BODY COMPOSITION AND CARCASS CHANGES OF YOUNG HOLSTEIN CATTLE

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This is to certify that the

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By

George Harvey Wellington

A THESIS

Submitted to the School of Graduate Studies of Michigan
State College of Agriculture and Applied Science
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BODY COMPOSITION AND CARCASS CHANGES

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AN ABSTRACT

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ABSTRACT

Animal husbandmen improve the economic value of slaughter cattle by feeding for optimum growth and fattening. However, more information concerning the influence of age and fat on the individual carcass characteristics of growing cattle is needed to support production recommendations. In this study the affect of age increases and of three levels of nutrient intake on the amount of edible meat, carcass length and thickness, weights of individual muscles, and tenderness were analyzed.

Twelve Holstein bull calves and thirty Holstein heifer calves were randomized within the three feeding levels and slaughter ages which ranged from 16 to 80 weeks. The calves on the low feeding level consumed approximately 61 to 75 percent of the amount of T.D.N. consumed by calves fed on the medium level, whereas calves on the high level of feeding consumed approximately 125 to 139 percent of the T.D.N. consumed by the medium group. The feeds conformed closely to those in use by farmers following unusually good, average, and limited feeding practices.

Indirect methods of determining body composition _in vivo_ can contribute useful information otherwise not obtained until slaughter. The accuracy of body water composition determined _in vivo_ by intravenous injection of a known amount of antipyrine and measuring the degree of dilution of the drug in all body water was evaluated. The percentage of body fat was calculated from the amount of body water.

Cattle with greater T.D.N. intake had a higher dressing percentage, increased length and thickness of carcass and a larger ratio of edible

meat to bone. Higher nutritional levels were associated with a smaller percentage weight of muscles in the carcass. The level of feeding tended to show no significant influence on tenderness.

As the cattle increased in age there were significant increases in length and thickness of the carcass and a larger ratio of edible meat to bone. Age showed no influence on dressing percentage and in general no consistant influence on percentage weight of muscles in the carcass. One muscle of the three observed became significantly less tender with age in the bulls and two muscles showed this trend in the heifers.

The total body water calculated for twenty cattle by the antipyrine technique was highly correlated, +.939, with the total body water determined by analyzing all body tissues for moisture.

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INTRODUCTION

Growth and fattening are fundamental to animal husbandry. In research studies with cattle it has been usually necessary to slaughter the experimental animal in order to determine accurately the degree of fattening. Recently several indirect methods of measuring body composition have been reported. One of the most promising methods is that of Soberman and associates (1949) by which the total amount of water in the body may be determined through the use of antipyrine as an indicator. The method is based upon the principle of determining the degree of dilution of a known quantity of antipyrine injected intravenously. Antipyrine is slowly metabolized and rapidly reaches equilibrium with tissue water. Since the water content of the fat-free body is relatively constant, the amount of fat can be determined from the percentage of water in the body. Likewise, the fat-free levels of protein and ash appear to be sufficiently constant to predict reasonably these constituents when water and fat levels are known.

Research workers in nutrition and meats have recognized the value of being able to determine the body composition of living experimental animals. A knowledge of the total change in the body constituents of livestock effected by the rations consumed would show the net value of the rations for a particular function. A large proportion of the attention given to the studies reported herein was spent in preparing body tissues for moisture analysis so that the water content of the experimental animals could be compared to the values for body water obtained by the antipyrine technique.

It is believed by most people that older animals give less tender meat. Furthermore, tenderness appears to be one of the most important palatability factors as judged by beef consumers. The influence of fat on the tenderness of beef is somewhat uncertain. More knowledge of the effect of feeding and fattening on muscle tenderness and on muscle development during growth would be helpful to animal husbandmen in making production recommendations.

A project of large scope has been in progress in the Department of Animal Husbandry, New York State College of Agriculture, concerning the effects of three levels of nutrition on the early growth and development of young cattle. Musgrave (1951), Dunn (1952), and Sorensen (1953) have reported the effect of nutrition on the reproductive performance of cattle under the treatments used in this study. This manuscript reports the effect of the three different levels of nutrition on body water content and on carcass changes during the first 80 weeks of life.

REVIEW OF LITERATURE

The Body Composition of Farm Animals

Scientists working with animals realized many years ago the need of determining the composition of the animal body and expressing it as moisture, fat, protein, and ash. The famous English scientists, Lawes and Gilbert (1859), were the first to report the analyses of the entire bodies of farm animals. Their early slaughter experiments proved that a large portion of the fat of fattened pigs was produced from constituents of the ration other than fat.

In this country, Jordan (1896) working at the Maine Agricultural Experiment Station conducted a slaughter experiment with two pairs of steers which had been fed rations differing widely in their nutritive ratio. The older steers which had been on feed longer contained a smaller proportion of water and a larger proportion of fat than younger steers.

For about ten years following World War I there was considerable interest in analyzing the bodies of farm animals. Much of the work was reported from Missouri Experiment Station, some from Minnesota, and some from Kansas and Illinois. The results of these early analyses on relatively few animals still provide the bases for some of our feeding requirements for meat animals. Agricultural experiment stations largely discontinued direct body composition studies with farm animals following this decade of activity. However, at Vermont, Ellenberger *et al.*, continued the laborious task of analyzing cattle and recently published (1950) the detailed analyses of 132 bodies ranging in age from a 135-day fetus to a 12-year-old cow.

Trowbridge, Moulton, and Haigh (1919) at the Missouri station made the first detailed and basic study of body composition in which they analyzed seven steers at various stages of fattening. Moulton (1920) gave additional information concerning the seven cattle and expressed some of the constituents on a fat-free basis. He observed that the moisture content on a fat-free basis was relatively constant after five months of age.

Haecker (1920) working at Minnesota analyzed the bodies of 49 cattle. He concluded that the percentage of water in the non-fatty matter diminishes with age and the percentage of ash and protein are correspondingly increased. However, the changes in water content were all between 78 and 70 percent and those in protein and ash content were between 20.36 and 25.19 percent and 4.44 and 5.62 percent, respectively.

Murray (1922) reviewed the publications of Haecker (1920), Swanson (1921), and Laws and Gilbert (1859) and concluded that animal bodies are composed of fat and non-fatty matter. The non-fatty matter consisted essentially of water, protein and ash. He proposed that the average composition of the whole body at any stage could be calculated when the live weight and percent of fat in it were known.

Moulton (1923), after rather extensive study, concluded that the relative fatness of animals of the same species does not affect the composition of the fat-free mass and that this is true of cattle. He proposed that the planes of nutrition would not affect the composition of the fat-free animal. Moulton is perhaps most often cited for the hypothesis, based on his data, that mammals show a rapid decrease in relative water content from earliest life until the time "chemical maturity" is reached. He thought this "chemical maturity" in cattle is arrived at between five and ten months of age and after the age of "chemical maturity" is reached the composition on a fat-free basis is constant.

Armsby and Moulton (1925) reviewed and compared all of the data available at that time dealing with the body composition of farm animals. Their review covers the Missouri, Minnesota, Kansas, Illinois, and some early Vermont reports. Armsby was somewhat cautious in drawing conclusions relative to the constancy of body composition. He noted that the variation in body constituents was much less when expressed on a fat-free basis.

Reid and Wellington (1954) have compared all available data on the body composition of cattle and have concluded that "chemical maturity" is reached much earlier than Moulton stated. Their observations on the existing data would indicate that when these values are calculated on a fat-free, moisture-free basis, the body ash and protein contents are constant from birth.

Hankins et al. (1939a) cited data from the Michigan Agricultural Experiment Station to show that in Hereford steers the ratio of edible meat to bone increased rapidly as the empty body weight increased from approximately 500 to 935 pounds. The fat alone increased at a rate only slightly less rapid than the weight of edible meat increased.

Methods of Indirect Measurement of Body Composition

The body composition studies previously discussed were both difficult and time consuming. Only one analysis could be made for each animal and it was necessarily at the close of the experiment. Indirect methods of accurately determining the composition of live animals have recently been proposed.

Moore (1946) stated that a known amount of deuterium oxide could be injected into an animal and that the amount of body water could be calculated from the dilution of the deuterium oxide. He reported that the body water of rabbits could be determined within two percent using this method. During the next year Pace, Kline, Schachman, and Harfenist (1947) reported on the use of tritium, according to the same dilution principle in effecting water measurement in rabbits and men. Checks with humans were made against a second indirect method, specific gravity. They concluded that tritium could be used to estimate body water within ten percent of the true value with rabbits.

Brodie, Axelrod, Soberman and Levy (1949) published methods of accurately determining the concentration of antipyrine in biological materials. This was significant because Soberman et al. (1949) reported that antipyrine was uniformly distributed in the various tissues in close proportion to the water content, that its excretion was negligible and that it was metabolized slowly. He outlined a method for employing antipyrine to measure body water according to the dilution principle.

Kraybill, Hankins, and Bitter (1951) applied the antipyrine method as outlined by Soberman and associates to the measurement of body water in thirty head of beef cattle. To check their values, Kraybill calculated body water content from the specific gravity of the carcass. There was good agreement in body water values obtained by the two methods, however the values were slightly higher by the antipyrine method. Their greatest difference was 3.1 percent and their average difference was 0.30 percent. In a later paper, Kraybill et al. (1952) gave additional information concerning the application of the specific gravity technique with cattle. The dressed carcasses were weighed in air and in water. To obtain a density value of the whole animal, the viscera, legs, and head were placed in a wire basket for weighing in water. The relationship between the dressed carcass specific gravity and whole animal specific gravity showed a correlation coefficient of +.990. The specific gravity of the 9-10-11th rib cut and that of the whole animal also were highly correlated (+.954).

The Oklahoma Experiment Station has applied the specific gravity method rather extensively as an indirect measurement of the leanness (or fatness) of hog carcasses. Whiteman, Whatley and Hillier (1953) summarized some of their observations relative to the manner of carrying out the technique. As a result of several years of experience in using the method they have concluded that:

1. Variations in the temperature of the water within a $20^{\circ}F$ range are not of practical consequence.
2. The weight must be read quickly or the warming effect of the water will reduce the carcass weight.
3. Differences in amount of exposed surface on various carcasses appear to be of no practical consequence.

Lesser, Blumberg, and Steele (1952) have reported the use of cyclopropane to determine body water indirectly. This method is based on the fact that the solubility ratio of cyclopropane in fat and in non-lipid body tissues is about 26:1. Application of the method has been limited to laboratory rats.

Levels of Feeding as they Affect the Animal Body and Carcass

The early body composition studies of Trowbridge *et al.* (1918) at Missouri included observations on the effect of various levels of nutrition on the body. Their work showed that fat was mobilized during starvation and replaced with water. They found that the growth of the skeleton persisted under very adverse conditions and that the growth consisted of an increase in protein and fat as well as in mineral constituents. In most severe starvation the fat of the skeleton was mobilized for energy.

Moulton, Trowbridge and Haigh (1922a) reported changes in the carcasses of cattle on three levels of nutrition. Thirty animals were divided according to level of feeding and slaughtered at various intervals from birth to four years of age. They summarized these rather extensive studies by the statement that the distribution of the total lean flesh was only slightly affected by age and fatness. In general, with increasing age and fatness, the fat percentage increased in the wholesale cuts and the bone percentage decreased. They concluded that the percentage of lean flesh may increase, remain constant, or decrease, but on the average it decreased with increasing age and fattening. In a second report, Moulton *et al*. (1922b) concluded that the chief effect of age and plane of nutrition on the chemical composition of the parts and total animal was through a change in fat content, which increased in most cases with increased age and higher plane of nutrition.

Branaman, Hankins, and Alexander (1936) grouped seventy-two Hereford steer and heifer carcasses according to varying degrees of fatness as determined by ether extract analysis of one-half of the carcass. Rib samples from the remaining one-half were used for palatability testing. Scores for intensity and desirability of flavor of lean and for quality and quantity of juice showed in general a progressive improvement with the increased fatness. On the other hand, tenderness appeared to have decreased somewhat with increased fatness.

McMeekan (1940) proposed that by controlling the rates of growth of pigs there could be introduced differences in the chemical composition of the muscle and fat tissue. Analyses for chemical composition of the whole body were not made. He produced the best bacon hog carcass by heavy feeding during the early growth period of maximum bone and muscle formation followed by only limited feeding when the deposition of fat normally predominates.

The Effect of Fat on Muscle Tenderness

Mackintosh and Hall (1936) correlated tenderness with the degree of marbling in 63 beef cattle of varying ages and degree of finish. The correlation coefficient between tenderness as measured by mechanical shear and marbling as measured by use of a grading chart was

$+.650 \pm .052$. The same comparison on 61 cattle using palatability scores for tenderness measurement gave a correlation coefficient of $+.675 \pm .047$.

Hankins and Ellis (1939b) reported tenderness studies relative to fatness on 797 cattle and 924 lambs. None of their correlation coefficients between indexes of fatness and tenderness was even moderately high. They concluded the evidence was strong that variations in tenderness were caused mainly by factors other than fatness. The data reported by Branaman, Hankins, and Alexander (1936) showed an apparent decrease in tenderness with increasing fatness, although the decrease was not maintained consistently.

The Effect of Age on Tenderness

The report of Helser, Nelson, and Lowe (1930) on the influence of age upon quality and palatability of beef did not completely support the common belief that older animals are less tender than younger ones. Rib roasts from 54 cattle grouped as feeder calves, fattened calves, yearling feeders, fattened yearlings, two-year-old feeders, and fattened two-year olds were roasted and scored by a palatability committee. The average tenderness score was lowest for the feeder calves (17.83) and highest for the fattened calves (22.39) and the average tenderness scores for all other categories fell within this rather narrow range. A definite trend for tenderness variation with age was not shown, perhaps due to the narrow range of the tenderness scores observed.

More recently Hiner and Hankins (1950) compared the relative tenderness of beef samples from nine different locations of the carcass and likewise compared samples from the same location in the carcasses of animals differing widely in age. A total of 52 animals was studied ranging from ten-week-old veal calves to five and one-half-year old cows. As the age of the animals increased, the tenderness at each of the nine locations in the carcass decreased. The difference in tenderness between veal calves and cows was highly significant, whereas that between veal and beef from 500-pound steer calves was not.

EXPERIMENTAL PROCEDURE

Experimental Design and Selection of Animals

A randomized block design was used for the animals studied. The blocks were feeding levels of 60, 100, and 160 percent of the upper limit of Morrison's T.D.N. recommendations for growing dairy heifers (1949). The calves were randomized within the following slaughter ages: 16, 32, 48, 64, and 80 weeks. Thus, one replicate consisted of three treatments x five slaughter ages, a total of 15 calves per replicate. Since the carcass and body composition studies were not included in the original experimental plan, only 64- and 80-week-old bulls are reported from replicates one and two. Replicates three and four consisted of heifers. The individual animal identity numbers are shown in Tables 1 and 2 according to the experimental design.

All calves in the experiment were selected by a professional cattle buyer and consisted of grade Holsteins obtained from auction sales and dairy farmers. The calves weighed from 80 to 100 pounds and were three to five days of age as judged by navel healing.

Criteria of Response

Measurements of growth taken at the end of the feeding periods were: a. live weight, b. carcass yield, c. carcass measurements, d. weights of certain muscles, and e. percent of edible meat and bone in the carcass.

TABLE 1. IDENTIFICATION NUMBERS OF BULLS AS RANDOMIZED WITHIN SLAUGHTER AGES AND FEEDING LEVELS

	Age in weeks at slaughter	
	64	80
Low feeding level (60% of medium)		
Replicate 1	50	47
Replicate 2	61	71
Medium feeding level (100%)		
Replicate 1	54	53
Replicate 2	58	62
High feeding level (160% of medium)		
Replicate 1	52	43
Replicate 2	72	60

TABLE 2. IDENTIFICATION NUMBERS OF HEIFERS AS RANDOMIZED WITHIN SLAUGHTER AGES AND LEVELS OF FEEDING

	Age in weeks at slaughter				
	16	32	48	64	80
Low feeding level (60% of medium)					
Replicate 3	202	206	207	213	211
Replicate 4	227	224	219	218	229
Medium feeding level (100%)					
Replicate 3	203	204	209	215	212
Replicate 4	226	222	220	217	228
High feeding level (160% of medium)					
Replicate 3	201	205	214	210	208
Replicate 4	221	223	230	216	225

The degree of fattening was indirectly measured by determining total body water using the antipyrine technique. For some of the replicates antipyrine values were checked by analyzing the body for water, for other replicates it was checked by taking specific gravity of the carcass.

The cooked muscles were evaluated for degree of tenderness by using the Warner-Bratzler Shear (1949) and by palatability committee scores.

Planned Feeding Levels and Feed Consumed

The planned feeding levels were defined as follows:

<u>Low level</u>. T.D.N. consumption was planned to be 60 percent of the medium level. Milk was to be fed for only five weeks. Roughage was to be of a poorer quality than that fed to the calves on medium and high levels.

<u>Medium level</u>. T.D.N. consumption was planned to be 100 percent of the upper limit of the recommended allowance for growing dairy heifers according to Morrison's (1948) standards. Roughage was to be mixed hay of good quality. Milk was to be fed for seven weeks.

<u>High level</u>. T.D.N. consumption was planned to be 160 percent of that of the medium level. The planned allowance was a maximum of 16 pounds of whole milk per day until 24 weeks of age. Vitamins A and D and mineral supplements were to be fed. Roughage was to be mixed hay of good quality.

The concentrates were made up of a basic starter and a grower ration recommended for growing dairy heifers. The composition of the hay and concentrates, the mineral and vitamin supplements fed, and the weekly feed schedules were reported in detail by Dunn (1952) and Sorensen (1953).

The animals on all feeding levels refused feed to the extent that the actual T.D.N. consumption was somewhat lower than planned. Normal calves refused some of the hay offered and thus did not consume 100 percent of the planned intake.

At the end of 48 weeks the percent of the planned T.D.N. intake that was consumed by heifers was 93.4, 92.6, and 73.9 percent for calves on low, medium, and high levels, respectively. Although detailed analysis of the feeding data for bulls and heifers completing the 64- and 80-week periods is still in progress, it is reasonable to assume that their intake was close to the values given for heifers up to 48 weeks.

When the T.D.N. consumption of the low and high level bulls through 48 weeks of age was expressed as percentage of that consumed by the medium level, the low level bulls ranged from 64 to 75 percent and the high level bulls from 125 to 139 percent. When the T.D.N. consumption of the heifers through 48 weeks of age was compared and expressed as percentage of that consumed by the medium level heifers, the low levels ranged from 61 to 72 percent and the high levels ranged from 128 to 136 percent.

Slaughter and Sampling of Body Parts for Water Analysis

Animals were taken off feed and water 24 hours prior to weighing. They were immediately trucked to slaughter following weighing. Any feces excreted between weighing and slaughter were collected and weighed. Urine was not voided during this interval.

The slaughtering method followed the procedure recommended by Deans (1951). The carcasses were washed but not shrouded. The carcasses were aged for seven days at temperatures ranging from 34° to 38° Fahrenheit.

Of the animals studied, 24 were analyzed for body water after dividing the body into eight analytical groups as explained in Table 3.

Group I, carcass meat, was obtained by removing the edible meat from the left side of the carcasses after aging. An attachment was placed on the meat grinder head to direct half of the meat into one tub and half into a second tub. One tub of meat was rejected and the other reground. After four grindings in this manner the portion remaining in one tub was mixed by hand and a sample taken. The first three grindings were made using a three-eights inch plate and the final grinding using a five thirty-seconds inch plate. All group samples were placed in pint glass jars with rubber gaskets and frozen until analyzed for moisture. All carcass weight losses between the hot carcass weight and the weight at boning were assumed to be moisture loss and considered a part of Group I. The meat removed for Group I represented half of the carcass meat and the weights were doubled when whole body water content was calculated.

The hard tissues placed in Group II were taken at slaughter and at the time the meat was boned. Any loss in weight between hard tissue removal and grinding was assumed to be moisture and considered a part of Group II. One half of all hard structures such as head bones, tail bones, and carcass bones went into this group and the weights were doubled for computation of total body water.

TABLE 3. BODY PARTS AS GROUPED FOR MOISTURE ANALYSIS

	Body parts included in group
Group I Carcass meat	All tissues other than bone in the left side of the carcass - largely fat and muscle
Group II Bones	All skeletal bones in the left half of the animal plus left dew claws and hooves
Group III Organs	Reproductive tract, urinary bladder, gall bladder, liver, spleen, lungs, pericardium, trachea, heart, thymus, large blood vessels in chest cavity, brain, spinal cord, and tongue.
Group IV Digestive tract	Small intestine, large intestine, stomachs, and esophagus
Group V Fat	Caul fat and ruffle fat
Group VI Blood	All blood recovered at slaughter
Group VII Hide and hair	Hide and hair
Group VIII Head meat	All tissues that could be removed from the skinned head except the brain and tongue

Group II was ground in a tractor powered, belt driven bone grinder and sampled. The largest ground particles were approximately three x two x eight millimeters.

Group III was a miscellaneous analytical group and included all tissues not listed in other groups. This group was composed of soft tissues except for the cartilage rings of the trachae. The group was chopped immediately after slaughter, or the following morning, in a 15-inch Hobart Silent Cutter. The rapidly rotating knives of this machine chopped the cartilage rings into small pieces and did not separate them from the softer tissues. After chopping, the group was thoroughly mixed by hand, sampled, and the sample frozen.

Group IV was obtained by opening, emptying, and washing the entire digestive tract. After washing, the intestines were cut into three to four foot lengths and hung over a horizontal board to drain. The stomachs and esophagus were prepared in the same manner. After draining for 30 to 45 minutes the tissues were chopped. This was followed by hand mixing and sampling.

The fat group, Group V, consisted of the ruffle fat and caul fat. Some of the smaller animals on the low feeding level did not have enough of these fats to make an analytical group, and the limited fat tissue present at these locations was placed in Group III.

All blood voided at slaughter was collected and weighed. Most of it could be caught when the animal was bled. The blood which ran onto the floor during slaughter was continually recovered by using a rubber floor scraper and shovel. The total weight of Group VI was the weight of all blood collected during the bleeding and dressing operations. The blood sample for Group VI analysis was collected during the first seconds of bleeding.

Group VII, the hide and hair, was removed in the usual manner and weighed. The hide was then spread out flesh side up and marked along the dorsal midline. Parallel strips, one inch wide, were then removed by cutting from this midline, until the edge of the hide was reached. In this manner a strip was removed from the neck, shoulder, rib, loin, and rump areas of the hide. In addition, a one-inch hide strip was removed from the forehead and cheek and a like strip from the hide of the tail. All strips were then chopped, mixed by hand, and sampled. The larger hide pieces after chopping were approximately two and one-half millimeters square.

Group VIII was made up of all soft tissues which could be removed from the bones of the left half of the head except the tongue and brain. The group was chopped, mixed by hand, and sampled.

After frozen storage each group sample was analyzed for moisture using the method of Bidwell and Sterling (1925), distillation under toluene. This method was chosen because rather large samples may be easily analyzed. For each determination enough material to yield from 21 to 24 milliliters of water was placed under toluene, distilled, and the volume of distilled water measured. Usually samples weighing 25 to 40 grams could be used for each moisture analysis. These relatively large samples compensated for the rather coarse tissue particles in some groups.

Carcass Measurements

Measurements of (a) length of body, (b) length of hind leg, (c) total length of carcass, (d) circumference of round, (e) depth of body, (f) length of loin, (g) width of shoulder, and (h) width of round, were taken according to the standard method recommended by Naumann (1951).

Muscle Weights and Preparation of Cooking Samples

Five muscles from the right side were removed following seven days of aging. They were trimmed free of all fat covering and weighed. The five muscles were:

(a) Total semimembranosus plus adductor (inside round)

(b) Total semitendenosus (eye of round)

(c) The anterior portion of the psoas major (tenderloin) which was separated from its posterior portion at a point level with the tuber coxae as the carcass hung from the meat rail

(d) The longissimus dorsi muscle from the midpoint between the 12th and 13th ribs to the midpoint between the 5th and 6th ribs (rib eye)

(e) Total triceps brachii, long head, (heavy muscle posterior to the arm bone)

After each muscle was weighed it was prepared for freezing. A thermocouple was inserted into the center of each roast before wrapping in cellophane (DuPont MSAT-87) and enclosed in stockinette. In the first series of animals, which consisted of the 64- and 80-week-old bulls, no attempt was made to prepare roasts of the same size and shape. The second series of animals consisted of the 16-, 32-, 48-, 64-, and 80-week-old heifers. Larger muscles were prepared into roasting pieces six inches long and two and a half inches in diameter. The standardization of size of roasting pieces greatly reduced the variability in cooking time.

Freezing and Frozen Storage of Cooking Samples

The packaged muscle samples from the bulls were frozen by placing them in contact with the refrigerant wall in a chest type home freezer and subjecting them to an air blast. The temperature of the compartment during freezing was 0° Fahrenheit. The wrapped muscle samples from the heifers were frozen at -5° Fahrenheit in an upright freezer. Storage of all samples was in a 12 cubic foot chest type freezer at an average temperature of -9° Fahrenheit. The length of the storage period ranged from three to eight months.

Percent Edible Meat and Bone in Carcasses

Weights of total edible meat included all lean and fat in the carcass. The weights of meat and carcass bones were taken at the time the left side was boned for moisture analysis.

Antipyrine Method for Measurement of Body Water

Animals were taken off feed and water 24 hours prior to injection with antipyrine. The solution injected contained .3 gram of antipyrine per milliliter. From seven to fourteen grams, depending on the size of the animal, were injected into the jugular vein. Blood was drawn for serum analysis of antipyrine at two and one-half, three and one-half, four and one-half and five and one-half hours following injection. At the time of injection an initial blood sample was taken for use in the blank determination of antipyrine in the serum. No anticoagulant was used. Blood samples were stored in a refrigerator until centrifuging. The maximum storage of samples was 24 hours.

The analysis for the determination of antipyrine in serum water was very similar to the precipitation procedure outlined by Brodie et al. (1949). However, a few alterations were made. The volumes of blood serum, zinc reagent and 0.75 Normal sodium hydroxide were increased to five milliliters each. Also 0.1 milliliter of 2 Normal H_2SO_4 and 0.1 milliliter of 0.2 percent $NaNO_2$ solution were used instead of one drop of 4 Normal H_2SO_4 and two drops of 0.2 percent $NaNO_2$.

The log of the concentration of the antipyrine in the serum samples was plotted against time of sampling for each animal. A regression equation was calculated from these concentrations. The theoretical concentration of antipyrine in body water was calculated from the regression equation. It was assumed that there was uniform and instantaneous distribution with none of the drug being metabolized. The milligrams of antipyrine injected divided by the concentration (milligrams per liter) of antipyrine in the serum water gave the number of liters of body water. Body water in liters divided by body weight in kilograms and multiplied by 100 gave percentage body water.

Specific Gravity of Carcasses

After the 60- and 80-week-old bulls and the 16- and 48-week-old heifers had been ground and sampled for body water analysis, it was decided to make specific gravity observations on the remainder of the animals slaughtered.

Carcass specific gravity was taken by first weighing the fore and hind quarters from the left side of the carcass on a platform scale to the nearest one-fourth of a pound. The quarters were then weighed to the nearest gram in water. To make this weighing, a four- by six-foot water vat was filled to a depth of two feet. A two- by ten-inch plank was placed horizontally over the water. A gram balance was placed on the plank with one pan over a one-inch diameter hole. A fine steel wire ran from the pan frame through the hole into the water. Three small metal hooks with 12- to 18-inch lengths of wire were secured to the pan wire, balanced, and used to grasp the beef quarter during weighing. The balance was adjusted quickly to the nearest gram and the weight recorded. Care was taken to eliminate trapped air underneath the diaphragm and flank. The water temperature ranged from 16° to 19° Centigrade.

The difference between the sum of the weights of the quarters in air and the sum of the weights in water were used for calculating specific gravity. The relationship proposed by Kraybill et al. (1952), $Y = 0.9955\,X - .0013$, was used to convert dressed carcass specific gravity to whole animal specific gravity. Percent body water was obtained from the equation of Kraybill et al. (1952):

$$\%\ \text{Water} = 100\left(3.896 - \frac{3.486}{\text{Specific Gravity}}\right)$$

Cooking and Tenderness of Muscles

Roasting. For palatability testing, the frozen roasts were quickly unwrapped and placed on wire racks, one-half inch high, in open stainless steel pans having a one-inch depth. The pans were placed in a well-insulated electric test oven. The terminal ends of the thermocouple were attached to a recording potentiometer. An additional thermocouple was attached to record the air temperature of the oven. The internal temperatures of the roast and the oven temperatures were recorded throughout cooking at one second intervals. The oven temperature was thermostatically controlled at 300° Fahrenheit. At the beginning of cooking the roasts registered 10° to 15° Fahrenheit. The roasts were removed from the oven when the internal temperature reached 156° Fahrenheit (medium doneness for beef).

Deep fat frying. Only the muscles from the 16-week-old and 32-week-old heifers were cooked in deep fat. The temperature of the fat was 350° Fahrenheit and the muscles were cooked to an internal temperature of 156° Fahrenheit.

Tenderness measurements. One-inch cores were removed parallel with the muscle fibers for shear resistance by using the Warner-Bratzler Shear (1949). The number of observations on each sample was as few as two in the smallest muscles and as many as four in the largest muscles. The mechanical shear gave the pounds of force required to sever the core, thus a lower score indicated more tender meat.

One inch squares of cooked meat were removed from slices cut one-sixteenth inch thick on a mechanical meat slicer. Each committee member

RESULTS AND DISCUSSION

Body Weights and Carcass Yields

The slaughter weights and dressing percentages are shown according to levels of nutrition in Tables 4 and 5. The live weights were consistantly greater with higher T.D.N. intake with the exception of the liveweight of one high feeding level heifer in the 64-week-old slaughter group. Live weights likewise increased with increases in age except for the live weight of this one heifer. The cattle on higher feeding levels appeared fatter and had higher dressing percentages. When analyzed statistically the increases in dressing percentage associated with feeding levels were significant at the one percent level as shown in Table 6. The differences in dressing percentage due to age were not statistically significant.

Carcass Measurements

The carcass measurements are given in detail in Appendix Tables II through IX. The measurements were consistently greater with increases in age and in T.D.N. intake. A summary of the statistical treatment of these data is shown in Table 7. In the heifer series, thirty carcasses were measured. The differences associated with feeding level and with age were highly significant for each of the eight measurements. The 12 bull carcasses were from only two age groups, 64 and 80 weeks. They showed the same trend, but the differences due to age were not significant for

TABLE 4. SLAUGHTER WEIGHT AND DRESSING PERCENT OF HEIFERS

Animal Number	Age in Weeks	Feeding Level: Low — Slaughter Weight	Low — Hot Dressing Percent	Medium — Slaughter Weight	Medium — Hot Dressing Percent	High — Slaughter Weight	High — Hot Dressing Percent
		lbs.	%	lbs.	%	lbs.	%
202	16	129.8	47.18				
227	16	141.9	46.86				
203	16			179.8	52.42		
226	16			210.6	52.11		
201	16					231.5	56.48
221	16					281.5	49.91
206	32	223.0	44.17[a]				
224	32	279.0	46.27				
204	32			403.0	47.64[a]		
222	32			329.0	52.28		
205	32					552.0	54.98[a]
223	32					481.0	56.34
207	48	372.0	47.85				
219	48	353.0	47.31				
209	48			521.0	55.47		
220	48			590.0	54.75		
214	48					756.0	59.52
230	48					664.0	58.28
213	64	443.0	47.63				
218	64	480.0	51.04				
215	64			751.0	56.59		
217	64			693.0	55.84		
210	64					675.0[b]	57.48
216	64					904.0	59.96
211	80	517.0	49.32				
229	80	550.0	52.36				
212	80			831.0	59.57		
228	80			905.0	55.91		
208	80					1,057.0	64.33
225	80					1,105.0	62.44

a Not off feed and water 24 hours prior to slaughter
b Apparently due to individual characteristics this heifer failed to respond to high level feeding to the same extent as the others on this treatment

TABLE 5. SLAUGHTER WEIGHT AND DRESSING PERCENT OF BULLS

Animal Number	Age in Weeks	Feeding Level: Low — Slaughter Weight	Low — Hot Dressing Percent	Medium — Slaughter Weight	Medium — Hot Dressing Percent	High — Slaughter Weight	High — Hot Dressing Percent
		lbs.	%	lbs.	%	lbs.	%
50	64	607.0	52.39				
61	64	576.0	53.65				
54	64			827.5	53.90		
58	64			727.3	53.21		
52	64					997.0	60.98
72	64					1,070.3	59.80
47	80	626.0	55.11				
71	80	652.0	48.61[a]				
53	80			929.0	57.91		
62	80			983.0	55.84		
43	80					1,151.0	63.01
60	80					1,186.0	62.98

a Bull got access to feed during the 24-hour fast

TABLE 6. ANALYSIS OF VARIANCE OF HOT DRESSING PERCENT

Sex	Source of Variance	Degrees of Freedom	Sum of Squares	Mean Square	F
Bulls	Levels	2	180.35	90.17	21.67**
	Ages	1	7.57	7.57	1.82
	L. x A.	2	11.59	5.79	
	Within	6	25.00	4.16	
Heifers	Levels	2	508.10	254.05	6.90**
	Ages	4	202.75	50.69	1.38
	L. x A.	8	30.70	3.84	
	Within	15	552.23	36.82	

** Significant (1% level)

TABLE 7. SUMMARY OF ANALYSIS OF VARIANCE OF CARCASS MEASUREMENTS

Sex	Source of Variance	Degrees of Freedom	Carcass Measurement							
			Length of Body	Length of Hind Leg	Total Length of Carcass	Circumference of Round	Depth of Body	Length of Loin	Width of Shoulder	Width of Round
			F value	F value	F value	F value	F value	F value	F value	F value
Bulls	**Levels**	2	31.71**	28.09**	41.13**	3.52	1.32	18.41**	23.78**	91.97**
	Ages	1	2.15	7.70*	4.37	1.04	7.15*	5.57	11.09*	18.15**
	L. x A.	2	0.71	2.49	1.24	0.743	0.006	0.129	0.109	0.199
	Within	6	(11.83)[a]	(4.237)	(22.30)	(9.391)	(13.24)	(4.633)	(0.959)	(0.231)
Heifers	**Levels**	2	40.35**	72.97**	97.00**	138.92**	91.36**	66.88**	142.79**	61.68**
	Ages	4	146.12**	211.18**	214.20**	129.85**	270.09**	162.89**	177.37**	89.20**
	L. x A.	8	1.15	2.47	1.92	2.16	1.68	1.05	0.40	1.55
	Within	14	(12.02)	(2.278)	(18.72)	(6.802)	(0.645)	(3.483)	(4.057)	(0.934)

a Values in parenthesis are Mean Squares
* Significant (5% level)
** Significant (1% level)

every measurement. This could be because the bulls were nearer to the end of their growth span.

Muscle Weights

Muscles were considered as percentage of the total carcass weight and are reported in Appendix Tables X through XIV. A summary of the statistical analysis of the differences associated with treatments is given in Table 8.

In the bulls increases in feeding levels were significantly associated with a lesser percentage of semimembranosus-adductor muscle and highly significantly associated with a lesser percentage of psoas major muscle.

In the heifers increases in feeding levels were highly significantly associated with a lesser percentage of semimembranosus-adductor muscles and also a lesser percentage of triceps brachii muscle. The higher levels of intake for heifers were highly significantly associated with greater percentages of longissimus dorsi muscle.

With respect to the effect of increases in age upon percentage of muscle weight, it was noted that in the bulls greater age was significantly associated with a higher percentage of the psoas major muscle. In the heifers greater age was highly significantly associated with a lesser percentage of semimembranosus-adductor muscles and significantly associated with a lesser percentage of psoas major muscle.

It should be noted that the only significant increase in muscle percentage produced by higher feeding levels was in the case of the longissimus dorsi of the heifers and the only significant increase in

TABLE 8. SUMMARY OF ANALYSIS OF VARIANCE OF MUSCLE WEIGHT DATA EXPRESSED AS PERCENT OF CARCASS WEIGHT

Sex	Source of variance	Degrees of freedom	Muscle				
			Semi-membranosus plus adductor	Semi-tendinosus	Psoas major	Longissimus dorsi	Triceps brachii, long head
			F value	F value	F value	F value	F value
Bulls	Levels	2	9.72*	0.777	27.09**	2.212	2.286
	Ages	1	1.75	0.764	11.52*	0.670	0.079
	L. x A.	2	0.57	0.264	2.14	0.526	0.135
	Within	6	(.0804)[a]	(.8452)	(.0035)	(40.05)	(.0465)
Heifers	Levels	2	12.37**	2.265	0.817	6.680**	7.283**
	Ages	4	5.09**	0.601	5.951*	2.840	2.637
	L. x A.	8	3.01	2.835	3.271	1.821	0.753
	Within	14	(.2010)	(.2316)	(.0084)	(.0310)	(.0456)

a Values in parenthesis are Mean Squares
* Significant (5% level)
** Significant (1% level)

muscle percentage produced by increases in age was in the case of the psoas major of the bulls. The last two trends, seemingly contrary to the others, occurred with muscles from which it was impractical in the experiment to remove the muscle in total. There is the possibility that error in removing a uniform portion of the muscle each time was responsible for this reverse trend.

Neither levels of feeding nor age was associated with any significant change in percentage weight of the semitendinosus, the longissimus dorsi, or the triceps brachii in the bulls. Age had no significant effect on the semimembranosus-adductor muscles in bulls. In the heifers levels of feeding had no significant effect on the semitendinosus or the psoas major muscle, and age had no significant effect on the semitendinosus, longissimus dorsi, and triceps brachii percentage weights.

Percent of Edible Meat and Bone in the Carcasses

The edible meat in the carcass included all lean and fat tissues. The bones made up the balance of the carcass. Edible meat data were taken only from the bulls slaughtered at 64 and 80 weeks of age and from the heifers slaughtered at 16 and 48 weeks of age. The percentages are given for each carcass in Table 9. Older animals and those on higher nutritional levels had carcasses containing a larger percentage of edible meat. The effect of age with respect to these differences was not significant for the bulls, but the effect of feeding levels was highly significant. With the heifer carcasses differences in percentage of edible meat associated with age and with levels of feeding were both highly significant. Table 10 summarizes the analysis of variance of these observations.

TABLE 9. PERCENT OF EDIBLE MEAT AND BONE IN CARCASS

Sex	Age in weeks	Feeding Level					
		Low		Medium		High	
		Meat	Bone	Meat	Bone	Meat	Bone
		%	%	%	%	%	%
Bulls	64	78.5	21.5	81.0	19.0	82.4	17.6
		78.4	21.6	81.5	18.5	82.9	17.1
	80	78.4	21.6	82.1	17.9	83.1	16.9
		74.9	25.1	79.9	20.1	86.6	13.4
Heifers	16	68.3	31.7	74.4	25.6	78.5	21.5
		68.6	31.4	75.1	24.9	78.6	21.4
	48	76.6	23.4	79.0	21.0	83.5	16.5
		75.0	25.0	80.1	19.9	83.5	16.5

TABLE 10. ANALYSIS OF VARIANCE OF EDIBLE MEAT IN CARCASSES

Sex	Source of Variance	Degrees of Freedom	Sum of Squares	Mean Square	F
Bulls	Levels	2	78.13	39.06	15.69**
	Ages	1	.01	.01	
	L. x A.	2	7.96	3.98	
	Within	6	14.92	2.49	
Heifers	Levels	2	159.30	79.65	219.24**
	Ages	1	23.55	23.55	64.83**
	L. x A.	2	78.01	39.00	107.35**
	Within	6	2.18	.3633	

** Significant (1% level)

Water and Fat Content of the Whole Body

The 64- and 80-week-old bulls and the 16- and 48-week-old heifers were analyzed for total body water by determining the amount of moisture in all body tissues. Determinations for total body water by means of antipyrine could not be made for the first four bulls slaughtered due to a delay in delivery of the drug from the supplier. All animals subsequently slaughtered were injected with antipyrine. After the 48-week-old heifers had been slaughtered, it was decided to discontinue the moisture analyses of body parts due to the extensive amount of labor required in preparing the tissues for sampling. Specific gravity observations were substituted for moisture analysis when the 64- and 80-week-old heifers were slaughtered. The 32-week-old heifers were not included in the observations for body water since their slaughter date coincided with the slaughter dates of the 80-week-old bulls and the necessary determinations could not be made.

Table 11 gives the percent body water for the individual animals as determined by the antipyrine method, by moisture analysis of body tissues, and by carcass specific gravity.

There were twenty cattle of varying degrees of fatness for which the amount of body water as determined by antipyrine could be compared with the amount determined by tissue analysis. The agreement between the antipyrine method and direct tissue analysis for these twenty cattle is shown in Table 12 and in Figure 2. The average difference between the two methods was .48 percent. With ten cattle the antipyrine method gave percentages of body water above that found by tissue analysis, and

TABLE 11. TOTAL BODY WATER OF CATTLE EXPRESSED AS PERCENTAGE OF LIVE WEIGHT

Animal Identity and Method of Determination	Feeding Level: Low		Normal		High	
64-week-old bulls						
Animal No.	50	61	54	58	52	72
Percent water						
By tissue analysis	71.44	72.63	72.41	70.04	61.94	64.73
By antipyrine	(a)	73.39	(a)	(a)	(a)	66.21
80-week-old bulls						
Animal No.	47	71	53	62	43	60
Percent water						
By tissue analysis	71.73	71.52	69.16	71.53	61.77	56.41
By antipyrine	71.86	74.05	72.29	68.16	60.79	55.54
16-week-old heifers						
Animal No.	202	227	203	226	201	221
Percent water						
By tissue analysis	78.31	72.96	69.74	69.75	67.30	71.63
By antipyrine	75.49	69.42	69.54	68.67	67.89	72.15
48-week-old heifers						
Animal No.	207	219	209	220	214	230
Percent water						
By tissue analysis	69.87	67.26	70.55	68.23	58.66	56.28
By antipyrine	72.37	67.03	67.75	70.02	60.73	55.65
64-week-old heifers						
Animal No.	213	218	215	217	210	216
Percent water						
By specific gravity	67.80	70.20	65.20	67.90	62.30	58.80
By antipyrine	65.07	(b)	63.24	67.07	62.52	61.67
80-week-old heifers						
Animal No.	211	229	212	228	208	225
Percent water						
By specific gravity	76.28	76.56	62.80	68.78	67.63	61.38
By antipyrine	82.81	69.70	64.43	58.36	71.22	86.98

(a) Not injected due to delayed receipt of antipyrine from supplier

(b) Injection of total dose of antipyrine into vein questionable

TABLE 11. TOTAL BODY WATER OF CATTLE EXPRESSED AS PERCENTAGE OF LIVE WEIGHT

Animal Identity and Method of Determination	Feeding Level					
	Low		Normal		High	
64-week-old bulls						
Animal No.	50	61	54	58	52	72
Percent water						
By tissue analysis	71.44	72.63	72.41	70.04	61.94	64.73
By antipyrine	(a)	73.39	(a)	(a)	(a)	66.21
80-week-old bulls						
Animal No.	47	71	53	62	43	60
Percent water						
By tissue analysis	71.73	71.52	69.16	71.53	61.77	56.41
By antipyrine	71.86	74.05	72.29	68.16	60.79	55.54
16-week-old heifers						
Animal No.	202	227	203	226	201	221
Percent water						
By tissue analysis	78.31	72.96	69.74	69.75	67.30	71.63
By antipyrine	75.49	69.42	69.54	68.67	67.89	72.15
48-week-old heifers						
Animal No.	207	219	209	220	214	230
Percent water						
By tissue analysis	69.87	67.26	70.55	68.23	58.66	56.28
By antipyrine	72.37	67.03	67.75	70.02	60.73	55.65
64-week-old heifers						
Animal No.	213	218	215	217	210	216
Percent water						
By specific gravity	67.80	70.20	65.20	67.90	62.30	58.80
By antipyrine	65.07	(b)	63.24	67.07	62.52	61.67
80-week-old heifers						
Animal No.	211	229	212	228	208	225
Percent water						
By specific gravity	76.28	76.56	62.80	68.78	67.63	61.38
By antipyrine	82.81	69.70	64.43	58.36	71.22	86.98

(a) Not injected due to delayed receipt of antipyrine from supplier

(b) Injection of total dose of antipyrine into vein questionable

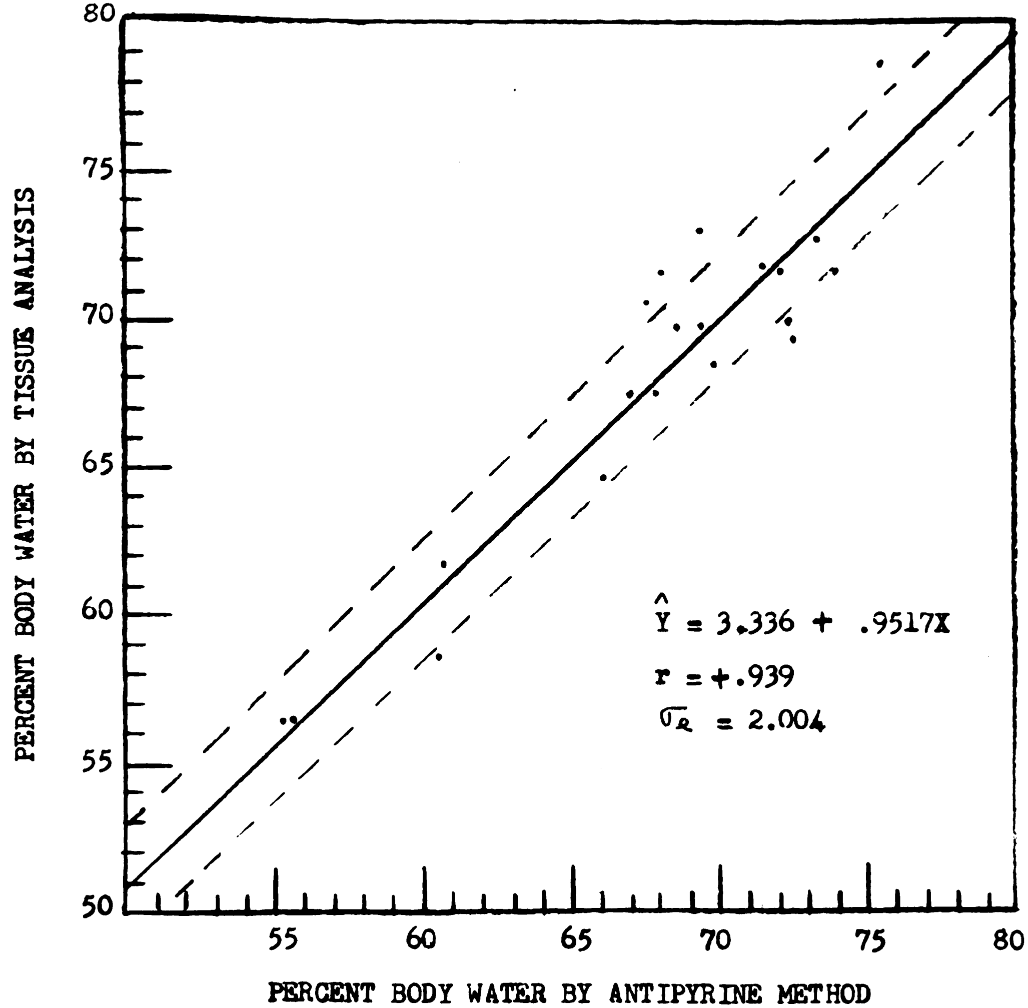

Fig. 2. Correlation between two methods of determining body water

TABLE 12. PERCENT OF BODY WATER IN CATTLE AS MEASURED BY ANTIPYRINE AND ANALYSIS OF BODY TISSUES

Number of Animals	Method	Range	Mean	Standard Deviation
20	Antipyrine	74.05 - 55.54	68.00	5.56
	Tissue analysis	78.31 - 56.28	67.95	5.62

with ten the antipyrine method gave lower percentages. The correlation coefficient between the two methods was +.939 with 95 percent confidence limits of +.850 and +.976. The agreement between the antipyrine method of determination of body water and determination by tissue analysis was similar to the agreement reported by Kraybill <u>et al</u>. (1951) between the antipyrine method and the calculation of body water from the carcass specific gravity.

There was close agreement between the percentage of body water by the antipyrine method and by calculation from carcass specific gravity for the 64-week-old heifers as is shown in Table 11. Heifer No. 218 had no antipyrine value recorded since unusual difficulty was experienced in injecting the antipyrine into the jugular vein. The antipyrine determinations for the 80-week-old heifers were subject to errors. The cause of the unusual body water percentages of this slaughter group was not determined. Discrepancies such as this have not occurred in continued use of the antipyrine method in the same laboratory with cattle on later experiments.

The total body fat percentage is given in Table 13. It was calculated from the percentage body water as determined by antipyrine. The equation of Reid et al. (1954), $Y = 356.87 + 0.3585\ X - 203.56\ \text{Log}\ X$, in which X equals the percentage body water was used to calculate the percentage fat. Reid's equation was calculated from all body composition data for cattle that could be found in the literature, and included 230 dairy and beef cattle ranging from new-born calves to aged cows. The cattle in this experiment on higher levels of nutrition had higher fat percentages by calculation than those cattle on lower levels. Likewise the cattle on higher levels were noticeably fatter in appearance before and after slaughter.

Tenderness of Cooked Muscles

Since the animals ranged from 16 to 80 weeks of age, they were young for slaughter cattle and all were relatively tender. The tenderness measurements were limited to three cooked muscles, the longissimus dorsi, the semimembranosus, and the psoas major. These muscles were not cooked for every animal slaughtered at every age period, but all three feeding levels and all slaughter ages were represented in the observations. The average tenderness scores as determined by the mechanical shear and by counting the number of chews to completely masticate a standardized portion of cooked muscle are given in Appendix Tables XV through XVIII. The statistical analysis of the tenderness differences found by counting chews were too small to be statistically significant. A summary of the statistical analysis of the scores by both methods of tenderness measurement is given in Tables 14 and 15.

TABLE 13. TOTAL BODY FAT OF CATTLE EXPRESSED AS PERCENTAGE OF LIVE WEIGHT*

	Feeding Level					
	Low		Normal		High	
64-week-old bulls						
Animal No.		61				72
Percent fat		3.41				9.94
80-week-old bulls						
Animal No.	47	71	53	62	43	60
Percent fat	4.73	2.86	4.35	8.07	15.55	21.65
16-week-old heifers						
Animal No.	202	227	203	226	201	221
Percent fat	1.67	6.91	6.79	7.60	8.33	4.47
48-week-old heifers						
Animal No.	207	219	209	220	214	230
Percent fat	4.28	9.14	8.45	6.36	15.61	21.51
64-week-old heifers						
Animal No.	213	218	215	217	210	216
Percent fat	11.08		12.93	9.11	13.69	14.59

* Fat percentage calculated from body water (by antipyrine technique) using the equation of Reid *et al*. (1954), $Y = 356.875 + 0.35853\ X - 203.563 \log X$, where X = percent body water

The mechanical shear indicated large enough differences in tenderness for statistical significance in some instances. In the heifers the differences due to levels of feeding were not significant for the muscles studied. In the bulls feeding levels had no significant influence on the longissimus dorsi and psoas major muscles. However, the semimembranosus was significantly less tender with higher feeding levels.

Increases in age were associated with highly significant decreases in tenderness by shear measurement for the semimembranosus and psoas major from heifers and for the semimembranosus from the bulls. Increases

TABLE 14. SUMMARY OF ANALYSIS OF VARIANCE OF MEASUREMENTS OF TENDERNESS OF COOKED MUSCLES FROM BULLS

Method of Measurement	Source of Variance	Degrees of Freedom	Longissimus dorsi		Semimembranosus		Psoas Major	
			Mean Square	F	Mean Square	F	Mean Square	F
Shear	Levels	2	47.08	.28	26.25	5.91*	8.31	.25
	Ages	1	132.66	.78	191.20	43.06**	11.41	.34
	L. x A.	2	76.29	.45	5.43	1.22	.30	.009
	Within	6	169.67		4.44		33.63	
No. of Chews	Levels	2	235.08	1.60	126.58	.28	352.33	2.19
	Ages	1	520.08	3.54	.34	.0007	192.00	1.19
	L. x A.	2	151.08	1.03	129.08	.29	91.00	.56
	Within	6	147.08		449.50		161.00	

* Significant (5% level)
** Significant (1% level)

TABLE 15. SUMMARY OF ANALYSIS OF VARIANCE OF MEASUREMENTS OF TENDERNESS OF COOKED MUSCLES FROM HEIFERS

Method of Measurement	Muscle Analysis											
	Longissimus dorsi				Semimembranosus				Psoas major			
	Source of Variance	Degrees of Freedom	Mean Square	F	Source of Variance	Degrees of Freedom	Mean Square	F	Source of Variance	Degrees of Freedom	Mean Square	F
Shear	Levels	2	20.98	.34	Levels	2	79.55	2.56	Levels	1	3.16	.82
	Ages	3	72.99	1.17	Ages	4	191.93	6.17**	Ages	3	49.50	12.83**
	L. x A.	6	29.74	.48	L. x A.	8	23.74	.76	L. x A.	3	.98	.25
	Within	10	62.50		Within	12	31.11		Within	5	3.86	
Number of Chews	Levels	2	163.54	.71	Levels	2	265.60	2.49	Levels	2	30.33	1.33
	Ages	3	280.49	1.22	Ages	3	353.90	3.31	Ages	1	3.00	.13
	L. x A.	6	425.32	1.85	L. x A.	6	18.80	.18	L. x A.	2	3.00	.13
	Within	11	230.46		Within	12	106.80		Within	4	22.50	

** Significant (1% level)

in age failed to show a significant effect on the tenderness of the longissimus dorsi and psoas major from the bulls or on the tenderness of the longissimus dorsi from the heifers.

The author placed more confidence in the mechanical shear for measuring muscle tenderness than in the number of chews recorded by the palatability committee. Although some results were inconsistent, there was a definite trend toward decreases in tenderness as the cattle increased in age from 16 to 80 weeks.

SUMMARY AND CONCLUSIONS

Holstein cattle were fed on low, medium, and high levels of nutrition from the first week of age until slaughter at 16, 32, 48, 64, and 80 weeks.

The cattle with greater T.D.N. intake had a higher dressing percentage, increased length and thickness of carcass and a larger ratio of edible meat to bone. Higher nutritional levels were associated with a smaller percentage weight of muscles in the carcass. The level of feeding tended to show no significant influence on tenderness.

As the cattle increased in age there were significant increases in length and thickness of the carcass and a larger ratio of edible meat to bone. Age showed no influence on dressing percentage and in general no consistant influence on percentage weight of muscles in the carcass. One muscle of the three observed became significantly less tender with age in the bulls and two muscles showed this trend in the heifers.

The percentage of total body water was calculated for twenty cattle by the antipyrine technique and by analyzing all body tissues for moisture. The correlation coefficient of the comparison of the two methods was +.939. The percentage of total body fat was calculated from the percentage of body water.

APPENDIX TABLE I. CARCASS AND WHOLE BODY SPECIFIC GRAVITY OF 64- AND 80-WEEK-OLD HEIFERS

Animal Number	Age in Weeks	Feeding Level: Low, Carcass Sp. Gr.	Low, Whole Body Sp. Gr. (1)	Medium, Carcass Sp. Gr.	Medium, Whole Body Sp. Gr. (1)	High, Carcass Sp. Gr.	High, Whole Body Sp. Gr. (1)
213	64	1.0893	1.0831				
218	64	1.0976	1.0914				
215	64			1.0809	1.0747		
217	64			1.0898	1.0836		
210	64					1.0710	1.0649
216	64					1.0598	1.0537
211	80	1.1189	1.1126				
229	80	1.1199	1.1136				
212	80			1.0728	1.0667		
228	80			1.0928	1.0866		
208	80					1.0889	1.0827
225	80					1.0682	1.0621

(1) Whole body specific gravity is calculated from carcass specific gravity of Kraybill (1952) $Y = 0.9955x - 0.0013$

APPENDIX TABLE II. CARCASS MEASUREMENTS OF LENGTH OF BODY

Sex	Age in weeks	Feeding Level		
		Low	Medium	High
		cm.	cm.	cm.
Bulls	64	109.9	125.5	127.6
		113.2	118.1	134.7
	80	111.5	126.5	131.0
		115.2	129.5	132.8
Heifers	16	70.1	76.6	82.1
		72.1	81.1	91.2
	32	82.7	96.1	105.3
			92.1	102.3
	48	91.5	108.3	115.1
		90.4	108.4	110.1
	64	104.4	117.1	112.1
		104.9	114.3	121.7
	80	108.9	130.0	130.3
		115.2	123.9	131.0

APPENDIX TABLE III. CARCASS MEASUREMENTS OF LENGTH OF HIND LEG

Sex	Age in weeks	Feeding Level: Low	Medium	High
		cm.	cm.	cm.
Bulls	64	71.9	76.9	81.9
		72.1	74.3	85.7
	80	73.0	80.5	85.6
		75.8	84.5	83.2
Heifers	16	50.6	54.6	57.6
		52.0	57.1	57.1
	32	53.6	61.8	66.8
			62.1	67.8
	48	64.5	71.8	75.2
		63.4	71.8	73.7
	64	69.6	76.0	71.7
		70.3	73.3	75.7
	80	72.7	77.5	80.1
		72.5	79.9	80.0

APPENDIX TABLE IV. CARCASS MEASUREMENTS OF TOTAL LENGTH OF CARCASS

Sex	Age in weeks	Feeding Level		
		Low	Medium	High
		cm.	cm.	cm.
Bulls	64	181.9	202.3	209.5
		185.3	195.5	220.3
	80	184.5	206.9	216.6
		191.0	214.0	216.0
Heifers	16	120.7	131.2	139.3
		124.1	138.2	148.8
	32	136.3	157.9	172.1
			154.2	170.1
	48	156.0	180.1	190.3
		153.8	180.2	183.8
	64	173.6	193.1	183.8
		175.2	187.7	197.3
	80	181.6	201.4	210.4
		184.7	209.9	211.0

APPENDIX TABLE V. CARCASS MEASUREMENTS OF CIRCUMFERENCE OF ROUND

Sex	Age in weeks	Feeding Level		
		Low	Medium	High
		cm.	cm.	cm.
Bulls	64	67.1	75.9	82.1
		66.7	74.5	82.9
	80	73.5	80.5	87.0
		65.8	82.9	93.7
Heifers	16	35.2	43.1	48.5
		38.2	45.8	48.5
	32	43.5	59.1	67.3
			52.5	63.9
	48	54.5	66.8	75.4
		54.1	69.9	73.6
	64	56.3	73.7	70.9
		59.2	73.3	78.8
	80	58.0	74.6	84.6
		63.6	75.6	83.6

APPENDIX TABLE VI. CARCASS MEASUREMENTS OF DEPTH OF BODY

Sex	Age in weeks	Feeding Level: Low	Medium	High
		cm.	cm.	cm.
Bulls	64	29.5	35.1	33.7
		38.3	38.5	41.7
	80	38.5	43.1	43.8
		40.2	41.4	43.5
Heifers	16	24.3	26.3	28.5
		25.3	26.5	28.9
	32	27.6	32.2	34.2
			30.4	33.1
	48	31.2	35.5	35.3
		29.8	34.2	35.0
	64	35.3	39.1	38.1
		35.5	37.7	39.7
	80	37.1	40.8	41.8
		37.2	41.1	43.8

APPENDIX TABLE VII. CARCASS MEASUREMENTS OF LENGTH OF LOIN

Sex	Age in weeks	Feeding Level		
		Low	Medium	High
		cm.	cm.	cm.
Bulls	64	57.5	65.7	66.1
		60.2	61.9	70.9
	80	60.7	66.5	70.0
		63.0	68.5	71.2
Heifers	16	36.8	40.3	43.1
		37.6	42.6	48.5
	32	44.9	51.7	56.3
			50.3	54.6
	48	51.8	60.5	62.6
		49.8	58.6	59.5
	64	57.8	64.5	61.7
		56.7	61.6	65.0
	80	59.0	67.5	70.3
		60.6	71.6	69.8

APPENDIX TABLE VIII. CARCASS MEASUREMENTS OF WIDTH OF SHOULDER

Sex	Age in weeks	Feeding Level		
		Low	Medium	High
		cm.	cm.	cm.
Bulls	64	16.5	18.7	20.3
		15.8	16.4	20.5
	80	17.9	20.8	21.6
		16.1	20.1	23.0
Heifers	16	8.2	9.9	11.1
		8.7	10.7	11.3
	32	9.0	11.3	14.1
			10.8	15.1
	48	12.2	16.5	17.5
		11.5	16.1	16.0
	64	13.2	17.5	17.5
		14.6	17.5	19.3
	80	15.1	18.0	21.0
		15.4	18.7	21.7

APPENDIX TABLE IX. CARCASS MEASUREMENTS OF WIDTH OF ROUND

Sex	Age in weeks	Feeding Level		
		Low	Medium	High
		cm.	cm.	cm.
Bulls	64	19.9	22.1	23.7
		19.7	22.7	24.7
	80	21.3	23.7	25.7
		20.2	23.7	25.3
Heifers	16	12.4	13.3	14.9
		11.8	14.1	14.5
	32	13.4	16.8	19.6
			16.2	19.1
	48	16.5	19.8	20.8
		17.8	20.3	21.7
	64	17.9	22.8	21.5
		18.5	22.0	24.7
	80	19.3	22.5	24.4
		19.8	23.1	27.5

APPENDIX TABLE X. SEMIMEMBRANOSUS PLUS ADDUCTOR MUSCLES EXPRESSED AS PERCENT OF CARCASS WEIGHT

Sex	Age in weeks	Feeding Level		
		Low	Medium	High
		%	%	%
Bulls	64	5.16	4.49	4.28
		4.84	4.62	4.11
	80	5.07	4.49	4.08
		4.39	4.66	3.51
Heifers	16	5.31	5.33	5.29
		4.63	5.75	4.69
	32	4.76	5.28	4.95
		4.52	5.35	4.73
	48	4.91	4.94	4.02
			5.13	4.32
	64	5.16	4.51	3.83
		5.05	4.98	1.96
	80	5.23	4.00	3.89
		4.88	4.21	3.24

APPENDIX TABLE XI. SEMITENDINOSUS MUSCLE EXPRESSED AS PERCENT OF CARCASS WEIGHT

Sex	Age in weeks	Feeding Level		
		Low	Medium	High
		%	%	%
Bulls	64	1.69	1.67	1.74
		1.97	2.39	1.61
	80	2.00	1.63	1.81
		1.60	1.80	1.35
Heifers	16	1.29	1.88	1.64
		1.18	1.70	1.43
	32	1.16	1.71	1.51
		1.64	1.38	1.56
	48	1.69	1.64	1.65
			1.68	1.65
	64	1.78	1.62	1.48
		1.61	1.64	1.29
	80	1.67	1.54	1.36
		1.86	1.59	1.46

APPENDIX TABLE XII. PSOAS MAJOR MUSCLE PORTION EXPRESSED AS PERCENT OF CARCASS WEIGHT

Sex	Age in weeks	Feeding Level		
		Low	Medium	High
		%	%	%
Bulls	64	.87	.77	.68
		.56	.67	.49
	80	.98	.72	.86
				.88
Heifers	16	.55	.68	.63
		.56	.67	.93
	32	.78	1.06	.79
		.64	.87	.69
	48	.66	.70	.68
			.74	.75
	64	.70	.48	.53
		.80	.59	.43
	80	.68	.67	.55
		.65	.51	.47

APPENDIX TABLE XIII. LONGISSIMUS DORSI MUSCLE PORTION EXPRESSED AS PERCENT OF CARCASS WEIGHT

Sex	Age in weeks	Feeding Level		
		Low	Medium	High
		%	%	%
Bulls	64	1.77	2.02	2.12
		1.67	1.85	1.92
	80	1.74	1.99	1.81
		1.52	1.97	1.74
Heifers	16	1.36	1.65	1.63
		1.02	1.65	1.62
	32	1.02	1.91	1.84
		1.46	1.57	2.05
	48	1.60	1.78	1.79
			1.92	1.80
	64	1.75	1.74	2.01
		1.82	1.90	1.61
	80	1.73	1.48	1.76
		1.72	1.87	1.57

APPENDIX TABLE XIV. TRICEPS BRACHII MUSCLE, LONG HEAD, EXPRESSED AS PERCENT OF CARCASS WEIGHT

Sex	Age in weeks	Feeding Level		
		Low	Medium	High
		%	%	%
Bulls	64	2.31	2.41	1.91
		2.10	1.95	2.02
	80	2.08	2.28	1.97
		2.58	2.09	1.91
Heifers	16	2.07	2.23	2.21
		2.08	2.27	1.90
	32	2.05	2.05	1.93
		2.78	2.21	1.89
	48	2.35	1.98	1.53
			1.91	1.94
	64	2.05	1.80	1.65
		2.02	1.94	1.70
	80	2.19	1.77	2.03
		2.04	1.67	1.42

APPENDIX TABLE XV. TENDERNESS OF COOKED MUSCLES FROM BULLS AS MEASURED BY MECHANICAL SHEAR

Muscle	Age in weeks	Feeding Level		
		Low	Medium	High
		lbs.	lbs.	lbs.
Longissimus dorsi	64	43.0	6.8	22.8
		24.0	40.0	21.3
	80	29.5	17.0	30.0
		8.3	13.7	19.5
Semimembranosus	64	11.6	11.1	15.3
		10.3	13.3	20.4
	80	29.6	21.1	25.9
		10.6	22.3	20.4
Psoas major	64	7.8	8.5	6.5
		10.8	11.5	6.7
	80	15.5	10.2	9.3
		7.2	11.8	9.5
Semitendinosus	80	25.8	30.2	27.8
		17.2	21.0	27.7

APPENDIX TABLE XVI. TENDERNESS OF COOKED MUSCLES FROM BULLS AS MEASURED BY AVERAGE NUMBER OF CHEWS

Muscle	Age in weeks	Feeding Level		
		Low	Medium	High
		Av. No.	Av. No.	Av. No.
Longissimus dorsi	64	140	118	127
		112	118	105
	80	120	88	123
		108	96	106
Semimembranosus	64	124	82	115
		84	106	118
	80	128	118	114
		83	90	94
Psoas major	64	90	88	72
		105	117	82
	80	98	74	73
		83	95	83

APPENDIX TABLE XVII. TENDERNESS OF COOKED MUSCLES FROM HEIFERS AS MEASURED BY MECHANICAL SHEAR

Muscle	Age in weeks	Feeding Level Low	Medium	High
		lbs.	lbs.	lbs.
Longissimus dorsi	32		11.5	10.5
			20.0	4.2
	48	17.5	17.0	23.0
		12.0	11.1	10.6
	64	33.5	22.0	15.2
		6.0	14.0	15.5
	80	25.7	18.0	20.5
		20.2	17.4	29.2
Semimembranosus	16	5.0	7.3	9.2
		12.8	11.4	
	32	7.0	9.7	14.2
		11.2	8.7	9.1
	48	12.0	9.7	11.0
		9.7	16.2	13.0
	64	16.0	31.3	15.2
		11.0	21.2	20.9
	80	14.2	22.1	23.9
			31.0	
Psoas major	32		10.5	9.5
				12.5
	48		10.7	9.7
			7.5	6.5
	64		9.7	8.5
	80		15.7	15.5
			18.7	15.2

APPENDIX TABLE XVIII. TENDERNESS OF COOKED MUSCLES FROM HEIFERS AS MEASURED BY AVERAGE NUMBER OF CHEWS

Muscle	Age in weeks	Feeding Level: Low	Medium	High
		Av. No.	Av. No.	Av. No.
Longissimus dorsi	32		108	75
			87	77
	48	73	90	100
		96	75	72
	64	117	100	76
		106	83	77
	80	108	85	60
		90	87	113
Semimembranosus	32	62	70	82
		73	83	87
	48	70	74	90
		78	80	79
	64	73	76	75
		80	88	104
	80	96	84	89
		82	110	100
Psoas major	48	70	62	60
		58	62	58
	80		65	59
			61	55

APPENDIX TABLE XIX. PERCENT MOISTURE IN GROUPS OF BODY PARTS FROM BULLS

Group	64-week-old bulls						80-week-old bulls					
	Feeding Level						Feeding Level					
	Low		Medium		High		Low		Medium		High	
	No. 50	No. 61	No. 54	No. 58	No. 52	No. 72	No. 47	No. 71	No. 53	No. 62	No. 43	No. 60
	%	%	%	%	%	%	%	%	%	%	%	%
Group I												
Carcass meat	71.42	73.65	71.14	69.83	60.17	64.06	71.56	70.50	68.80	71.46	60.90	53.94
Group II												
Skeletal bones	34.37	35.76	33.99	33.51	31.32	33.77	29.36	34.52	29.47	36.50	30.56	28.53
Group III												
Organs	71.06	70.83	67.01	70.19	61.58	63.10	70.29	72.32	71.34	71.16	64.94	61.90
Group IV												
Digestive tract	78.15	76.55	76.01	74.71	70.23	68.68	71.37	76.59	71.62	74.93	59.89	60.40
Group V												
Fat	42.61	31.28	27.49	30.33	11.34	14.76	25.05	31.08	25.43	28.22	11.42	8.58
Group VI												
Blood	80.25	79.57	81.76	81.45	80.56	75.01	83.09	81.32	81.24	81.36	80.80	79.50
Group VII												
Hide	66.35	65.39	64.71	64.93	63.16	64.60	67.66	66.62	66.38	65.98	63.95	57.22
Group VIII												
Head tissues	68.45	71.15	70.82	67.61	63.18	65.70	67.36	68.70	67.40	67.66	64.38	59.48

APPENDIX TABLE XX. PERCENT MOISTURE IN GROUPS OF BODY PARTS FROM HEIFERS

Group	16-week-old heifers Feeding Level						48-week-old heifers Feeding Level					
	Low		Medium		High		Low		Medium		High	
	No. 202	No. 227	No. 203	No. 226	No. 201	No. 221	No. 207	No. 219	No. 209	No. 220	No. 214	No. 230
	%	%	%	%	%	%	%	%	%	%	%	%
Group I												
Carcass meat	75.34	77.54	72.09	73.47	70.91	66.19	67.64	57.73	62.18	67.21	54.28	61.95
Group II												
Skeletal bones	51.04	56.06	46.67	43.03	42.20	42.29	36.66	42.42	34.87	35.68	33.09	32.95
Group III												
Organs	75.70	76.50	74.97	73.86	73.83	66.51	70.71	68.32	69.26	69.61	65.68	66.81
Group IV												
Digestive tract	84.37	84.80	83.05	80.42	79.84	77.05	68.48	79.57	66.03	68.65	66.04	60.19
Group V												
Fat	none	none	55.14	*	29.43	22.08	30.25	54.26	16.21	22.82	11.06	10.90
Group VI												
Blood	83.96	81.24	81.29	83.34	81.81	80.79	82.20	83.64	81.12	82.72	82.27	79.43
Group VII												
Hide	65.99	66.12	67.22	67.78	66.80	67.36	65.29	67.74	63.04	64.74	61.49	58.87
Group VIII												
Head tissues	73.94	73.58	70.45	70.14	68.76	65.99	67.84	72.08	62.90	64.66	58.48	60.15

* with organs

APPENDIX TABLE XXI. WEIGHTS OF BODY PARTS AS GROUPED FOR ANALYSIS FROM 64-WEEK-OLD BULLS

	Feeding Level					
	Low		Medium		High	
	No. 50	No. 61	No. 54	No. 58	No. 52	No. 72
	grams	grams	grams	grams	grams	grams
Group I						
Carcass meat after dehydration	108,202.8	103,250.7	154,677.6	137,667.6	223,572.4	229,068.0
Group I						
Dehydration	3,176.0	8,166.0	21,794.0	8,164.0	9,980.0	11,792.0
Group II						
Skeletal bones before dehydration	41,027.0	38,662.6	49,673.0	42,679.4	57,545.0	63,025.1
Group III						
Organs	12,020.4	11,226.6	15,195.6	14,855.4	19,958.0	22,680.0
Group IV						
Digestive tract	11,680.2	11,793.6	18,597.6	17,463.6	19,164.6	21,205.8
Group V						
Fat	2,183.0	3,288.6	2,664.9	5,329.8	16,896.6	14,742.0
Group VI						
Blood	10,126.4	10,037.0	14,365.0	12,037.6	20,969.2	22,145.8
Group VII						
Hide	20,412.0	21,999.6	29,370.6	27,669.6	36,855.0	44,452.8
Group VIII						
Head tissues	4,362.0	4,780.0	4,878.0	5,364.0	6,974.0	9,086.0
Total weight	213,189.8	213,204.7	311,216.3	271,231.0	411,914.8	438,197.5

APPENDIX TABLE XXII. WEIGHTS OF BODY PARTS AS GROUPED FOR ANALYSIS FROM 80-WEEK-OLD BULLS

	Feeding Level					
	Low		Medium		High	
	No. 47	No. 71	No. 53	No. 62	No. 43	No. 60
	grams	grams	grams	grams	grams	grams
Group I						
Carcass meat after dehydration	117,482.4	104,328.0	192,780.0	192,780.0	267,624.0	273,737.2
Group I						
Dehydration	10,660.0	8,618.0	10,660.0	11,112.0	12,700.	14,516.0
Group II						
Skeletal bones before dehyration	44,185.4	46,909.2	56,498.8	64,567.4	69,597.0	57,949.0
Group III						
Organs	10,659.6	12,360.6	16,443.0	18,257.4	24,040.8	23,587.2
Group IV						
Digestive tract	14,968.8	13,834.8	20,752.2	24,040.8	25,515.0	24,154.2
Group V						
Fat	408.0	1,304.1	5,131.4	3,090.2	21,772.8	23,927.4
Group VI						
Blood	9,687.4	11,183.4	14,323.2	16,482.8	19,367.2	17,555.4
Group VII						
Hide	22,680.0	25,515.0	35,154.0	40.710.6	34,700.4	42,638.4
Group VIII						
Head tissues	4,358.0	5,530.0	6,680.0	7,628.0	6,596.0	7,574.0
Total weight	235,089.6	229,583.1	358,422.6	378,669.2	481,913.2	490,638.8

APPENDIX TABLE XXIII. WEIGHTS OF BODY PARTS AS GROUPED FOR ANALYSIS FROM 16-WEEK-OLD HEIFERS

	Feeding Level					
	Low		Medium		High	
	No. 202	No. 227	No. 203	No. 226	No. 201	No. 221
	grams	grams	grams	grams	grams	grams
Group I Carcass meat after dehydration	17,406.9	18,994.5	29.654.1	34,587.0	44,793.0	47,174.4
Group I Dehydration	3,176.0	1,044.0	3,175.2	3,856.0	2,722.0	4,084.0
Group II Skeletal bones before dehydration	11,112.4	12,240.8	13,989.0	15,929.4	16,833.2	17,833.0
Group III Organs	3,260.2	3,373.6	4,706.1	6,237.0	5,613.3	8,505.0
Group IV Digestive tract	4,186.0	5,244.8	5,499.9	6,804.0	6,038.6	7,541.1
Group V Fat	none	none	680.4	with organs	1,956.2	3,231.9
Group VI Blood	2,717.0	2,637.0	4,266.0	4,732.0	5,532.8	5,705.8
Group VII Hide	2,948.4	4,989.6	5,125.7	5,443.2	7,711.2	8,731.8
Group VIII Head tissues	1,006.0	1,212.0	1.202.0	1,454.0	1,692.0	2,156.0
Total weight	45,812.9	49,736.3	68,298.4	79,042.6	92,892.3	104,963.0

APPENDIX TABLE XXIV. WEIGHTS OF BODY PARTS AS GROUPED FOR ANALYSIS FROM 48-WEEK-OLD HEIFERS

	Feeding Level					
	Low		Medium		High	
	No. 207	No. 219	No. 209	No. 220	No. 214	No. 230
	grams	grams	grams	grams	grams	grams
Group I Carcass meat after dehydration	56,473.2	52,390.8	97,977.6	109,771.2	165,564.0	140.162.0
Group I Dehydration	7,258.0	6,352.0	7,484.0	9,980.0	7,253.0	6,350.0
Group II Skeletal bones before dehydration	24,142.8	23,794.8	34,763.4	36,314.8	42,854.4	22,861.8
Group III Organs	7,711.2	6,350.4	12,700.8	11,680.2	14,515.2	14,061.6
Group IV Digestive tract	3,628.8	8,845.2	15,309.0	15,422.0	18,016.8	16,783.0
Group V Fat	1,607.0	1,190.7	5,556.6	5,670.0	10,716.3	13,608.0
Group VI Blood	5,804.6	5,348.0	11,004.0	9,979.2	11,995.2	16,669.8
Group VII Hide	11,340.0	9,752.4	17,690.4	18,824.4	26,308.8	24,381.0
Group VIII Head tissues	2,386.0	2,508.0	2,640.0	3,760.0	4,612.0	4,048.0
Total weight	120,351.6	116,532.3	205,125.8	221,401.8	301,840.7	258,925.2

APPENDIX TABLE XXV. SLAUGHTER WEIGHTS OF BODY PARTS FROM 64-WEEK-OLD BULLS ON LOW FEEDING LEVEL

Part	Animal No. 50		Animal No. 61	
	Wt. of Part	Wt. of Contents	Wt. of Part	Wt. of Contents
	grams	grams	grams	grams
Adrenals	11.6		10.9	
Blood	10,126.4		10,037.0	
Brain	402.0		628.0 (Brain and Spinal cord)	
Spinal cord	217.0			
Carcass, hot	144,244.8		140.162.4	
Cartilage (1st and 2nd Thoracic)	69.0		56.0	
Caul Fat	430.0		632.0	
Dew Claws	100.0		98.0	
Esophagus	334.0	31.0	264.0	537.0
Epididymis	34.8		33.1	
Gall bladder	26.0	143.0	39.0	310.0
Head meat	4,362.0		4,780.0	
Head bones	5,846.0		4,900.0	
Heart	843.0		839.0	
Hide and hair	20,412.0		21,999.6	
Kidney	with carcass		521.0	
Intestines	4,649.4	51,333.8 (Intestines and Stomachs)	6,237.0	4,215.2
Stomachs	7,597.8		6,804.0	41,844.6
Liver	2,789.0		2,525.0	
Lungs	2,524.0		2,115.0	
Trachea, diaphragm & attach. tissues	1,653.0		1,983.0	
Pancreas	169.0		130.0	
Penis & root	263.0		1,096.0	
Pituitary	1.4		1.4	
Ruffle fat	2,191.0		661.0	
Shanks	5,427.0		4,959.0	
Spleen	480.0		505.0	
Seminal vesic.	44.0		48.0	
Tail	529.0		667.0	
Testicles & attach. tissues	396.0		328.0	
Tongue	957.0		916.0	
Trimmings, reprod. tract	176.0			
Thymus	379.0		128.0	
Thyroid	10.6		16.1	
Urinary bladder & urethra	78.0	174.0	69.0	358.0
Vomit at slaughter		213.0		none
Totals	217,772.8	51,894.8	214,188.5	47,264.8
Total body & contents	269.667.6		261.453.3	

APPENDIX TABLE XXVI. SLAUGHTER WEIGHTS OF BODY PARTS FROM 64-WEEK-OLD BULLS ON MEDIUM FEEDING LEVEL

Part	Animal No. 54		Animal No. 58	
	Wt. of Part	Wt. of Contents	Wt. of Part	Wt. of Contents
	grams	grams	grams	grams
Adrenals	13.0		16.8	
Blood	14,365.0		12,037.6	
Brain	362.0		666.0	
Spinal cord	none			
Carcass, hot	202,305.6		175.543.2	
Cartilage (1st and 2nd Thoracic)	55.0			
Caul fat	1,104.0		1,142.0	
Dew claws	90.0		118.0	
Esophagus	264.0	3.0	407.0	7.0
Epididymis	49.0		39.9	
Gall bladder	52.0	267.0	25.0	152.0
Head meat	4,878.0		5,364.0	
Head bones	6,321.0		6,092.0	
Heart	1,181.0		1,112.0	
Hide and hair	29,370.6		27,669.6	
Kidney	with carcass		604.0	
Intestines	7,387.0	9,600.6	6,350.4	7,736.6
Stomachs	11,793.6	61,689.6	12,247.2	48,988.8
Liver	3,779.0		3,540.0	
Lungs	2,391.0		2,838.0	
Trachea, diaphragm & attach. tissues	2,323.0		2,293.0	
Pancreas	258.0		134.0	
Penis	699.0		1,293.0	
Root	600.0			
Pituitary	1.7		1.7	
Prostate	1.7			
Ruffle fat	1,610.0		2,356.0	
Shanks	6,726.0		5,289.0	
Spleen	574.0		671.0	
Seminal vesic.	55.0			
Tail	838.0		734.0	
Testicle & attach. tissues	673.0		376.0	
Tongue	1,319.0		1,104.0	
Thymus	520.0		579.0	
Thyroid	20.7		18.6	
Urinary bladder & urethra	218.0	573.0	85.0	288.0
Vomit at slaughter		30.0		297.0
Totals	302,197.9	72,163.2	270,747.0	57,469.4
Total body & contents	374,361.1		328,216.4	

APPENDIX TABLE XXVII. SLAUGHTER WEIGHTS OF BODY PARTS FROM 64-WEEK-OLD BULLS ON HIGH FEEDING LEVEL

Part	Animal No. 52 Wt. of Part	Animal No. 52 Wt. of Contents	Animal No. 72 Wt. of Part	Animal No. 72 Wt. of Contents
	grams	grams	grams	grams
Adrenals	17.7		16.5	
Blood	20,969.2		22,145.8	
Brain	443.0		} 754.0	
Spinal cord	346.0			
Carcass, hot	275.788.8		290,304.0	
Cartilage (1st and 2nd Thoracic)			88.0	
Caul fat	7,407.8		6,056.0	
Dew claws	168.0	none	141.0	
Esophagus	506.0	63.0	347.0	
Epididymis	46.0		48.0	
Gall bladder	66.0	284.0	56.0	221.0
Head meat	6,974.0		9,086.0	
Head bones	7,439.0		7,016.0	
Heart	1,687.0		1,662.0	
Hide and hair	36,855.0		44,452.8	
Kidney			1,145.0	
Intestines	6,920.0	5,327.2	7,030.8	6,463.8
Stomachs	12,201.8	36,333.4	15,082.2	36,514.8
Liver	5,375.0		6,006.0	
Lungs	3,119.0		3,287.0	
Trachea, diaphragm & attach. tissues	4,158.0		4,095.0	
Pancreas	225.0		488.0	
Penis & root	1,877.0		1,776.0	
Pituitary	1.9		2.5	
Ruffle fat	10,432.8		8,845.2	
Shanks	6,660.0		8,211.0	
Spleen	1,139.0		898.0	
Seminal vesic.	54.9		75.7	
Tail	973.0		1,297.0	
Testicles & attach. tissues	452.0		492.0	
Tongue	1,279.0		1,517.0	
Thymus	783.0		937.0	
Thyroid	34.5		36.0	
Urinary bladder & urethra	88.0		88.0	49.0
Vomit at slaughter		907.2		274.0
Totals	414,487.4	42,914.2	443,482.5	43,522.6
Total body & contents	457,402.2		487.005.1	

APPENDIX TABLE XXVIII. SLAUGHTER WEIGHTS OF BODY PARTS FROM 80-WEEK-OLD BULLS ON LOW FEEDING LEVEL

Part	Animal No. 47		Animal No. 71	
	Wt. of Part	Wt. of Contents	Wt. of Part	Wt. of Contents
	grams	grams	grams	grams
Adrenals	10.0		11.8	
Blood	9,687.4		11,183.4	
Brain	384.0		649.0 (Brain and spinal cord)	
Spinal cord	219.0			
Carcass, hot				
Left side	76,204.8		73,483.2	
Right side	80,287.2		70.308.0	
Caul fat	420.0		617.0	
Dew claws	131.0		147.0	
Esophagus	332.0	9.0	375.0	80.0
Epididymis	39.4		36.2	
Gall bladder	54.0	87.0	55.0	92.0
Head meat	4,358.0		5,530.0	
Head bones	5,084.0		5,876.0	
Heart	822.0		1,032.0	
Hide and hair	22, 680.0		25,515.0	
Kidney	459.0		530.0	
Intestines	7,875.0	4,844.6	14,742.0 (Intestines and stomachs)	65,856.8 (Intestines and stomachs)
Stomachs	7,521.0	42,601.8		
Liver	2,430.0		2,870.0	
Lungs, Trachea, diaphragm & attach. tissues	3,046.0		4,309.2	
Pancreas	208.0		180.0	
Penis & root	1,073.0		1,094.0	
Pituitary	1.2		1.5	
Ruffle fat			709.0	
Shanks	6,321.0		5,896.0	
Spleen	400.0		485.0	
Seminal vesic.	33.8		44.7	
Tail	783.0		589.0	
Testicles & attach. tissues	290.0		324.0	
Tongue	1,045.0		811.0	
Thymus			160.0	
Thyroid	10.8		17.0	
Urinary bladder & urethra	85.0	121.0	100.0	160.0
Vomit at slaughter		1,925.0		1,486.0
Totals	232,294.6	49,588.4	227,681.0	67,674.8
Total body & contents	281,883.0		295,355.8	

APPENDIX TABLE XXIX. SLAUGHTER WEIGHTS OF BODY PARTS FROM 80-WEEK-OLD BULLS ON MEDIUM FEEDING LEVEL

Part	Animal No. 53		Animal No. 62	
	Wt. of Part	Wt. of Contents	Wt. of Part	Wt. of Contents
	grams	grams	grams	grams
Adrenals	13.7		14.3	
Blood	14,323.2		16,482.8	
Brain	383.0		743.0 (Brain & Spinal cord)	
Spinal cord	267.0			
Carcass, hot				
Left side	123,379.2		126,554.4	
Right side	121,111.2		122,472.0	
Caul fat	2,048.0		1,157.0	
Dew claws	188.0		190.0	
Esophagus	472.0		481.0	49.0
Epididymis	34.6		47.9	
Gall bladder	58.0	149.0	60.0	246.0
Head meat	6,680.0		7,628.0	
Head bones	7,044.0		7,256.0	
Heart	1,360.8		1,472.0	
Hide and hair	35,154.0		40,710.6	
Kidney	771.0		898.0	
Intestines, Stomachs	20,865.6	55,067.0	24,880.2	64,613.4
Liver	4,422.6		4,917.0	
Lungs, Trachea, diaphragm & attach. tissues	5,443.2		5,896.8	
Pancreas			277.0	
Penis & root	1,976.0		1,614.0	
Pituitary	1.7		1.8	
Ruffle fat	3,220.0		1,620.0	
Shanks	6,830.0		8,665.0	
Spleen	695.0		608.0	
Seminal vesic.	57.7		82.3	
Tail	1,230.0		884.0	
Testicles & attach. tissues	297.0		468.0	
Tongue	1,105.0		1,435.0	
Thymus			500.0	
Thyroid	22.3		31.3	
Urinary bladder & urethra	127.0	577.0	123.0	494.0
Vomit at slaughter		547.0		949.0
Totals	359,580.8	56,340.0	378,170.4	66,351.4
Total body & contents	415,920.8		444,521.8	

APPENDIX TABLE XXX. SLAUGHTER WEIGHTS OF BODY PARTS FROM 80-WEEK-OLD BULLS ON HIGH FEEDING LEVEL

Part	Animal No. 43 Wt. of Part	Animal No. 43 Wt. of Contents	Animal No. 60 Wt. of Part	Animal No. 60 Wt. of Contents
	grams	grams	grams	grams
Adrenals	14.0		18.4	
Blood	19,367.2		17,555.4	
Brain & Spinal cord	766.0		659.0	
Carcass, hot				
Left side	167,378.4		168,739.2	
Right side	161,935.2		170,100.0	
Caul fat	10,886.4		10,092.6	
Dew claws	278.0		203.0	
Esophagus	447.0	215.0	480.0	6.0
Epididymis	52.0			
Gall bladder	240.0	140.0	97.0	383.0
Head meat	6,596.0		7,574.0	
Head bones	6,508.0		6,952.0	
Heart	2,122.0		1,778.0	
Hide and hair	34,700.4		42,638.4	
Kidney	1,043.0		1,258.0	
Intestines	10,999.8	8,505.0	10,773.0	2,835.0
Stomachs	16,102.8	40,257.0	12,020.4	42,525.0
Liver	6,010.2		6,804.0	
Lungs, Trachea, diaphragm & attach. tissues	8,958.6		7,484.4	
Pancreas	350.0		512.0	
Penis & root	1,810.0		875.0	
Pituitary	2.4		1.8	
Ruffle fat	10,432.8		15,762.6	
Shanks	8,343.0		7,559.0	
Spleen	1,117.0		1,075.0	
Seminal vesic.	84.4		65.5	
Tail	944.0		1,137.0	
Testicles & attach. tissues	468.0		426.0	
Tongue	1,415.0		1,494.0	
Thymus	295.0		678.0	
Thyroid	29.6		27.1	
Urinary bladder & urethra	108.0	212.0	78.0	721.0
Vomit at slaughter		364.0		
Totals	479,804.2	49,693.0	494,917.8	46,470.0
Total body & contents	529,497.2		541,387.8	

APPENDIX TABLE XXXI. SLAUGHTER WEIGHTS OF BODY PARTS FROM 16-WEEK-OLD HEIFERS ON LOW FEEDING LEVEL

Part	Animal No. 202		Animal No. 227	
	Wt. of Part	Wt. of Contents	Wt. of Part	Wt. of Contents
	grams	grams	grams	grams
Adrenals	3.7		4.0	
Blood	2,717.0		2,637.0	
Brain	265.0		291.0	
Spinal cord	97.0		92.0	
Carcass, hot	27,783.0		30,164.4	
Dew claws	22.0		23.0	
Esophagus	100.0		133.0	165.0
Gall bladder	9.0	58.0	7.0	21.0
Head meat	1,006.0		1,212.0	
Head bones	1,350.0		1,564.0	
Heart	243.0		288.0	
Hide and hair	2,948.4		4,989.6	
Kidneys	264.0		238.0	
Intestines	2,766.0	2,166.9	3,473.0	1,902.8
Stomachs	1,864.0	7,454.8	2,164.0	9,629.6
Liver	992.0		939.0	
Lungs	568.0		646.0	
Trachea, diaphragm & attach. tissues	448.0		439.0	
Ovaries	5.7		2.6	
Pancreas	61.0		46.0	
Pituitary	.5		.5	
Shanks	1,659.0		1,913.0	
Spleen	116.0		109.0	
Tail	119.0		130.0	
Tongue	285.0		333.0	
Thymus	30.0		63.0	
Thyroid	6.7		9.2	
Udder	47.7		4.2	
Urinary bladder	54.0	96.0	67.0	61.0
Uterus	17.6		22.4	
Vagina and vulva	52.4		44.0	
Vomit at slaughter		232.0		253.0
Totals	34,900.7	10.007.7	52,047.9	12,032.4
Total body and contents	55,908.4		64,080.3	

APPENDIX TABLE XXXII. SLAUGHTER WEIGHTS OF BODY PARTS FROM 16-WEEK-OLD HEIFERS ON MEDIUM FEEDING LEVEL

Part	Animal No. 203 Wt. of Part	Animal No. 203 Wt. of Contents	Animal No. 226 Wt. of Part	Animal No. 226 Wt. of Contents
	grams	grams	grams	grams
Adrenals	6.4		5.3	
Blood	4,266.0		4,732.0	
Brain	275.0		284.0	
Spinal cord	89.0		109.0	
Carcass, hot	42,751.8		49,782.6	
Caul fat	119.0		144.0	
Dew claws	29.0		35.0	
Esophagus	426.0		145.0	77.0
Gall bladder	15.0	64.0	16.0	38.0
Head meat	1,202.0		1,454.0	
Head bones	1,618.0		1,920.0	
Heart	403.0		416.0	
Hide & hair	5,125.7		5,443.2	
Kidneys	389.0		418.0	
Intestines	3,163.0	1,787.6	3,602.0	3,410.2
Stomachs	2,654.0	9,502.5	3,339.0	11,970.0
Liver	1,434.0		1,854.0	
Lungs	790.0		1,060.0	
Trachea, diaphragm & attach. tissues	1,378.0		635.0	
Ovaries	3.4		8.6	
Pancreas	81.0		97.0	
Pituitary	1.8		.8	
Ruffle fat	606.0		699.0	
Shanks	2,115.0		2,482.0	
Spleen	199.0		217.0	
Tail	153.0		211.0	
Tongue	353.0		345.0	
Thymus	195.0		249.0	
Thyroid	36.3		10.3	
Udder	55.0		91.0	
Urinary bladder	54.0	27.0	64.0	276.0
Uterus	31.9		26.7	
Vagina and vulva	65.7		80.7	
Vomit at slaughter				49.0
Totals	70,084.0	11,381.1	79,976.2	15,820.2
Total body and contents	81,465.1		95,796.4	

APPENDIX TABLE XXXIII. SLAUGHTER WEIGHTS OF BODY PARTS FROM 16-WEEK-OLD HEIFERS ON HIGH FEEDING LEVEL

Part	Animal No. 201		Animal No. 221	
	Wt. of Part	Wt. of Contents	Wt. of Part	Wt. of Contents
	grams	grams	grams	grams
Adrenals	5.6		7.4	
Blood	5,532.8		5,705.8	
Brain	309.0		308.0	
Spinal cord	95.0		130.0	
Carcass, hot	59,308.2		63,730.8	
Caul fat	450.0		1,322.0	
Dew claws	27.0		41.0	
Esophagus	142.0	100.0	129.0	37.0
Gall bladder	13.0	60.0	23.0	106.0
Head meat	1,692.0		2,156.0	
Head bones	2,070.0		2,174.0	
Heart	417.0		536.0	
Hide & hair	7,711.2		8,731.8	
Kidneys	315.0		529.0	
Intestines	3,384.0	990.8	4,082.4	4,705.2
Stomachs	2,910.0	8,656.8	4,082.4	16,556.4
Liver	1,672.0		2,515.0	
Lungs	967.0		1,220.0	
Trachea, diaphragm & attach. tissues	828.0		974.0	
Ovaries	3.0		4.9	
Pancreas	86.0		127.0	
Pituitary	.9		1.2	
Ruffle fat	1,522.0		1,872.0	
Shanks	2,430.0		2,618.0	
Spleen	222.0		348.0	
Tail	267.0		288.0	
Tongue	444.0		488.0	
Thymus	419.0		513.0	
Thyroid	15.1		7.7	
Udder	597.0		739.0	
Urinary bladder	38.0		78.0	
Uterus	39.0		44.0	
Vagina and vulva	109.0		113.1	
Vomit at slaughter		125.0		118.0
Totals	94,049.8	9,932.6	105,639.5	21,522.6
Total body and contents	103,982.4		127,162.1	

APPENDIX TABLE XXXIV. SLAUGHTER WEIGHTS OF BODY PARTS FROM 48-WEEK-OLD HEIFERS ON LOW FEEDING LEVEL

Part	Animal No. 207		Animal No. 219	
	Wt. of Part	Wt. of Contents	Wt. of Part	Wt. of Contents
	grams	grams	grams	grams
Adrenals	4.1		7.1	
Blood	5,804.6		5,348.0	
Brain	385.0		306.0	
Spinal cord	177.0		120.0	
Carcass, hot				
Left side	40,824.0		38,556.0	
Right side	39,916.8		37,195.2	
Caul fat	440.0		197.0	
Dew claws	with shanks		83.0	
Esophagus	429.0	90.0	171.0	55.0
Gall bladder	30.0		27.0	
Head meat	2,386.0		2,508.0	
Head bones	3,340.0		3,032.0	
Heart	690.0		463.0	
Hide & hair	11,340.0		9,752.4	
Kidneys	365.0		335.0	
Intestines	3,628.8	6,165.0	4,139.1	4,819.5
Stomachs	4,876.2	33,339.6	4,422.6	26,422.2
Liver	2,034.0		1,797.0	
Lungs, Trachea, diaphragm & attach. tissues	2,268.0		2,041.2	
Pancreas	not taken		not taken	
Pituitary	.1		.8	
Ruffle fat	752.0		681.0	
Shanks	3,402.0		3,175.2	
Spleen	354.0		288.0	
Tail	407.1		345.0	
Tongue	600.0		630.0	
Thymus	319.0		224.0	
Thyroid	22.2		14.6	
Udder	423.0		352.0	
Urinary bladder	43.0	70.0	58.0	3.0
Uterus & ovaries	49.0		34.1	
Vagina and vulva	186.0		244.0	
Vomit at slaughter		344.0		310.0
Totals	125,495.9	40,008.6	116,547.3	31,640.7
Total body and contents	165.504.5		148,188.0	

APPENDIX TABLE XXXV. SLAUGHTER WEIGHTS OF BODY PARTS FROM 48-WEEK-OLD HEIFERS ON MEDIUM FEEDING LEVEL

Part	Animal No. 209		Animal No. 220	
	Wt. of Part	Wt. of Contents	Wt. of Part	Wt. of Contents
	grams	grams	grams	grams
Adrenals	10.6		11.6	
Blood	11,004.0		9,979.2	
Brain	397.0		411.0	
Spinal cord	181.0		212.0	
Carcass, hot				
Left side	65,772.0		73,936.8	
Right side	65,318.4		72,576.0	
Caul fat	1,739.0		1,480.0	
Dew claws	128.0		105.0	
Esophagus	224.0	80.0	232.0	
Gall bladder	46.0	136.0	53.0	220.0
Head meat	2,698.0		3,760.0	
Head bones	3,832.0		3,938.0	
Heart	913.0		933.0	
Hide & hair	17,690.4		18,824.4	
Kidneys	527.0		645.0	
Intestines	7,257.6	4,309.2	6,662.4	3,969.8
Stomachs	8,505.0	26,875.8	9,072.0	41,051.0
Liver	3,267.0		3,692.0	
Lungs, Trachea, diaphragm & attach. tissues	3,298.0		4,195.0	
Pituitary	1.3		1.4	
Ruffle fat	2,381.4		2,494.0	
Shanks	4,649.4		4,762.8	
Spleen	535.0		618.0	
Tail	578.0		552.0	
Tongue	920.0		892.0	
Thymus	654.0		508.0	
Thyroid	22.0		16.3	
Udder	1,420.0		1,236.0	
Urinary bladder	89.0		92.0	259.0
Uterus & ovaries	148.0		192.0	
Vagina and vulva	307.0		491.0	
Vomit at slaughter		173.0		105.0
Totals	204,513.1	31,574.0	222,573.9	45,604.8
Total body and contents	236,087.1		268,178.7	

APPENDIX TABLE XXXVI. SLAUGHTER WEIGHTS OF BODY PARTS FROM 48-WEEK-OLD HEIFERS ON HIGH FEEDING LEVEL

Part	Animal No. 214		Animal No. 230	
	Wt. of Part	Wt. of Contents	Wt. of Part	Wt. of Contents
	grams	grams	grams	grams
Adrenals	12.5		13.4	
Blood	11,995.2		17,443.8	
Brain	352.0		413.0	
Spinal cord	258.0		246.0	
Carcass, hot				
Left side	103,420.8		87,091.2	
Right side	100,699.2		88,452.0	
Caul fat	6,349.0		5,383.6	
Dew claws	200.0		112.0	
Esophagus	213.0		176.0	
Gall bladder	104.0	187.0	98.0	237.0
Head meat	4,612.0		4,048.0	
Head bones	4,514.0		4,092.0	
Heart	1,205.0		1,362.0	
Hide & hair	26,308.8		24,381.0	
Kidneys	849.0		820.0	
Intestines	6,577.2	4,762.8	6,860.7	5,471.7
Stomachs	11,226.6	25,741.8	9,366.0	22,839.6
Liver	4,478.0		4,186.0	
Lungs, Trachea, diaphragm & attach. tissues	4,869.6		4,422.6	
Pituitary	1.2		1.3	
Ruffle fat	6,123.6		5,131.2	
Shanks	5,443.2		4,692.0	
Spleen	597.0		655.0	
Tail	868.0		675.0	
Tongue	1,226.0		884.0	
Thymus	665.0		547.0	
Thyroid	23.5		22.4	
Udder	4,045.0		3,046.0	
Urinary bladder	124.0		56.0	
Uterus & ovaries	230.0		120.0	
Vagina and vulva	445.0		565.0	
Vomit at slaughter		287.0		125.0
Totals	308,035.4	30,978.6	275,362.2	28,800.3
Total body and contents	339,014.0		304,162.5	

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