HIGH VS. MODERATE LEVELS OF TDN INTAKE ON FEEDLOT PERFORMANCE AND CARCASS COMPOSITION OF BEEF STEERS

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

INTRODUCTION

> As an animal grows up two things happen: (1) it increases in weight until mature size is reached; this we shall call Growth, and (2) it changes in its body conformation and shape, and its various functions and faculties come into full being; this we shall call Development.

The above comments by Palsson are cited by Hammond (1955). Can the producers of beef cattle control these two processes to produce the specific type of carcass demanded by the consumer? As people become more conscious of dieting a greater demand exists for meat which has the desired qualities of flavor, tenderness, and juiciness, but which has as little waste fat as possible.

Many workers have shown that the plane of nutrition can influence the development of different cuts in the carcass, (Trowbridge 1910, 1918, 1919; Moulton 1922b; and Wellington 1954). In showing the effects of nutrition on growth and development, these early workers used extreme planes of nutrition to obtain maximum or retarded growth.

In five experiments conducted at the Oklahoma Station, the post-weaning plane of nutrition was varied within practical conditions to provide moderate or rapid rates of gain. The purpose of these experiments was to determine how carcass composition might be affected by using feeding regimes considered practical by livestock producers. The principal question was: what plane of nutrition leads to maximum muscle development and greatest feed efficiency in fattening cattle?

This thesis describes an experiment in which calves were fed post-weaning for moderate versus rapid gains, and slaughtered on a weight- vs. age-constant basis.

REVIEW OF LITERATURE

The review of literature is presented in three parts: (1) the early studies of growth and carcass composition, (2) the effect of plane of nutrition upon carcass composition, and (3) the use of specific gravity as a means of estimating the fat, lean, and bone content of the carcass.

Early Growth Studies

The influence of the plane of nutrition on carcasses of farm animals has been studied for many years. Early experiments showed that the nervous tissues in the body developed first and were followed by bone, muscle, and fat, in that order, (Hammond 1941; McMeekan 1940, 1941; and Palsson and Verges 1952a).

Palsson and Verges (1952a) found that fat was not only the last tissue to develop, but that it was also deposited in a definite order. Subcutaneous fat first, followed by intra-muscular, and then inter-muscular fat. Lawes and Gilbert, as cited by Kleiber (1961) used cattle, sheep, and swine to show that the fat content was the most variable constituent in the body. Spray and Widdowson (1950) established an inverse relationship between fat and water, i.e., as the per cent fat content of the animal increased, the per cent water decreased.

The first extensive work proving that plane of nutrition influenced rate of development of lean, fat, and bone in the carcass was that of Waters in 1895, cited by Hammond (1955). Waters found that animals continued to develop skeletal-wise on a sub-maintenance ration, even at the expense of fat deposits and muscle development in the animal body.

Addis, et al. (1936) and Pomeroy (1941) showed that even in fasting animals, bone will continue to develop for a short period of time. These authors also found that in fasting animals the body tissues were used to provide energy for the maintenance of life. Furthermore, these tissues were catabolized in the reverse order of their deposition, i.e., fat was used first to supply maintenance energy, muscle second, and bone last. Moreover, the fat deposits were catabolized in a definite order. The kidney fat was catabolized first, then subcutaneous fat, later developing intra-muscular, caul and mesenteric fat.

Jordan (1895) employed widely differing nutritive ratios of 1:5.2 and 1:9.7 (digestible protein to digestible non-nitrogenous nutrients) to establish that the relative weights of the various body organs and parts were essentially the same with steers of the same age, independent of the ration fed. Neither growth, nor the proportion of fat, protein, ash, or water in the carcass differed materially between animals of the same age. It was concluded that severe measures of energy restriction must be imposed to influence the growth pattern of an animal.

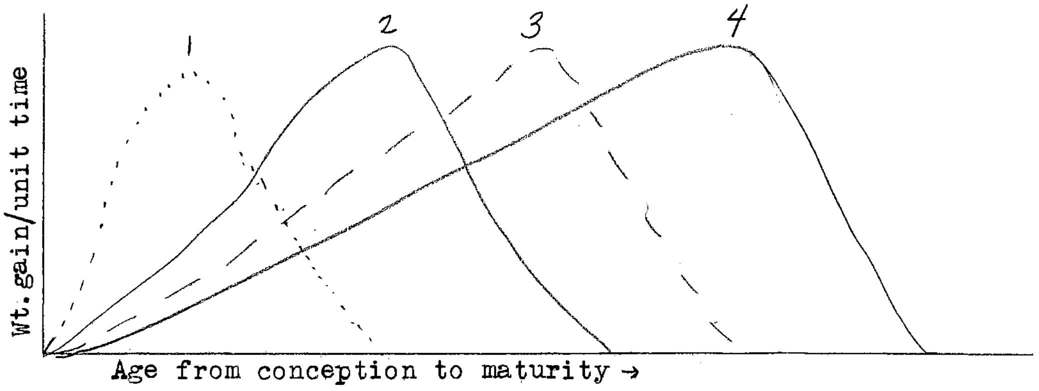
Other workers imposed more severe treatments than those used by Jordan and found that the growth pattern could be altered. Moulton et al. (1922b), Guilber et al. (1944), Palsson and Verges (1952a), and Trowbridge et al. (1918) found that muscle development in the hindquarter and the percent of fat in the carcass could be partially controlled by plane of nutrition, if energy was restricted.

The work of these early investigators indicated that if growth was retarded by energy restriction the effects were greater on the later developing parts of animals (fat, loin and pelvis) than on the early maturing parts (head, neck, and bone).

Also noted by these early workers was the fact that young animals possessed a great ability to recover from retarded growth. Hogan (1929) concluded that a low plane of nutrition lengthened the growth period--as much as three years in one case. However, retarding growth did not result in abnormalities in conformation of cattle, unless restriction was very severe. This was in agreement with results reported by Echols and Swett (1918), who showed that, after restricted feeding, calves made even faster and more economical gains when placed on a high plane of nutrition than did calves fed throughout the growing period on a high plane of nutrition. This was later called "compensatory growth" by some workers. Nevertheless, these authors found that if the restriction was carried too far it hindered skeletal development, and the mature weight of the animal was lowered.

Hammond (1955), in summarizing European research on retarded growth, noted the following general trends: (1) restriction during any age interval has a direct retarding affect on the various tissues and parts of the body being developed during the period of restriction; (2) a low plane of nutrition during the growing period lengthens the time required for the animal to reach maturity, or an early maturing animal reared on a low plane of nutrition during growth acquired the form of a late maturing animal, Figure 1.

Early maturing or high plane nutrition



Late maturing or low plane nutrition

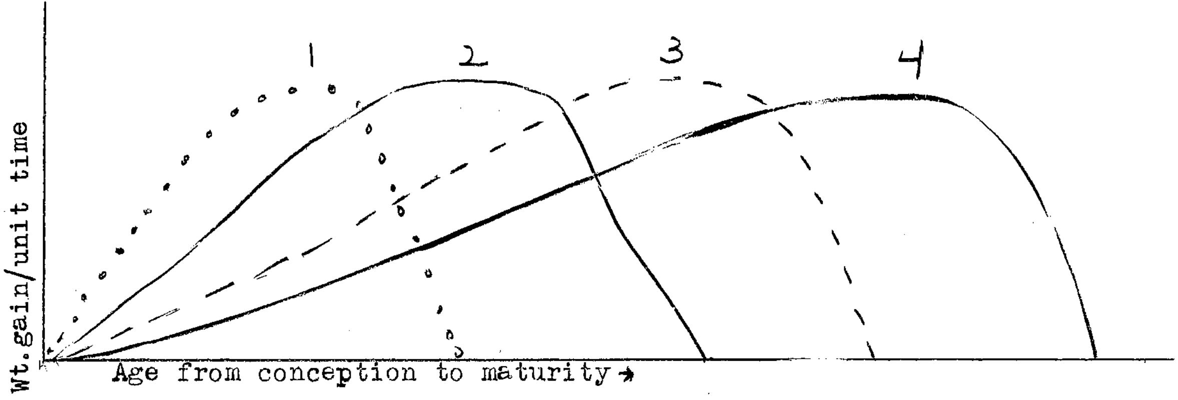


Figure 1. The changes in weight of various tissues and parts of the body as demonstrated with Suffolk ewes, Hammond (1955).

Curves:

1	2	3	4
Head	Neck	Thorax	Loin
Brain	Bone	Muscle	Fat
Cannon	Tibia-fibula	Femur	Pelvis
Kidney fat	Intramuscular fat	Subcutaneous fat	Marbling Fat

(3) that any tissue retarded by energy restriction exhibited a great recuperative capacity when the animal was placed on a high nutritional

regime, unless very severely restricted; (4) if kept on a submaintenance ration the tissues were used for energy in reverse order than they were usually formed; and (5) the final effects of restriction depend upon the age of the animal at the time of restriction, the particular tissues being formed, the duration and severity of the restriction, and the nutrient(s) being restricted.

Carcass Composition

Dowe et al. (1957), working with steers on pasture, found that steers given a half-feed of grain on pasture, followed by full feeding in dry lot, produced carcasses that were of the same merit as those full-fed on pasture and followed by full-feeding in dry lot. Guilbert et al. (1944) and Thompson et al. (1962) reported similar results.

Guilbert et al. (1944) studied the effect of nutritional regime on carcass composition during two periods of growth. In the first period he used either forage alone or a full-fed of concentrates. In the second period both groups were full-fed. The small, but significant differences favored the steers full-fed throughout the experiment. The full-fed steers produced heavier carcasses than the steers fed on forage alone in the first period. In addition the hindquarters from the full-fed steers constituted a greater percent of the carcass weight. These workers established no difference in the proportion of lean to bone in the fat-free cuts due to feeding regime. Also the total amount of fat in the carcass was not significantly different. These results led the authors to conclude that any difference occuring in the first period by the steers subsisting on roughage alone could be recovered in the feedlot after full-feeding.

Thompson et al. (1962) varied protein and energy intake of steers during the winter before placing them on the same fattening ration in the spring. All steers were slaughtered after a combined total gain of 550 pounds. Results indicated that limited protein (1 pound crude protein per day), regardless of energy level, gave the lowest quality carcasses with the greatest amount of fat trim. These steers also made the slowest and least efficient gains. On the other hand, steers fed adequate energy (9.0 pounds TDN per day) and adequate protein (1.6 pounds crude protein per day) had the best carcasses and most efficient gains.

The effect of plane of nutrition on the development and composition of the various body parts has been studied by many workers (Trowbridge et al. 1918; Hammond 1941; Palsson and Verges 1952a, 1952b; and Wellington 1954). The general conclusion was that a low plane of nutrition had a greater influence on the muscle and fat content of the slower maturing regions of the body than on the faster maturing regions.

The work of Moulton et al. (1922a, 1922b, 1922c) at Missouri provided a landmark in the early studies of the nutritional affect upon the development of the animal. Thirty steers on three planes of nutrition (1-fed all the animal would consume to develop maximum growth and finish; 2-fed for maximum growth with a minimum of finish, 1 pound of gain per day; and 3-fed for retarded growth, gain approximately ½ pound a day) were slaughtered periodically from birth to 4 years of age.

These results showed that the percent of carcass weight to live decreased until the animals were about $8\frac{1}{2}$ months old, then increased to its highest point at 3 to 4 years of age. The better fed steers had a greater dressing percent than the poorer fed steers--after the first six months. It was also detected that the carcasses of thinner steers had a somewhat larger but statistically insignificant cooler shrinkage.

Nutritional level also influenced the wholesale cuts of the carcasses. The fatter animals showed an increase in percent of loin, rump, and flank, but a decrease in round and chuck. The rib, on the average, remained relatively constant in percent of the carcass over all three groups.

In short it was generally noted that as age and plane of nutrition increased a greater part of the energy in the ration was used for fat deposition, and less energy was used for lean and bone development. This is also in agreement with work cited by Morrison (1959) where it was demonstrated that the first 500 pounds gain acquired by a thrifty 750 pound steer contained 46% fat, 12% protein, and 22% water, while the second 500 pounds gain was 68% fat, approximately 7% protein and 22% water.

Callow (1944, 1947) found that the changes in carcass composition due to fattening could be fitted to a straight line equation. For each 1% increase in fatty tissue in the carcass the content of muscle and bone tissue was diminished by 0.7% and 0.26% respectively. The dressing percent was found to depend almost entirely upon finish.

For each 1% increase in dressing percent the fatty tissue in the carcass increased by 1.43%, the chemical fat in the edible meat by 1.45%, and the edible itself by only 1.23%. All of these values were expressed as a percent of the live weight.

Callow also reported that the palatability of the meat increased as the fat content in the meat increased until the level of fat reached about 33%, whereupon the palatability fell sharply as the fat content continued to increase (Figure 2).

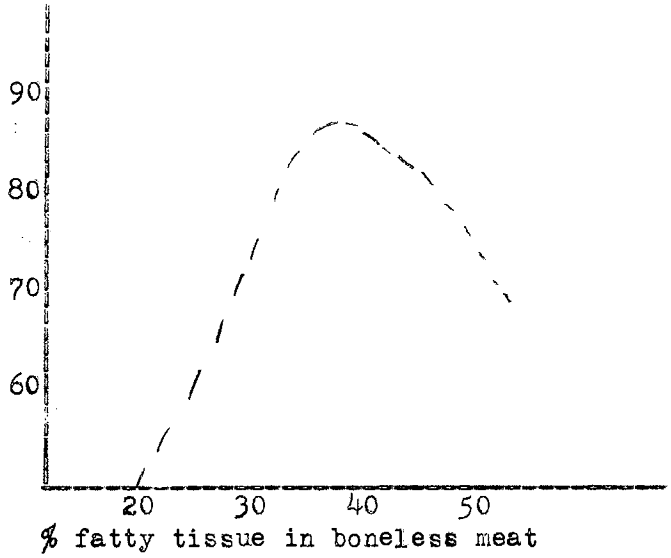


Figure 2. The relationship between fatness and palatability of beef.

The results of Winchester *et al.* (1957), indicated in general that severe restriction of both protein and energy of six month old calves, had little or no affect on carcass composition when the calves were fed a finishing ration following the restriction period. An exception, one pair of identical twins, showed an adverse affect on the carcass, *i.e.*, lower protein and higher fat content.

The earlier work of Winchester and Howe (1955) and Winchester and Ellis (1956), with identical twins, showed basically the same results. Energy restriction as low as maintenance of young calves, provided other nutrients are adequate, can be imposed without later lowering feed efficiency, meat quality, proportion of lean to fat or lean to bone in the carcass when fed a high energy ration prior to slaughter.

Hendrickson (1962) in studies at the Oklahoma Station, used sixty-four individually fed steers in four trials to study the effect of moderate energy restriction on carcass composition. His results indicated that carcasses from steers full-fed were superior in conformation to carcasses from steers moderately restricted. This affect was also noted in the work of Wellington _et al_. (1954).

Hendrickson's work also showed that muscle development favored full-fed steers, if the steers were slaughtered on an age-constant basis. However, when the steers were slaughtered on a weight constant basis little difference was found. This is in agreement with the work of Palsson and Verges (1952b) and Winchester _et al_. (1957). Hendrickson also indicated that full feeding was less efficient in the amount of energy and crude protein required to produce a pound of lean meat and a pound of protein in the carcass.

Measures of Carcass Composition

Specific gravity has been used by many workers as an indicator of carcass composition. Rathburn and Pace (1945) working with guinea pigs, and Da Costa and Clayton (1950) using albino rats found an inverse relationship between specific gravity and fat content in the body.

However, Da Costa and Clayton reported that the relationship between specific gravity and fat content increased as the fat content became greater.

Among the first research with livestock, using specific gravity as an indicator of fat in the body, was the work of Kraybill et al. (1952). These workers used thirty Hereford steers and heifers which were divided equally into two lots with the lots as nearly alike as possible in line of breeding, age, and weight. The rations fed consisted of hay, cottonseed meal, and cracked corn. Group 1 received a full-feed of corn, while group 2 was limited to one-half the amount of corn alloted group 1. When slaughtered the experimental cattle weighed from 500 to 1050 pounds. The carcass composition was estimated by physical separation of the 9-10-11th rib and the values substituted into Hopper's (1944) equations. The specific gravities were determined on the fore- and hindquarters, 9-10-11th rib, and the viscera, head, and shanks.

These authors reported that the specific gravity of the dressed carcass and the whole animal were closely related ($r = .99$), and the specific gravity of the 9-10-11th was closely related to that of the carcass ($r = .95$) and to the body ($r = .95$). The specific gravity of the 9-10-11th rib was also highly correlated to the percent fat in the carcass ($r = .91$).

Assuming that the mean value of water in lean meat is 72.6%, Kraybill et al. (1952) derived the following equations for estimating the percent fat and water in the body.

$$\% \text{ fat} = 100 \left(\frac{4.802}{\text{S.G.}} - 4.366 \right)$$

$$\% \ H_2O = 100 \left(3.896 - \frac{3.486}{\text{S.G.}} \right)$$

The authors felt that these equations could be used with some degree of precision for estimating fat and water content in the carcass from carcass specific gravity. It was also concluded that the very good results obtained with the specific gravity of the 9-10-11th rib could provide a good and convenient method for estimating carcass composition.

Whiteman _et_ _al_. (1953) also demonstrated that the ham from a swine carcass is a good indicator of total carcass composition. These workers reported a correlation of .912 between the specific gravity of the ham and percent moisture, protein, and ether extract of the carcass. It was further indicated that the percent of fat and skin or the percentage of lean in the ham had a greater influence on specific gravity than did the percentage of bone.

Following this early research others have shown a relationship of specific gravity to the fat and lean content in the carcass and various wholesale cuts (Lofgreen _et_ _al_. 1954; Orme _et_ _al_. 1958; and Bieber _et_ _al_. 1961). Lofgreen _et_ _al_. (1954) and Klieber (1961) have presented equations suitable for use in estimating carcass content from specific gravity.

Other workers (Cole _et_ _al_. 1960a, 1960b) have reported low, but highly significant correlations between specific gravity and various measures of eating quality in beef. In addition specific gravity was found to be highly correlated to certain physical and chemical measures of fat, but was not significantly correlated to Warner-Bratzler shear scores.

EXPERIMENTAL DESIGN AND PROCEDURE

Thirty-six, half-sib, weanling Hereford steers, purchased from a large commercial ranch which had used an artificial insemination program, were allotted according to weaning weight and grade into six groups of six steers each. The design of the experiment is shown in Figure 3, and Table 1.

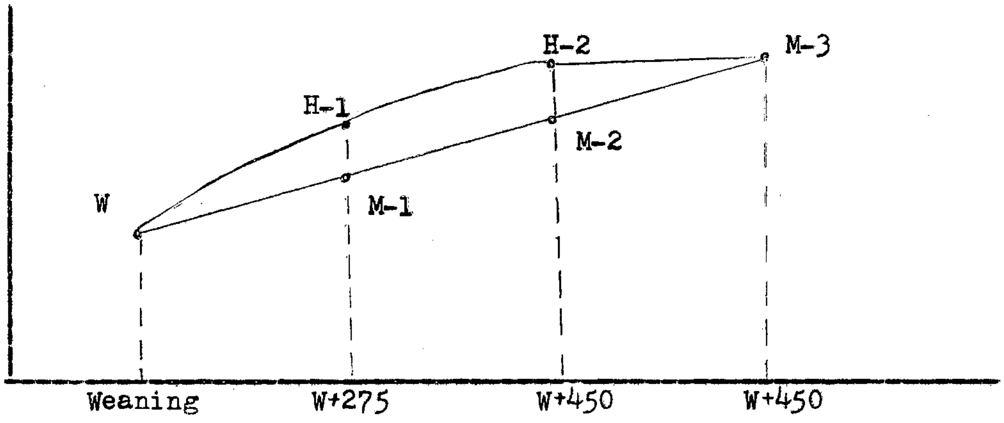


Figure 3. Experimental design.

TABLE I
EXPECTED POST WEANING GAIN

Treatment	Expected post-weaning gain to slaughter (lb.)
Weaning (w)	slaughtered at weaning
High Plane	
(H-1)	275
(H-2)	450
Moderate Plane	
(M-1)	275
(M-2)	450
(M-3)	450

Six weaning (W) steers were slaughtered at the beginning of the experiment to establish a base point for carcass composition. The "Highs" (H) were fed a 70% TDN ration, and were divided into two groups according to the post-weaning weight desired before slaughter. The H-1 group steers were to acquire a feedlot gain of 275 pounds, while the H-2 group steers were to gain 450 pounds above weaning. The "Moderates" (M) were fed a 54% TDN ration, and were divided into three groups. The M-1 and H-1 calves were slaughtered at the same time regardless of M-1 group's gain to that point; calves from the M-2 group were slaughtered on an age-constant basis with the H-2 calves; and the M-3 group was allowed to attain the same total feedlot gain as the H-2 group before being slaughtered.

The high level ration was formulated so that the Highs would gain in excess of two pounds a day, while the moderate plane of nutrition was to give gains of 1.5 to 1.7 pounds per day. To obtain these different rates of gain, the amount of steam rolled corn and cottonseed hulls in the rations was varied. In order to maintain the desired rates of gain, it was necessary, after 60 days, to adjust the protein level in the rations. The protein content for the high plane of nutrition was increased from 11 to 13%, and the moderate ration from 9 to 10%. The ration shown in Table II was fed the remainder of the trial.

Although the experiment was originally designed to practice adlibitum feeding the moderate steers had to be hand fed. This restriction was necessary in order to control energy intake and provide desired rates of gain.

TABLE II

COMPOSITION OF RATIONS FED[1]

	Plane of Nutrition	
Ingredient (%)	H	M
Corn	58.7	16.5
Cottonseed meal	13.3	15.3
Dehydrated alfalfa leaf meal	7.0	7.0
Cottonseed hulls	15.0	54.7
Molasses	5.0	5.0
Ground limestone	0.5	1.0
Salt	0.5	0.5
Chemical Composition (%)		
Dry matter	96.25	96.34
Ash	4.45	5.65
Protein	13.60	10.40
Fat	2.49	2.22
Fiber	8.87	22.51
N.F.E.	66.84	55.56

[1] In addition, 1 pound of vitamin A mix was added per ton of mix in each ration, and a mineral mixture of 2:1, salt to dicalcium phosphate, was fed free choice.

Records obtained on feedlot performance were: feed efficiency, (calculated as either feed/pound of gain or TDN/pound of gain); feed consumption; and rate of gain. The TDN intake and requirements per 100 pounds of body weight were calculated from Morrison's standards.

The controls were slaughtered at the Oklahoma State University Meat Laboratory, but all other cattle were slaughtered at Oklahoma City. At time of slaughter, the weights of the hide, head, liver, pluck, heart, full and empty rumen and reticulum, full omasum and abomasum, and full intestine were obtained. The contents of the rumen and reticulum were used to estimate fill.

Physical carcass measurements were also taken. These included carcass weight, warm and after 48 hours chill; length of leg, loin, and body; thickness of the round and shoulder; and depth of body. In addition to these carcass measurements, the ribeye area was determined at the 6th, 9th, and 12th ribs. Color of lean and marbling scores were also obtained on the Longissimus dorsi muscle at the 12th rib.

After 72 hours chill one side of each carcass was quartered and the weight and specific gravity of each quarter determined. The specific gravity of the side was calculated using the weights of the fore- and hindquarters. Following this the fore- and hindquarters were broken down into the ten standard wholesale cuts. The weight and specific gravity of each cut was then determined. The wholesale rib was then broken down farther into the 6-7-8-th, 9-10-11th, and 12 rib cuts; these were also weighed and their specific gravity determined. Specific gravity readings were taken in the cooler to assure the same temperature of the meat and water.

Each wholesale cut was boned out and the weight of bone and "meat" recorded. The meat was thoroughly ground twice through a 1/16 inch plate, and a random sample taken for chemical analysis. As the cuts were boned out the specific gravity of the bones in each cut were determined. The 9-10-11th rib was used for a detailed analysis. This included a physical separation of the lean, fat, and bone, and the calculation of the percent of each constituent. Chemical analyses were made on the ribeye, fat, and other lean, and also the specific gravity of the bone and the Longissimus dorsi muscle from the 9-10-11th rib was determined.

Estimates of the lean, fat, and bone, using data from physical separation of the 9-10-11th rib, were calculated using the equations of Hankins and Howe (1946).

$Y = 16.08 + 0.80X$; Y = percent lean in carcass, X = percent separable lean in the 9-10-11th rib.

$Y = 3.54 + 0.80X$; Y = percent fat in carcass, X = percent separable fat in the 9-10-11th rib.

$Y = 5.52 + 0.57X$; Y = percent bone in carcass, X = percent separable bone in the 9-10-11th rib.

These values were correlated to the actual lean, fat, and bone in the carcasss; the lean and fat determined by chemical analysis, (lean = moisture + protein + ash; fat = ether extract). Efficiency of conversion of feed constituents to carcass lean was also calculated.

The specific gravities of the fore- and hindquarters, side, and wholesale cuts were correlated to the percent lean, fat, and bone in the carcass. The correlations were determined by use of the I.B.M. 650, and the Beaton Correlation routine.

RESULTS AND DISCUSSION

Feedlot Performance and Feed Conversion

Feedlot performance data and efficiency of feed conversion are summarized in Table III. Differences in post-weaning lean production, feed and TDN required to produce a pound of lean are presented graphically in Figure 4. Since group-feeding was practiced, average values for feed consumption and feed efficiency are the only data available for each treatment.

Although the H-1 and H-2 calves gained from 0.6 to 0.3 pounds a day more the Moderates, it is apparent from Table III that the M-1, M-2, and M-3 steers continued to gain at a relatively constant rate throughout the feeding trial, whereas the H-1 and H-2 calves declined in rate of gain as the feeding period advanced. The gains for both the High and Moderate groups were higher than those reported by Hendrickson (1962), when individual feeding was practiced.

The moderately-fed calves required a greater length of time to achieve the same feedlot gain than those fattened rapidly; this is illustrated by the M-3 vs. the H-2 group. The M-3 calves required an average of 39 days longer in the feedlot to reach the desired 450 pounds gain. This longer interval on feed was to be expected of the group of calves on this lower feeding regime.

TABLE III

FEEDLOT PERFORMANCE AND EFFICIENCY OF FEED CONVERSION DATA

Treatment	W	H-1	M-1	H-2	M-2	M-3
FEEDLOT PERFORMANCE						
Initial wt.	495.0±18.2[a]	499.2±21.1	492.5±8.7	488.3±42.6	490.8±10.8	503.3±8.7
Avg. days on feed		116.3± 4.2	116.3±4.2	218.7± 7.4	218.7± 7.4	258.0±5.0
Avg. daily gain		2.42±0.04	1.83±0.07	2.04±0.08	1.72±0.11	1.81±0.06
Avg. feed consumption/day		18.47	20.84	18.86	20.83	20.98
FEED CONVERSION						
Lbs. feed/lb. gain		7.64	11.39	9.25	12.09	11.62
Lbs. TDN/lb. gain		5.31	6.19	6.41	6.54	6.31
Lbs. feed/lb. lean		45.1	55.5	73.7	89.0	95.1
Lbs. TDN/lb. lean		31.4	30.2	51.1	48.3	51.6

[a] $s_{\bar{x}}$ This notation is used through the rest of the tables and is calculated according to Steel and Torrie (1960).

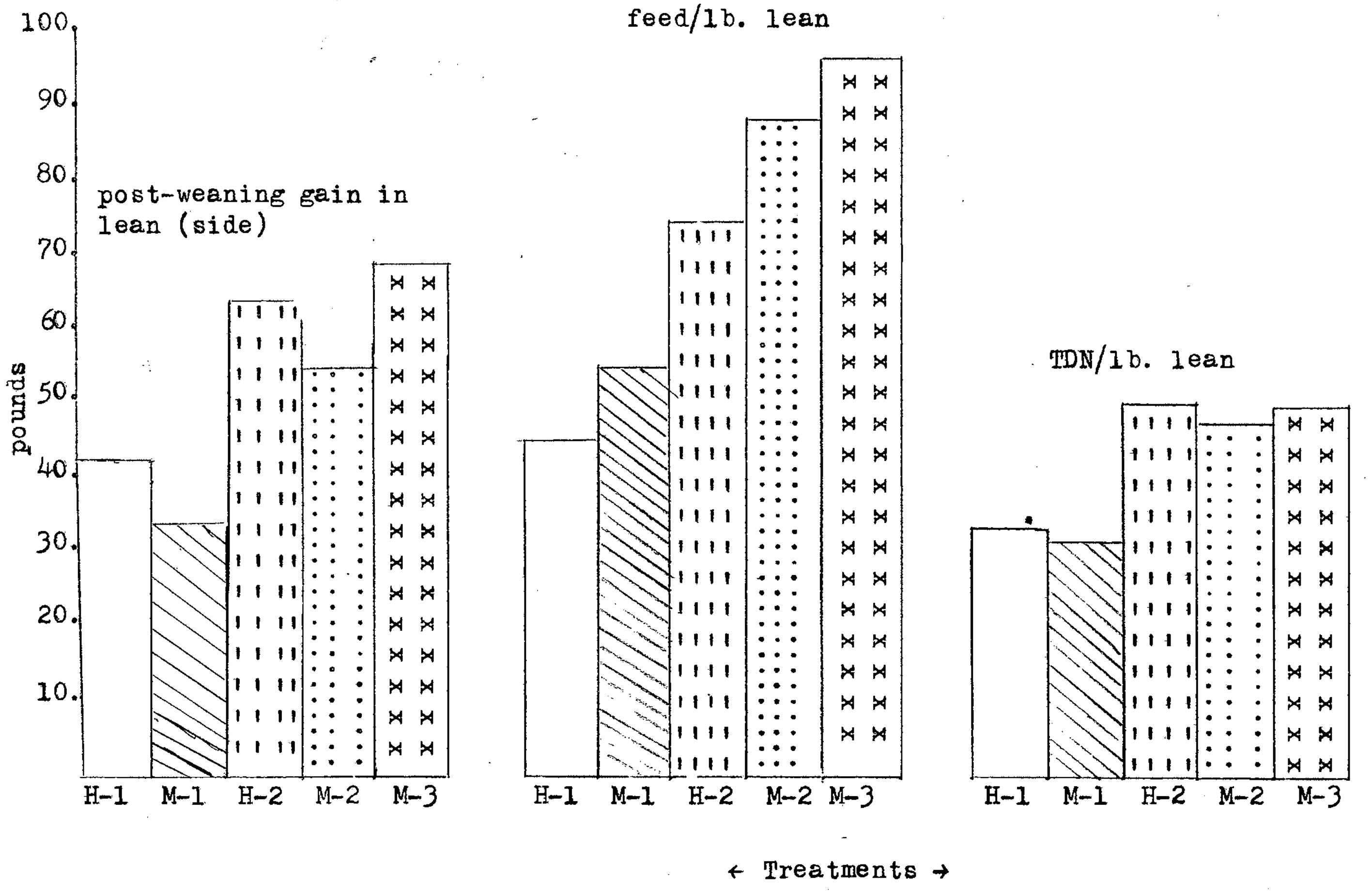


Figure 4. Production of lean in the carcass, and efficiency of feed and TDN conversion to carcass lean.

The H-1 and H-2 calves consumed approximately two pounds less total feed per day than the M-1, M-2, and M-3 calves. However, since the ration for the H-1 and H-2 steers contained a larger percent of TDN than the moderate ration, these calves consumed nearly two pounds more total digestible nutrients than the Moderates.

Feed efficiency, when expressed as the total pounds of feed required to produce a pound of gain, largely favored the H-1 and H-2 steers. However, if efficiency is calculated on a TDN basis, very little difference is apparent between the two feeding regimes when the calves were slaughtered on a weight-constant basis. The results are similar to those reported by previous investigators (Winchester and Howe 1955; Winchester and Ellis 1956; and Hendrickson 1962). When the steers were slaughtered on an age-constant basis, however, the H-1 and H-2 calves were more efficient than the M-1 and M-2 calves. This may be explained by the increase in nutrients consumed above maintenance by the H-1 and H-2 steers. Also it was noted that within each feeding regime, steers fed for a shorter period of time (H-1 and M-1) were more efficient in conversion of TDN to gain than the H-2, M-2, or M-3 calves.

Conversion of feed to carcass lean also favored steers fattened on the higher plane of nutrition. However, when expressed on a TDN basis, the Moderates were slightly more efficient than the Highs. This suggests that as more daily energy is consumed by an animal a greater portion of this increased energy consumption is used for fat production, and less is used for muscle development.

TABLE IV

CARCASS DATA AND MEASUREMENTS

Treatment	W	H-1	M-1	H-2	M-2	M-3
Slaughter weight (lb)	520.0	780.0	705.0	934.0	867.0	969.0
Carcass weight (lb)	310.0	479.0	429.0	608.0	519.0	592.0
Dressing percent	59.5±.44	61.3±.46	60.8±.42	65.0±.44	59.8±.94	61.1±.78
Carcass grade[a]	14.0±.22	16.5±.56	15.8±.60	17.5±.43	15.5±.61	16.7±71
Marbling score[b]	4.0±.43	6.5±1.18	7.0±1.67	9.3±.89	7.2±.83	8.6±1.83
Ribeye area (sq. in.)	7.4	8.4	8.5	9.9	9.3	9.8
Ribeye/cwt. carcass	2.4±.05	1.8±.07	2.0±.06	1.7±.06	1.8±.08	1.7±.07
Fat thickness (inches)	0.77	1.48	1.25	1.86	1.29	1.53
Fat area (sq. in.)	1.4±.14	3.4±.28	2.9±.19	4.4±.31	3.1±.36	4.2±.09

[a] 14 = average standard, 17 = average good, and 20 = high choice

[b] 5 = practically devoid, 8 = traces.

The conversion of TDN to carcass lean also favored steers fed for a shorter period of time (see Figure 4). The H-1 calves required 61.5% less TDN to produce a pound of lean than did the H-2 steers. With the M-1 steers approximately 62.5% as much TDN was required to produce a pound of lean as compared to the M-2 group, and only 58.5% as much TDN as the M-3 calves.

Effect of High vs. Moderate Gains on Carcass Measurements

It is apparent from the carcass data shown in Table IV that there was an advantage in dressing percentage (1 to 4%) in favor of the steers receiving the greater amount of TDN (H-1 and H-2). Other workers (Wellington *et al*. 1954; Weber *et al*. 1931; and Palsson and Verges 1952a, 1952b) also observed a similar effect of plane of nutrition on dressing percentage, although the latter two authors employed restricted or very low planes of nutrition. Several other workers (Guilbert *et al*. 1944; Winchester *et al*. 1957; and Hendrickson 1962) reported little or no affect of plane of nutrition on dressing percentage if cattle were slaughtered on a weight-constant basis. However, the cattle studied by these authors were of equal grade when slaughtered.

The H-1 and H-2 calves produced slightly higher grading carcasses, with higher marbling scores than their moderate counterparts, see Table IV. Marbling scores however, were not consistently higher for the H-1 and H-2 steers, as indicated by the large standard deviations. One of the M-1 steers had an exceptional amount of marbling, which may possibly be explanied by the dam's pre-weaning affect, or by age as other authors (Palsson and Verges 1952a) have shown other factors than plane of nutrition may also play an important role in marbling.

It is apparent from data in Table IV that the H-1 and H-2 calves had more external fat covering over the ribeye than the M-1, M-2, or M-3 steers. The fat per hundred pounds of chilled carcass weight and fat area over the ribeye were also much greater in the carcasses from H-1 and H-2 steers. There was little difference in area of ribeye between the H-1 and M-1 groups, and only a small difference in H-2 vs. M-2. Also it is indicated that as carcass size increased, the area of ribeye per hundred pounds of carcass weight decreased markedly. If ribeye area is regarded as an indicator of muscling in the carcass, there was apparently very little effect of a lower plane of nutrition on muscle development. However, Cole <u>et al</u>. (1960) have shown that only a small part (approximately 18%) of the variation in muscling in a carcass can be accounted for by estimates from ribeye area.

Effect on Carcass Composition and Skeletal Development

Carcass composition and skeletal development data are presented in Table V.

Chemical analysis indicates that the nutritional regimes employed had a more pronounced effect on carcass composition than was indicated by ribeye area. When steers were slaughtered on an age-constant basis, the pounds of lean in the carcass strongly favored the more rapidly gaining cattle. This agrees with the research of the early workers (Moulton <u>et al</u>. 1922b, 1922c; Trowbridge <u>et al</u>. 1918, 1919; Palsson

TABLE V

CARCASS COMPOSITION[a] AND SKELETAL DEVELOPMENT[b] DATA

Treatments	W	H-1	M-1	H-2	M-2	M-3
CARCASS COMPOSITION (lb.)						
Lean	95.1±3.73	138.4±4.24	127.9±5.51	161.0±4.69	149.6±3.81	162.9±2.40
Fat	24.9±1.99	52.3±3.13	43.0±4.28	83.2±3.93	58.9±5.75	71.2±4.18
Bone	25.5±1.64	33.9±1.22	31.3±0.82	36.1±1.00	36.2±1.03	40.7±0.94
Moisture	73.0	107.2	99.8	124.4	115.9	125.9
Protein	21.1	29.9	26.9	34.7	32.1	35.3
Ash	1.02	1.33	1.24	1.92	1.58	1.77
SKELETAL DEVELOPMENT						
Length of body	39.1±0.59	43.6±0.44	42.8±0.38	45.6±0.23	45.2±0.33	46.5±0.24
Length of loin	20.7±0.32	23.2±0.34	22.7±0.30	23.5±0.25	23.7±0.17	24.0±0.16
Length of leg	25.0±0.46	27.7±0.27	27.5±0.22	28.3±0.26	28.4±0.18	29.4±0.28
Width of shoulder	6.5±0.13	7.9±0.17	7.5±0.12	8.9±0.20	8.1±0.15	8.4±0.05
Width of round	7.2±0.15	8.2±0.12	8.2±0.15	9.0±0.29	8.7±0.13	9.2±0.11

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[a] Values for carcass composition are for one side, and were determined by chemical analyses.

[b] All values for skeletal development data are presented in inches.

and Verges 1952a, 1952b; Winchester et al. 1957; and Hendrickson 1962). The data suggest that the steers in this experiment were still growing, and the rate of gain of the Moderates in this experiment did not satisfy the maximum growth potential of muscle tissue in these steers.

Slaughtering the cattle on a weight-constant basis gave only a very slight increase in lean production. This is contrary to the results reported by the early researchers. However, in many of the early experiments cattle were used that probably gained at a much slower rate than those used in this trial. As a result, cattle fed on very low planes of nutrition in early studies had very little fat deposition, and the gain was largely bone and muscle.

Although the H-1 and H-2 calves had an increase in lean production, over the M-1, and M-2 calves, less than 3 pounds of this increased lean production was protein. On the other hand, nearly 8 pounds of the lean was moisture. Ash was relatively constant among all groups.

The M-1, M-2, and M-3 calves showed decidely less external fat covering, and percent fat in the carcass than the H-1 and H-2 calves. However, the percent of fat in the carcass of the M-3 calves approached that of the calves fed on a higher plane of nutrition.

Bone weight was approximately equal for the High and Moderate calves fattened for the same length of time. Slaughtered on a weight-constant basis, however, the M-3 steers had more bone than the H-2 calves, as was to be expected with an increase in age. Although bone was nearly equal when the steers were slaughtered on an age-constant basis, it is shown in Table V that the H-1 calves had slightly more bone than the M-1 calves. This may have been due to chance allotment of the steers since H-2 and M-2 calves showed no difference. This indicates that the moderate level of feeding practiced in this experiment was adequate for maximum skeletal development. Early workers also found that the skeleton developed adequately in steers fed on a moderate nutritional regime (Trowbridge _et al_. 1918, 1919; Moulton _et al_. 1922a, 1922b). Further evidence of adequate bone development is also shown by data in Table V where the length of loin, leg, and body, and depth of body are almost identical between treatments, with the M-3 calves showing some further development over the H-2 calves.

The effect of nutritional plane on the composition of the wholesale cuts was similar to the trend noted in the carcass--a decrease in percent lean and an increase in the percent fat. The major or high-priced cuts (chuck, rib, loin, etc.) expressed as percent of the carcass decreased from the controls (W), see Table VI. This agrees with the results reported by Moulton _et al_. (1922b, 1922c). The effect of nutritional regime on the major wholesale cuts was slightly more pronounced with the H-1 and H-2 steers than with the M-1 and M-2 steers.

Although the percent of major cuts and percent lean content in these cuts declined with increasing fat deposition, they showed a weight increase over the calves slaughtered at weaning (W). As indicated in Table VI, the increased lean in these cuts was approximately 10 pounds greater in the Highs when the steers were slaughtered on a weight-constant basis. Slaughtered on an age-constant basis, however, the Moderates had approximately a 2.5 pounds advantage in lean production.

TABLE VI

YIELD AND COMPOSITION OF CUTS

	W	H-1	M-1	H-2	M-2	M-3
MAJOR CUTS [a]						
Wt. (lb.)	110.1	164.0	148.8	203.8	178.2	206.1
% carc.	71.5	68.6	69.8	68.1	69.7	69.4
Lean (lb.)	72.6	104.0	94.9	121.1	113.2	123.6
Fat (lb.)	36.1	33.9	28.0	53.0	38.0	34.4
Bone (lb.)	16.6	19.9	20.1	23.8	24.3	27.0
MINOR CUTS[b]						
Wt. (lb.)	39.8	65.5	57.9	82.1	67.8	80.6
% carc.	25.8	27.4	26.6	27.4	25.6	27.3
Lean (lb.)	22.7	34.8	31.7	39.9	34.5	39.3
Fat (lb.)	12.8	16.4	15.1	30.3	20.9	27.9
Bone (lb.)	10.0	12.7	11.2	12.2	12.0	13.3

[a] chuck, rib, loin, rump, cushion round.

[b] hind shank, fore shank, flank, plate, brisket.

The minor or low-priced cuts (shanks, flank, plate, and brisket) as percent of the carcass increased in the fatter animals. However, the amount of fat present in these cuts increased in a more pronounced manner than did lean. The M-3 steers had carcasses that were equal to the H-2's in total lean produced in the minor cuts, but were lower in the amount of fat in these cuts.

Indicators of Carcass Composition

The estimates of percent lean, fat, and bone in the carcass, using data obtained from physical separation of the 9-10-11th rib, (Hankins and Howe 1946) were significantly correlated at the .01 level to the lean, fat, and bone in the carcass as determined from chemical analysis. These correlations, as presented in Table VII, were .952, .969, and .913, respectively. Although the correlations were highly significant, the estimated lean was always lower than that determined by chemical analysis, and estimated fat was consistently higher than chemically determined fat. The estimates of bone were more variable in relation to the actual amount of bone in the carcass.

Results of specific gravity determinations are presented in Table VIII. Specific gravities of all the wholesale cuts except the fore- and hindshanks were significantly correlated at the .01 level to the percent lean, fat, and bone in the carcass. This suggests that several of these cuts can be used individually or in combination to estimate carcass composition. Many other authors have also reported high correlations between specific gravity of various cuts and carcass composition (Kraybill et al. 1952; Whiteman et al. 1953; Lofgreen et al. 1954; Breidenstine et al. 1953; Orme et al. 1958; and Bieber et al. 1961).

TABLE VII

TOTAL CARCASS COMPOSITION[1] AS DETERMINED BY CHEMICAL ANALYSIS AND ESTIMATED FROM THE 9-10-11th RIB SEPARATION

	Chemical			Estimated		
Treatments	Lean[a]	Fat[b]	Bone[c]	Lean[a]	Fat[b]	Bone[c]
W	197.8	59.2	53.0	188.5	74.4	47.1
H-1	285.5	124.1	69.9	207.2	142.3	65.6
H-2	335.6	197.6	75.4	308.9	217.1	82.7
M-1	262.1	102.5	64.4	251.8	113.7	63.1
M-2	307.2	137.5	74.2	281.3	162.4	74.7
M-3	341.6	165.2	85.2	307.2	198.9	85.8

[a] r = .925

[b] r = .969

[c] r = .913

[1] All figures above are given in pounds.

TABLE VIII

CORRELATION OF SPECIFIC GRAVITY OF CUTS IN THE CARCASS TO PERCENT LEAN, FAT, AND BONE IN THE CARCASS

Cut Studied	% lean	% fat	% bone
Side	.835**	-.898**	.802**
Hind quarter	.847**	-.900**	.783**
Fore quarter	.798**	-.851**	.747**
Rump	.830**	-.873**	.739**
6-7-8th rib	.796**	-.856**	.766**
Plate	.780**	-.858**	.808**
Flank	.783**	-.835**	.732**
9-10-11th rib	.753**	-.835**	.797**
Loin	.748**	-.805**	.722**
Brisket	.768**	-.791**	.634**
Cushion round	.710**	-.763**	.680**
Chuck	.679**	-.754**	.723**
Rib	.583**	-.592**	.456**
Hind shank	.412*	-.376*	.197
Fore shank	.389*	-.399*	.317

** Significant at the .01 level.

* Significant at the .05 level.

The cut most frequently used for estimating carcass composition is the 9-10-11th rib. The specific gravity of this cut was also found to be correlated at the .01 level to percent lean, fat, and bone in the carcass ($r = +.753, -.835$, and $+.797$ respectively).

Several of the other cuts, however, gave as high or higher correlations to carcass composition than the 9-10-11th rib. These cuts included the rump, flank, plate, and 6-7-8th rib. Of the twelve cuts studied, the rump was the most highly correlated to percent lean and fat in the carcass, and was also highly significantly correlated to percent bone in the carcass ($r = +.830, -.873$, and $+.739$, respectively, for percent lean, fat and bone). The high correlations of specific gravity of the rump to carcass composition may be due in part to the rapidly maturing bone, and the small deviation of bone in this cut.

Specific gravities of the side, fore-and hindquarters were also very highly correlated to carcass composition (Table VIII).

The specific gravities of the fore-and hindshanks gave the lowest correlations to carcass constituents. This is probably due to the extreme variation in the amount of bone present in these two cuts among animals. Also there is a very small amount of lean and fat in these cuts. This agrees with the work of Whiteman et al. (1953), using pork carcasses, who found that the percentages of either fat or lean had a greater influence than bone on the specific gravity of the ham.

SUMMARY

Thirty-six, half-sib, weanling Hereford steers were used to study the effect of post-weaning rate of gain on carcass composition. The steers were allotted according to grade and weight into six uniform lots of six steers each. Lot 1 calves served as the controls and were slaughtered at the beginning of the trial to estimate initial carcass composition. Calves in the other five lots were fed varying amounts of TDN to obtain High vs. Moderate rates of gain, and were removed from feed and slaughtered on either an age- or weight-constant basis.

The High groups (H-1 and H-2) were fed a 55% rolled corn ration to obtain gains in excess of two pounds a day; Moderately-fed calves (M-1, M-2, and M-3) received a 15% corn ration and gained approximately 1.7 pounds per head daily. Groups H-1 and M-1 were slaughtered on an age-constant basis, when the H-1 calves had achieved a feedlot gain of 275 pounds. Calves in the H-2 and M-2 groups were slaughtered on an age-constant basis after the H-2 calves had achieved 450 pounds post-weaning gain. The M-3 calves were slaughtered on a weight-constant basis with the H-2 treatment calves after they achieved the same total gain.

Detailed slaughter and carcass information was obtained in the weight of hot and chilled carcass, grade and marbling score, ribeye area, yield of wholesale cuts, and specific gravities of the side,

fore- and hindquarters, as well as each wholesale cut, 9-10-11th rib and the 6-7-8th rib cuts.

Protein, moisture, ash, lean, and fat in the carcass was determined by chemical analysis of ground samples of each wholesale cut. Estimates were made of carcass lean, fat, and bone from physical separation of the 9-10-11th rib.

When the steers were slaughtered on an age-constant basis it was apparent that carcasses from the M-1 and M-2 calves contained less total lean than those on the H-1 and H-2 regimes. This suggests that the Moderate rate of gain in this experiment was not adequate for maximum muscle development. When the calves were slaughtered on a weight-constant basis, total lean was slightly in favor of the M-3 vs. H-2 calves. Less fat was deposited in the carcasses of steers fattened on a moderate plane of nutrition whether slaughtered on an age-constant basis or slaughtered after equal feedlot gain.

Nearly 1.7 times as much TDN was required to produce a pound lean during the last 160 pounds of feedlot gain, as compared to the first 275 pounds, for steers fattened rapidly, however, only one third of an increase in carcass grade was obtained in the latter preiod. Moderate steers required about 1.6 times as much TDN to produce a pound of lean during the second period, with no increase in carcass grade.

A decrease in percent of the high priced cuts (rib, round, loin, rump, and chuck), especially on the H-1 and H-2 regimes, was observed as the steers continued to fatten. Similarly, percent lean within each wholesale cut declined, while percent fat increased. The wasty cuts showed a general increase, as percent of carcass weight, as fattening continued.

Although the percent of major cuts and percent lean content in these cuts declined with increasing fat deposition, they showed an increase in weight over calves slaughtered at weaning (W). The increased lean in these cuts was approximately 10 pounds in favor of the Highs when the steers were slaughtered on a weight-constant basis. Slaughtered on an age-constant basis, however, the Moderates had about a 2.5 pounds advantage in lean production.

The H-1 and H-2 calves produced slightly higher grading carcasses with higher marbling scores than their moderate counterparts. The Highs also had decidely more external fat covering and percent fat in the carcass than the Moderates.

The bone weight was approximately equal for the High and Moderate calves fattened for the same length of time. This indicates that the Moderate level of feeding practiced in this experiment was adequate for maximum skeletal development..

Correlations of specific gravity of each wholesale cut, except the fore- and hindshanks, the side, fore- and hindquarter, 9-10-11th rib, and 6-7-8th rib cuts revealed highly significant values to percent lean, fat, and bone in the carcass.

Of the wholesale cuts studied, the rump was the most highly correlated to percent lean and fat in the carcass, and was also very highly correlated to percent bone in the carcass (r = +.830, -.873, and +.739, respectively). This suggests that one or more of the wholesale cuts might be employed to estimate carcass composition.

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