. Warner, K. F. Progress report of the mechanical tenderness of meat. Amer. Soc. Anim. Prod. Proc. 1928:114.

46. Wilson, J. and Curtiss, C. F. Steer and heifer beef I. Ia. Agr. Exp. Sta. Bul. 24. 1894.

47. _____ and _____. Steer and heifer beef II. Ia. Agr. Exp. Sta. Bul. 33. 1896.