EFFECT OF NUTRITIONAL LEVEL IMPOSED FROM BIRTH TO EIGHT MONTHS OF AGE ON THE GROWTH AND DEVELOPMENT PATTERNS OF BEEF CALVES FED THE SAME RATION FROM EIGHT MONTHS TO A CONSTANT MARKET WEIGHT

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Bachelor of Science

Iowa State University

Ames, Iowa

1964

Submitted to the faculty of the Graduate College
of the Oklahoma State University
in partial fulfillment of the requirements
for the degree of
MASTER OF SCIENCE
May, 1967

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ACKNOWLEDGMENTS

The author wishes to express his appreciation to Dr. S. A. Ewing, Professor of Animal Science, for his guidance and assistance during the course of this study.

Very special appreciation is extended to Dr. J. J. Guenther of the Animal Science Department for his valuable assistance in obtaining the necessary carcass information and for his continual guidance and advice throughout the duration of this study. Grateful acknowledgment is also extended to Dr. R. D. Morrison, Professor of Mathematics and Statistics, for suggestions and aid in conducting the statistical analyses of data.

The author is indeed grateful to Tove Auda for conducting the chemical analyses, to fellow graduate students for their assistance and suggestions, to Ann Hood, Pat Parker and Patricia Wiseman for assistance in the preparation of this manuscript and to all who aided in conducting this experiment.

Sincere appreciation is extended to the author's parents for their encouragement throughout this program of graduate study.

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INTRODUCTION

Research in the field of agriculture is generally directed toward the extension of knowledge and experience which will increase the quantity and/or quality of food production. Under conditions of famine, quantity is obviously the most important factor. However, when food supply is great, quality and consumer preference become the important considerations in food production. The latter is presently the case with beef production in the United States.

Calorie conscious beef consumers in the U.S. are demanding high quality, tender, flavorful retail beef cuts which contain a minimum amount of fat. Unfortunately, only a small percentage of the beef being marketed today combines these traits. In order to satisfy consumer demand for "quality," producers, in effect, have been compelled to ignore the surplus fat problem. As the result, retailers have had no alternative but to trim fat from high quality beef prior to sale. The production of excessive quantities of fat is expensive both from the standpoint of nutrient utilization, and the amount of labor required in processing beef for the retail trade.

Obviously, it would be desirable to economically produce high quality, tender, flavorful beef which required little or no fat trim. It is believed that significant progress will be made toward this objective only when the producer is armed with fundamental information regarding the factors affecting performance and development of the beef animal.

Many investigations have been conducted which reveal the effects of various nutritional levels, imposed during the postweaning period, on the growth and development of beef animals. However, limited data pertaining to the effects of different planes of preweaning or early life nutrition upon subsequent growth and development is currently available.

The present study was designed to elucidate the effect of nutritional level imposed from birth to 8 months of age, on the growth and development patterns of beef calves fed the same ration from 8 months to a constant market weight.

REVIEW OF LITERATURE

This literature review is presented in two parts, encompassing (1) general patterns of growth and development and (2) effects of plane of nutrition on growth and development.

General Patterns of Growth and Development

The complex process referred to as growth, is very difficult to define. Several definitions have been proposed by various research workers. Scholoss (1911), as cited by Hammond (1955), defined growth as the 'correlated increase in mass of the body in definite intervals of time in a way characteristic of the species.' This does not include the fact that skeletal growth may occur while body weight remains constant or even diminishes when animals are on maintenance or submaintenance diets (McCay et al., 1939; Pomeroy, 1941; Trowbridge et al., 1918; Winchester and Howe, 1955).

Hammond (1955) defines growth as the increase in weight of an animal until its mature size is reached. Development, according to Hammond, refers to changes in body conformation and shape, along with changes in body functions and faculties. For quantitative purposes, Brody (1945) defines growth as the 'relatively irreversible time change in magnitude of the measured dimension or function.' The concept of irreversibility excludes time changes which might be caused by factors such as fluctuating food supply, gestation, or lactation.

Before patterns of growth and development could be elucidated, early investigators were confronted with the problem of establishing adequate methods for measuring growth. Many studies involving extensive carcass measurements have revealed the inadequacy of live weight as a measure of growth in the animal body. For example, when young steers were fed rations which permitted no gain in weight, Waters (1908) found that skeletal growth continued while lean and fat regressed or were severely retarded. Eckles and Swett (1918) observed a differential growth among the various body parts of dairy heifers. Many other workers (Brody, 1927; Callow, 1948, 1949; Guenther et al., 1965; Joubert, 1959; Lowrey, 1911; Luitingh, 1962; McMeekan, 1940a, b, c; Moulton et al., 1922a, b; Palsson and Verges, 1952a) have also noted that different anatomical regions and tissues of the body grow at different rates and in a definite order of development.

Perhaps the most classical work concerned with elucidating the rate and order of development of the various body tissues was conducted by McMeekan (1940a, b, c). As the result of a very extensive study involving swine, McMeekan (1940a) found that postnatal growth in body proportions exhibited a well defined anterior to posterior gradient from earlier to later developing regions. The directional development occurred in terms of length, depth and width, respectively. The limbs appeared to be relatively early developing regions, with the hindlimb developing slightly later than the forelimb. It was observed that the major body tissues exhibit differential growth patterns in that nervous, bone, muscle and fat tissue develop in that order. Therefore, bone makes a greater proportion of its growth earlier in life than does muscle or fat.

More specifically, McMeekan (1940a) observed that the developmental changes in swine were caused by several waves of growth. A primary wave of growth was noted to begin at the cranium and move down the facial parts of the head and backward to the lumbar region. A secondary wave of growth initiating from the lower parts of the limbs and trunk to the lumbar region was noted. The lumbar region was the last part of the body to attain its maximum growth rate and was, consequently, the latest maturing region of the body. Moreover, body dimensions in terms of length increased relatively more in early growth stages than thickness. Variations were noted within tissues, for example, intermuscular fat accumulated in the various fat depots before subcutaneous fat.

With McMeekan's classical studies as a basis, research conducted both prior to and following these studies will be reviewed.

Early evidence which indicated that the head is the earliest portion of the body to develop was obtained by Lowrey (1911). Using swine, it was found that the head attained its maximum relative size of 30 percent of the total body length prior to birth, decreasing to 22 percent at birth and to 6 percent in the mature animal. More recent evidence with lambs indicates that relative to the brain plus eyes, which are very early maturing body parts, the feet have the slowest growth rate in postnatal life in proportion to their weight at birth, followed by the head, legs, neck, shoulders, thorax, pelvis and loin (Palsson and Verges, 1952a). Along with this gradient in growth of the body parts, the order of increasing growth rate of body tissues with age followed an outward trend from the central nervous system to bone, tendon, muscle, intermuscular and subcutaneous fat. These trends are very much in agreement with those obtained by McMeekan (1940a).

Further studies involving the order of development of the body parts were conducted by Joubert (1959) on cattle. It was found that the final stages of development occurred at approximately the junction of the thoracic and lumbar vertebrae. Similar results obtained by Guenther et al. (1965) indicated that the longissimus dorsi muscle matured first at the more anterior locations (6th and 9th thoracic vertebrae) than at the more central location (12th thoracic vertebra).

Growth and development in terms of body composition was extensively studied by Haecker (1920). Fifty steers were slaughtered at various stages from 45.35 to 680.27 kilograms live weight. It was observed that as the animal increased in live weight, the percent water, protein and ash decreased while the percent fat in the carcass increased. Beyond 362.8 kilograms live weight, fat accounted for an increasingly greater portion of the weight gain than did protein. Moulton et al. (1922a) using Hereford-Shorthorn cross beef steers observed similar results in that as an animal increases in age the percent lean and bone decreases while the percent fat tissue increases. The increases in percent fat were found to be greatest in the plate, loin, flank, rib and rump. In addition to carcass composition, growth and development is often measured in terms of linear body and carcass measurements. Guilbert and Gregory (1952) conducted a study on purebred Hereford cattle maintained under favorable and uniform environmental conditions. The animals were permitted to grow continuously to the limit of their inherent ability. It was observed that linear skeletal growth (length and height) increased faster and matured earlier than thickness growth. In calves, it was noted that the cannon bone had attained 85-90 percent of its mature length at birth and only 55 percent of its mature thickness. In swine, McMeekan (1940a) observed that bone thickness increased relatively more in later growth stages than did bone length.

Due to the limited number of experimental studies involving the growth and development of beef steers, growth and development patterns have been presented for various species. There are various problems associated with correlating results obtained among different species. For example, the lamb is born in a more advanced stage of development than the pig (Palsson and Verges, 1952a). Development at birth is quite closely related to the length of the gestation period (Moulton, 1923). In addition, growth rates cannot be used to determine equivalent ages, since different animals do not necessarily grow fastest at similar stages of development (Brody, 1927). Moulton (1923) found that mammals reach "chemical maturity," defined as a point when the chemical content of the body remains relatively constant, at different ages. However, the age at which "chemical maturity" is reached appears to be relatively constant in terms of the length of the total life cycle. Moulton suggests that various species can be compared on a fat free basis when they reach "chemical maturity."

In an attempt to obtain general growth patterns applying to meat animals (swine, cattle, sheep), Callow (1948) used anatomical and chemical data obtained from 29 head of cattle which included eight different breeds ranging in age from 1 week to 12 years of age, 55 head of sheep which included eight different breeds varying in age from 4 weeks to several years of age, and 42 pigs ranging in age from newly born to 2 years of age. The results disclosed that when a carcass contains over 20 percent fatty tissue, the percentages of muscular tissue, bone and tendons all decrease continuously as the percent of fatty tissue rises.

It was found that at any age, provided the carcass contained more than 18 percent fat tissue, the percentage of muscular tissue was approximately the same for the species analyzed.

Effect of Plane of Nutrition on Growth and Development

Having reviewed the general patterns of growth and development, this section is divided into two parts, involving the nutritional effects on (1) live animal growth and performance and (2) carcass development and composition.

Live Animal Growth and Performance

The response criteria most commonly used to reflect effects of various planes of nutrition have been live weight gains along with feed conversion efficiencies. In addition, measurements of size have been used to indicate skeletal growth, with thickness measurements indicating muscle and fat development.

McMeekan (1940a, b, c) imposed four different levels of nutrition on swine from shortly after birth to 90.7 kilograms live weight. The four levels were: high plane throughout (H-H); high plane to 16 weeks of age, followed by a low plane (H-L); and a low plane to 16 weeks of age, followed by a high plane (L-H); and a low plane throughout (L-L). The animals in each group were fed to gain according to predetermined growth curves from birth to 90.7 kilograms live weight. It was observed that the H-L pigs had the highest feed efficiency, consuming 4.28 kilograms of feed per kilogram of gain. The L-H pigs had the lowest feed efficiency (5.61), while the H-H and L-L pigs were intermediate (5.05 vs. 5.17). McMeekan attributed the differences to the differential growth of the body tissues. The H-L pigs were placed on a restricted level of nutrition when fat was the most rapidly growing tissue. The conversion of feed into fat requires much energy, therefore, restriction of feed at this stage improved the efficiency. Conversely, the L-H pigs were placed on the high plane of nutrition when fat was in its most rapid stage of development. Overall results indicate that long term retardation may result in poor feed conversion, however, short term retardation at the right period in life may result in improved feed efficiency.

In more recent work with swine, Lucas and Calder (1956) imposed three levels of nutrition on swine from weaning to slaughter weight. The levels were: very high plane throughout (VH-VH); high plane to 45.35 kilograms live weight, followed by a restricted plane (VH-R) and a very low plane throughout (VL-VL). When the growing and finishing periods were combined, the pigs on the VH-R and VL-VL planes grew 9 and 43 percent more slowly, respectively, than pigs on the VH-VH plane. The VH-R and VL-VL planes required 1 and 14 percent, respectively, more TDN (total digestible nutrients) per kilogram of gain than the VH-VH plane ($P < .001$). Lucas et al. (1960) noted that pigs restricted by 13 (H-H) and 26 (L-L) percent of the VH-VH plane from 8 weeks to a slaughter (90.7 kilograms), made gains 13 and 22 percent slower than the VH-VH group. Only small differences were noted in the feed conversion efficiencies.

In an attempt to study the effect of the length of feeding period and plane of nutrition, Weber et al. (1931) subjected lambs to the following nutritional regimes: (1) full feeding for 84 days; (2) maintenance for 56 days, followed by full feeding for 84 days; (3) full feeding for 84 days, followed by maintenance for 56 days and (4) full feeding for 140 days. During the 84 day full feeding period, group two lambs gained 3.17 kilograms more per head than those in group three on less grain, however, a greater amount of roughage was required.

Using sheep, Palsson and Verges (1952a) conducted an extensive experiment with a design similar to McMeekan's swine experiments. High and low planes of nutrition were imposed on the lambs from the third month of fetal life to 41 weeks of age. Following birth, wide differences in growth rates were observed. In addition, Palsson and Verges (1952b) studied the development of lambs from the third month of fetal life until they reached a 13.6 kilogram carcass weight. The treatments imposed were identical to those used by McMeekan with swine (H-H, H-L, L-H and L-L). Treatments were changed (high to low or low to high) after 6 weeks of postnatal life. Average daily gains were quite different among groups, as can be extrapolated from the fact that slaughter ages were: 9, 15, 15 and 41 weeks on the four levels.

The effect of a period of restricted level of nutrition on subsequent growth has not been clearly defined by previous experimental work. Much of the experimental work has been carried out on small laboratory animals, usually the rat. Early work conducted by Osborne and Mendel (1915, 1916) illustrated that satisfactory and usually accelerated growth could be attained with a suitable diet, following long periods of growth suppression caused by energy and protein restriction. Similar results with rats have been noted by Jackson (1936).

Using a very limited number of animals, Hogan (1929) found that moderate nutritional restriction did not influence the ability of beef steers to recover in terms of growth rate. However, severe nutritional restriction for a long period of time appeared to reduce mature size.

The relative effects of continuous and interrupted growth of beef steers were studied by Winchester and Howe (1955). Six pairs of monozygotic twins were used. One member of each set was fed a liberal ration while the other members were given rations supplying approximately 75, 62 and 50 percent of the energy supplied by the liberal ration. The animals were placed on the experimental rations at 6 months of age, and upon reaching 12 months of age they were again fed liberal rations. All animals were slaughtered when they reached approximately 453.5 kilograms. After restricted feeding ended, weight gains of the retarded calves either equaled or exceeded those of the controls. The retarded calves required a longer time to reach 453.5 kilograms, however, cumulative energy intake for the control and experimental animals from the beginning of the trials until a final weight of 453.5 kilograms was reached was about the same. The authors concluded that growing cattle can be carried for as long as 6 months at low energy levels, if the known nutritional needs aside from the energy required for growth are met, without subsequent loss of efficiency of feed utilization. Similar results were observed by Winchester and Ellis (1956) when one member of each monozygotic twin pair was fed a limited caloric allowance from 3 to 6 or from 4 to 8 months of age.

In a later experiment, Winchester *et al.* (1957) used monozygotic twin beef calves to compare the effects which might accompany simultaneous restriction of energy and protein. The restrictions were imposed from 6 to 12 months of age, at which time all cattle were realimentated on a good ration until slaughtered at a constant grade. The eight treatments produced differences in response, ranging from a loss of weight to a gain of 0.86 kilograms per day. In spite of the differences produced, overall efficiency of feed utilization was similar for all groups.

The effects of under nutrition on subsequent growth following re-alimentation in rats and sheep has been studied by Meyer and Clawson (1964). Identical treatment designs were used for both rats and sheep. One group was given an adequate ration fed _ad libitum_ to produce maximum growth. Animals in five other groups were given a feed intake of 84, 68, 52, 36 and 20 percent, respectively, of the _ad libitum_ fed controls based on a unit of metabolic body size (body weight $^{0.75}$). Twenty-one and 42 day restriction periods were imposed on the rats and sheep, respectively. At the end of the restriction period, one-third of the animals in each treatment were slaughtered, one-third were fed _ad libitum_ until they had consumed an amount equivalent to that consumed by the _ad libitum_ fed controls and one-third were fed _ad libitum_ until they attained a body weight equivalent to the control animals. Overall efficiency of feed utilization was somewhat lower for the restricted animals. The authors suggested that the compensatory growth was the result of increased efficiency of feed utilization above maintenance upon realimentation, since additional feed intake per unit of metabolic weight did not occur. Quite similar results were obtained by Meyer _et_ al. (1965) in studying the influence of various levels of energy intake during a growing phase (postweaning), on subsequent compensatory growth responses in the feedlot.

Brookes and Vincent (1950), as cited by Hammond (1955) and Brookes and Hodges (1959) imposed four different nutritional regimes on cattle. The treatments were: high level of feeding up to 8 months of age, followed by a high level in subsequent winters (H-H); high level up to 8 months of age, followed by a moderate level in subsequent winters (H-M); moderate level up to 8 months of age, followed by a high level in subsequent winters (M-H); and a moderate level up to 8 months of age, followed by a moderate level in subsequent winters (M-M). Upon attaining an estimated 57 percent dressing yield, the calves were slaughtered. The H-H and M-H calves reached this point in 2 years, H-M calves in 2.5 years and M-M calves in 3.5 years. At 8 months of age the calves raised on the high level had grown at twice the rate of those fed the moderate level. When representatives of the two initial treatments (high and moderate levels of intake to 8 months of age) were subsequently fed a high level, the difference in live weight shown at 8 months was reduced but did not disappear. The calves were first placed on grass at approximately 14 months of age. Calves on the moderate feeding level during the winter gained nearly 0.23 kilograms per day more during the summer than those on the high level. The authors attributed the profitability of the H-M calves to the fact that when the moderate plane was introduced, the animals had reached a stage of development which permitted them to effectively convert cheaper feeds into live weight gain. In a similar study, Callow (1961) observed nearly identical results.

Hendrickson (1961) imposed the following postweaning planes of nutrition on steer calves: full feeding for 163.3-181.4 kilograms feedlot gain (H-H); full feeding for approximately half of the total gain, followed by a moderate level of feeding throughout (H-M); moderate feeding, followed by full feeding (M-H) and a moderate level of feeding throughout (M-M). The H-H and M-H calves had significantly greater average daily gains (approximately 0.13 kilograms per day) than H-M and M-M groups. Since different rations were fed, efficiency of feed utilization was calculated on the basis of TDN per kilogram of gain. It was noted that the M-H and M-M groups consumed significantly ($P < .01$) less TDN per kilogram of gain than the H-H and H-M groups.

A study concerned only with the postweaning development of beef calves on two different planes of nutrition was conducted by Guenther et al. (1965). High level calves were slaughtered after attaining 125 (H-1) and 205 (H-2) kilograms of postweaning gain. Moderate level calves (M-1 and M-2) were slaughtered at the same time as the H-1 and H-2 calves, and M-3 calves were slaughtered after attaining 205 kilograms of postweaning gain. Rate of gain was quite constant throughout the trial for the moderate calves, however, the high level calves showed a significant ($P < .01$) decrease in rate of gain as the feeding period was prolonged. Feed utilization was most efficient during the initial phase of the trial on both levels. On an age constant basis, the H-1 and H-2 calves averaged 36 and 28 percent, respectively, less feed per kilogram of lean produced than the M-1 and M-2 calves. However, on a weight constant basis little difference was noted in the efficiency of lean production.

Innumerable studies (Black, 1939; Bohman, 1955, Joubert, 1954; Lawrence and Pearce, 1964a) have been conducted on the effect of different planes of nutrition during the wintering of young cattle, on their growth during subsequent grazing seasons. These workers found that calves on restricted levels of nutrition during their first winter were able to partially compensate by making greater gains during the subsequent summer. However, when the identical treatments were applied to the same cattle during the following winter, the restricted and control animals finished their second grazing period without significant weight differences. Joubert (1954) suggested that older animals could more favorably contend with periods of restricted nutrition and could demonstrate greater ability to recover than younger animals.

In general, it appears that the effects of different planes of nutrition on rate of gain and feed efficiency are quite similar for all species of meat animals (swine, cattle, and sheep). Nutritional levels appear to have a greater effect on daily gains than on overall efficiency of feed utilization.

Carcass Development and Composition

The development and composition of an animal is the result of differential growth rates of the various body parts, organs and tissues. Many methods and techniques have been used to quantitatively measure carcass development and composition. No attempt has been made to review research work evaluating various techniques, nor will all measurements which reflect development be included. This review will include a portion of those factors and measurements which might reflect the influence of different planes of nutrition on carcass development and composition.

Low expense and ease of handling has inspired the use of rats or small laboratory animals in attaining information pertaining to the influence of nutrition on carcass development and composition. Outhouse and Mendel (1933) studied the influence of growth rate on the skeletal development of the albino rat. Nutritional levels which provoked growth rates of 2 and 4 grams per day were established following weaning. Animals from each treatment were killed as they attained body weights of 60, 90, 120, ..., 360 and 420 grams. Examination of the animals revealed that body proportions were nearly identical, irrespective of their age and rate at which they were reared, when examined at the same weight. Age appeared to have an effect on the length of the limb bones, in that at a constant weight the bones were longer in the slower growing, older animals, than in the more rapidly growing group.

Much work has been conducted on the subsequent recovery of rats following a period of suppressed growth, caused by energy and/or protein restriction. McCay, et al. (1939) imposed severe nutritional restrictions on rats. Following weaning, 106 rats were divided into a control and an experimental group. The control animals were allowed to grow normally while the experimental rats received a level of energy which would maintain a stationary body weight. Animals were permitted to grow after 300, 500, 700 and 1000 days of retardation. In general, retarded animals were never able to attain the body weights of the control animals, however, bone growth did continue throughout the maintenance periods. Bone growth appeared to be stunted in that retarded animals did not attain the body length of the control animals. In a similar study, Clark (1938) noted that recovery of weight appeared possible, however, extended periods of retardation reduced ultimate skeletal development. More recently, Meyer et al. (1956) observed that rats restricted in energy for a 28 day period were able to make complete recovery in terms of body composition when realimentated on a normal ration. Rats which were restricted in terms of total diet (energy, protein, vitamins, and minerals) for a 28 day period, recovered in terms of body weight, however, the restricted rats had a greater amount of fat and a smaller amount of fat free tissue than the control rats.

The effects of four different levels of nutrition on the development and composition of the swine carcass was studied by McMeekan (1940a, b, c). The nutritional levels imposed from shortly after birth to 90.7 kilograms live weight were: high plane throughout (H-H); high plane to 16 weeks of age, followed by a low plane (H-L); low plane to 16 weeks of age, followed by a high plane (L-H) and a low plane throughout (L-L). The different planes of nutrition exerted differential effects on the development of the different body parts in the order of their maturity (the early maturing head was least affected, followed by the shoulder, limbs, neck, pelvis, thorax and loin). At 16 weeks of age, the high plane animals contained 221, 291 and 1,007 percent as much skeletal, muscle and fat tissue, respectively, as the low plane pigs. These results illustrate the differential effects of nutritional level on the body tissues. When comparing the four treatment groups at a constant slaughter weight of 90.7 kilograms, McMeekan found that the H-H and L-H treatments produced carcasses of similar type. However, the carcasses were shorter, had greater depth and a higher proportion of later maturing parts (loin and thorax) than pigs on the L-L and H-L treatment levels. In contrast, the L-L and H-L carcasses were composed of a greater proportion of the earlier developing body parts. The amount of bone and muscle increased, and fat decreased, in the order L-H, H-H, H-L and L-L. This demonstrated that the recuperative capacity was greatest in the later maturing fat tissue. Bone lengths were approximately the same in the H-H and L-H groups, being somewhat shorter than in the H-L group and very much shorter than in the L-L group.

Using swine, Pomeroy (1941) observed that the level of nutrition affected the tissues in the order of their development (a greater effect was observed in the later developing tissues). These results agree with those of McMeekan's, however, McMeekan worked with above maintenance rations, while Pomeroy imposed submaintenance rations.

In 1949, Winters _et al_. imposed H-H, H-L, L-H and L-L treatments on swine. It was noted that the animals restricted throughout, produced the leanest carcasses. Similarly, Lucas and Calder (1956), using VH-VH, VH-R and VL-VL nutritional levels, observed that the animals subjected to the VL-VL level had significantly ($P < .001$) less backfat and significantly ($P < .05$) larger loin eyes than those on the other treatments. In a later study, Lucas et al. (1960) observed that a restricted level of nutrition had no significant effect on carcass length, however, backfat thickness was reduced.

In swine, the effects of different nutritional levels on carcass composition appear to be least in skeletal tissue, followed by muscle, with fat being most affected. Though dependent upon treatment and genetic differences, these general trends were noted in all studies reviewed.

An extensive study on the effects of plane of nutrition on growth and development of sheep was conducted by Palsson and Verges (1952a, b). High and low planes of nutrition were imposed on half-sib lambs from the third month of fetal life to 41 weeks of age. Carcass analyses were carried out at birth, 9 weeks and 41 weeks of age. The results were in close agreement with the growth patterns and gradients found by McMeekan (1940a). It was found that nearly any organ, part or body tissue was proportionately more affected by nutritive supply (whether high or low) at the age of its highest growth intensity than at any other age, for example, the low plane of nutrition had an increasingly retarding effect on the development of the various anatomical parts and tissue in the direct order of their maturity. By expressing the weight of various tissues and body parts of the high plane lambs as a percent of the part in the low plane lambs at the same age, Palsson and Verges found that at 41 weeks of age the brain, skeleton, muscle, intermuscular fat and subcutaneous fat were 5, 89, 140, 366 and 894 percent greater, respectively, in the high plane lambs. These results support the growth patterns observed by McMeekan in swine.

In another experiment, Palsson and Verges (1952b) imposed H-H, H-L, L-H and L-L treatments on similar lambs from the third month of fetal life until attaining a carcass weight of approximately 13.6 kilograms. Two distinct types of carcasses were produced, the H-H and L-H carcasses were of similar conformation (short limbed, blocky, and well covered with subcutaneous fat, with well developed thoracic, loin and pelvic regions). In contrast, the H-L and L-L carcasses were of similar conformation (long limbed, lank and poorly covered with subcutaneous fat, with poorly developed thoracic, loin and pelvic regions). Bone weight was less in the L-L group in spite of the greater length of the individual bones. The fact that the L-L lambs were able to develop as much total fat relative to the other groups was attributed to the decreasing growth intensity of the earlier maturing tissues (bone and muscle in that order) with age, thus enabling fat to successfully compete with these tissues for available nutrients. It appeared that age was an important factor in the development of intramuscular fat (marbling), inasmuch as it was best developed in the L-L, H-L, L-H and H-H carcasses, respectively. In all cases, however, tissues in the later developing regions of the body were more affected than those in the early developing regions. Wilson (1960) observed similar growth patterns when dwarf goats were reared on H-H, H-L, L-H and L-L planes of nutrition from birth to 7.3 and 13.6 kilogram weights. However, Wilson's overall conclusions were that the proportions of the body at any given stage of growth, evaluated on a weight constant basis, are very constant apart from large variations in fat content.

Very few experiments have been conducted on the carcass composition of cattle, as influenced by level of nutrition. Early experiments were often carried out with a limited number of animals. In addition, treatments were often of such a severe nature that the results were difficult to interpret in terms of what might occur under more practical conditions.

Callow (1961) imposed four different planes of nutrition on three breeds (Hereford, Dairy Shorthorn, and Friesian) of cattle. The treatments were: high level to 8 months of age, with a high level in subsequent winters (H-H); high level to 8 months of age, with a moderate level in subsequent winters (H-M); the reverse (M-H) and moderate level to 8 months of age, with a moderate level in subsequent winters (M-M). All animals were grazed during the summer. The steers were slaughtered when they had attained an estimated 57 percent yield. No significant differences in the proportion of muscle tissue were found, however, the mean values for percent of lean suggested an increase, in the order H-H, M-H, M-M and H-M. This is the same order in which fat was found to decrease. The older animals (H-M and M-M) had the greatest amount of bone. The results may have been influenced by the fact that the H-M and M-M groups were slaughtered immediately following a summer grazing season.

Effect of wintering yearling beef cattle on different planes of nutrition were studied by Lawrence and Pearce (1964a, b). During the wintering period, animals were fed to gain according to predetermined growth curves designed to give live weight gains of 0.68 kilograms per day (high level), 0.34 kilograms per day (moderate level) and no gain (low level). After a summer grazing period all animals received the same ration designed to produce live weight gains of 0.91 kilograms per day. Animals were slaughtered at a constant weight of approximately 469 kilograms. The high level animals reached the desired slaughter weight 2 and 8 weeks before the moderate and low animals, respectively. The only significant difference in carcass measurements was noted in length. The moderate level calves were the shortest, followed by the high level calves, with the low level calves having the longest carcasses.

Using 6 pairs of identical twins, Winchester and Howe (1955) studied the effects of continuous and interrupted growth. One member of each pair of twins was fed a control ration; while the other animals received 50, 62 and 75 percent of the liberal ration from 6 to 12 months of age. The retarded animals were then fed liberally until attaining 453.5 kilograms live weight. The total lean development, as estimated by 9-10-11th rib separation, was not limited by restricted growth. However, the retarded animals tended to have more fat (estimated by 9-10-11th rib separation). Similar results were obtained by Winchester and Ellis (1956). Identical twins were used, the diets included submaintenance, maintenance, and above maintenance levels from 3 to 6 or 4 to 8 months of age. Animals were slaughtered at a low prime grade.

Winchester *et al.* (1957) reported no significant differences in carcass composition due to caloric and/or protein restriction. In this study, 12 pairs of identical dairy-beef cross twins were fed restricted rations between the ages of 6 and 12 months, followed by realimentation on a liberal ration. The animals were slaughtered at a constant grade. Effects of protein and energy restriction on tissue development and the extent of recovery following realimentation were studied by Carroll *et al.* (1963). Twelfth rib analyses showed no significant differences in percent bone, lean or fat, in external fat thickness and in ribeye area. It was noted that animals which were not restricted had more intramuscular fat in the *longissimus dorsi* muscle.

Four planes of nutrition (H-H, H-M, M-H and M-M) were imposed during the postweaning feeding period by Hendrickson (1962). The H-M and M-H groups switched levels after having attained approximately half of the 163.3-181.4 kilograms of feedlot gain. Physical separation data indicated that steers fed for rapid gain (H-H) produced higher grading carcasses which contained more fat and less lean and bone than those from steers fed to gain at a moderate rate (M-M). Carcasses produced from the H-M and M-H treatments were intermediate to those from the H-H and M-M regimes in composition and grade. However, the carcasses from the M-H groups contained a greater percentage of fat and a lower percentage of lean and bone relative to those from the H-M group.

Recently, Guenther *et al.* (1965) conducted a study involving the effect of postweaning rate of gain on the growth and development of the major carcass tissues in beef calves. Two levels of nutrition were imposed: high level to obtain gains in excess of 0.91 kilograms per day (H), and a moderate level to obtain a gain of approximately 0.77

kilograms per head per day (M). On an age constant basis, carcasses from the M-1 and M-2 calves contained less lean than those of the H-1 and H-2 calves (H-1 and H-2 calves were slaughtered after achieving feedlot gains of approximately 124.7 and 204.1 kilograms respectively). A decrease in the percent rib, round, loin, rump and chuck was observed as the steers continued to fatten. When the calves were slaughtered on a weight constant basis, the carcasses from the M-3 groups (slaughtered after attaining 204.1 kilograms feedlot gain) contained less fat and slightly more total lean than those from the H-2 groups. Bone development appeared to be related to animal age rather than the nutritional levels imposed. Various skeletal measurements indicated that calves on the moderate plane of nutrition developed at about the same rate as those on the high plane.

In summary, the experiments reviewed indicate that animals have a remarkable ability to recover from periods of restricted levels of nutrition during their growth process. The growth patterns and effects of various nutritional levels appear to be quite similar for all species reviewed. Very little work has been conducted on the effects of various planes of nutrition imposed during the early life (prenatal and preweaning periods) of beef calves. Present knowledge indicates that the level of nutrition imposed during the months immediately before slaughter have the greatest effect on carcass composition. The present study was designed to provide information regarding the effect of nutritional level imposed from birth to 8 months of age, on the growth and development patterns of beef calves.

MATERIALS AND METHODS

Data reported in this study were obtained from 60 Hereford steer calves. The prefeedlot phase of this experiment was conducted at the Lake Carl Blackwell experimental range near Stillwater. Cows of similar genetic background were allotted, prior to calving, into five different groups on the basis of their previous milk production. Groups possessing above average (high) and below average (low) milk producing abilities were selected, while the remaining three groups were considered to have an average milk producing ability. Calves in each group were sired by three or more bulls. Nutritional levels of all dams were approximately equal, both prior to and following calving. Milk production levels of the dams in groups two and five were determined at approximately 28 day intervals during the nursing period.

Calves from each of the five groups of dams were subjected to a different level of nutrition from birth to 8 months of age as indicated in Table I.

Calves in groups four and five were given access to creep feed from approximately 3 to 8 months of age. Average composition of the creep ration is presented in Table II. Total creep consumption was recorded for each group.

At approximately 8 months of age, final shrunk weights (12 hours off feed and water) were obtained on all animals. A random sample (the number selected from each group is given in Table I) was selected from

TABLE I

NUTRITIONAL LEVELS FROM BIRTH TO EIGHT MONTHS OF AGE[a]

Treatment Group	Very Restricted 1	Restricted 2	Normal 3	High 4	Very High 5
Weaning Age, Days	170[b]	240	240	240	240
Milk Production of Dam	Average	Low	Average	Average	High
Supplemental Feed	-	-	-	Creep	Creep
Total No. of Calves	11	13	11	12	13
Slaughter Sample at 8 Months	5	5	5	6	6

[a]All cow-calf units were given access to an equivalent amount of range.

[b]Calves were weaned at approximately 170 days, then subjected to limited hay and pasture to restrict gains until 240 days of age.

TABLE II

AVERAGE COMPOSITION OF CREEP RATION

Ingredient[a]	Percent
Steamed Rolled Corn	24.0
Steamed Rolled Milo	15.0
Steamed Rolled Barley	15.0
Steamed Rolled Oats	15.0
Wheat Bran	5.0
Dehydrated Alfalfa Meal	5.0
Soybean Oil Meal	6.0
Linseed Meal	6.0
Molasses (Wet)	4.0
Animal Fat (Stabilized)	4.0
Trace Mineral Salt	0.5
Dicalcium Phosphate	0.5

[a]In addition, vitamin A was added in the quantity of 4,400 I.U./kg. of feed.

each treatment group for slaughter. Sixteen hour shrunk weights were obtained immediately preceeding slaughter at Harris Packing Plant, Oklahoma City, Oklahoma. Hot carcass weights were obtained immediately following slaughter. Twenty-four to 36 hours after slaughter the right side of each carcass was transferred to the Oklahoma State University Meat Laboratory, where the carcasses were subjectively evaluated in terms of conformation, maturity, marbling and carcass grade. In addition, the following carcass measurements were determined, according to the standard methods (Naumann, 1952): carcass length, length of leg, length of loin, depth of body, thickness of shoulder and thickness of round. Reference points for these measurements are presented in Appendix Table VIII.

Area of the ribeye (longissimus dorsi muscle) was measured with a planimeter from an appropriate tracing secured at the 12th thoracic vertebra.

Carcass cut out values were obtained by cutting the right side into 10 standard wholesale cuts (chuck, rib, loin, rump, cushion round, hind shank, flank, plate, brisket and foreshank) following the procedure of Wellington (1953). Each cut was physically separated into a bone and a lean-fat portion, and their respective weights were recorded. The lean-fat portion from each cut was ground through a 2.4 mm. plate thoroughly hand mixed and reground through the same plate, followed by another thorough mixing. Small pinch samples were taken from the ground and mixed lean-fat portion, at random, until duplicate 250 gram samples were obtained. The samples were frozen at -17.8° C while awaiting chemical analysis. Prior to analysis, the samples were blended into a homogeneous paste by means of a Servall Omni-mixer, and duplicate aliquots were analyzed for moisture, protein, ash and fat (A.O.A.C., 1955).

The calves remaining in each group (those not slaughtered at 8 months of age) were placed in the feedlot at the Fort Reno Experiment Station until attaining a shrunk weight of approximately 430 kilograms. All groups were placed on feedlot test (at the same time) following a 1 to 2 week adjustment period after weaning or reaching 8 months of age. At approximately 28 day intervals, all calves were shrunk and weighed throughout the feeding period. Animals were weighed more frequently as they approached the final shrunk weight (16 hours without water).

Throughout the feeding period, the same ration was fed *ad libitum* to each group. Feed consumption was recorded for each 28 day period and for the total feeding period on a group basis. Average composition of the finishing ration is given in Table III.

TABLE III

AVERAGE COMPOSITION OF FINISHING RATION

Ingredient[a]	Percent
Milo	59.70
Cottonseed Meal (41% Solvent)	8.96
Alfalfa Hay	9.95
Cottonseed Hulls	14.93
Molasses	4.96
Salt	1.00
Ca	0.50

[a]In addition, an aureomycin premix was supplied at the rate of 1 kilogram per 1,000 kilograms of feed during the first 28 day feeding period.

Upon attaining approximately 430 kilograms, the calves were slaughtered at Wilson Packing Company, Oklahoma City, Oklahoma. Hot carcass weights were obtained. The right side of each carcass was transferred to the Oklahoma State University Meat Laboratory, and evaluated, measured and analyzed in a manner identical to that indicated for the calves slaughtered at 8 months of age.

Data were analyzed by methods outlined by Steel and Torrie (1960) for a completely randomized design. Duncan's new multiple-range test was used to assess statistical significance between means. Tests of significance were conducted at $P < .05$ level.

RESULTS AND DISCUSSION

Effect of Nutritional Level on Animal Performance

Performance data of all calves, from birth to 8 months of age and of the sample slaughtered at a constant market weight are presented in Table IV. Since there were no statistically significant differences in birth weights, the increase in live weight, hence gain, could be attributed directly to the nutritional treatment imposed. These data clearly indicate that there was a progressive increase in live weight and in total gain, to 8 months, with an increase in nutritional level. Calves in the restricted, normal, high and very high treatment groups exceeded the average daily gain of the very restricted group by .04, .16, .25 and .23 kilograms per day, respectively. Obviously, in order to reach a constant market weight, more feedlot gain was required of the calves subjected to the lower levels of nutrition from birth to 8 months of age.

High and very high level calves consumed (free choice) approximately 348 and 194 kilograms of creep feed, respectively, from birth to 8 months of age. This may partially account for the fact that the high level calves exceeded the very high level calves in average daily gain. As originally designed, the only difference between the treatment of the high and very high level calves was to be in the milk producing ability of the dams. However, the milk production of dams of calves in the high level was not measured during the treatment period, but was assumed to

TABLE IV

EFFECT OF NUTRITIONAL LEVEL IMPOSED FROM BIRTH TO EIGHT MONTHS OF AGE IN PERFORMANCE OF ALL CALVES

Item	Treatment Group: Very Restricted 1	Restricted 2	Normal 3	High 4	Very High 5	EMS[a]
Birth to 8 Months						
Birth wt., kg.	33.8	35.7	33.4	33.9	34.6	12.236
Eight month wt., kg.	195.3^{c}	210.0^{d}	226.6^{e}	251.8^{f}	254.8^{f}	422.853
Gain to 8 months, kg.	161.5^{c}	174.3^{d}	193.2^{e}	217.9^{f}	220.2^{f}	415.464
Average daily gain, kg.	0.66^{c}	0.70^{d}	0.82^{e}	0.91^{f}	0.89^{f}	0.0062
Feedlot Performance						
Gain on test, kg.	238.5^{c}	213.6^{d}	215.8^{c,d}	180.7^{e}	175.2^{e}	405.418
Days on test	236.0^{c}	200.0^{d}	194.5^{d}	186.0^{d}	175.0^{d}	580.709
Average daily gain, kg.	1.01	1.07	1.10	0.97	1.00	0.027
Kg. feed/kg. gain[b]	9.19	9.10	9.03	9.83	9.93	----

[a] Error mean square

[b] Animals were group fed, therefore, data could not be statistically analyzed.

[c, d, e, f] Means on the same line bearing the same superscript do not differ significantly ($P < .05$).

be average. These facts suggest that high level calves may have actually been subjected to a level of nutrition equivalent to or higher than that of the very high level calves. However, this is only a suggestion which deserves recognition throughout this paper.

The feedlot performance data (Table IV) show that there were no statistically significant differences in the average daily gains of the calves from the various treatment groups. Thus, the feedlot time necessary for the various groups to attain a constant market weight was proportional to the required gain. Calves subjected to the lower planes of nutrition during early life required more days in the feedlot and consequently were older when they reached the desired market weight. Observations which lend support to these results were published by Winchester and Howe (1955). These authors observed that weight gains of restricted calves, after restricted feeding had ended, nearly equaled those of calves fed a liberal ration throughout life. However, it has been reported (Bohman, 1955; Bohman and Torell, 1956; Brooks and Hodges, 1959; Heinemann and VanKeuren, 1956; Hendrickson, 1961; Meyer _et al._, 1965; Weber _et al._, 1931) that following a period of restricted feeding, beef calves tend to compensate with greater average daily gains than calves fed a liberal ration throughout the growth and fattening period. This apparent discrepancy might be attributed to variation in severity and time of imposition of the restriction and to the fact that the experiments were terminated on different criteria.

Animals within each treatment were fed as a group in the feedlot which made it impossible to statistically analyze feed efficiency data. The mean values in Table IV indicated that calves subjected to normal or lower levels of nutrition during early life, utilized feed more efficiently in the feedlot than those subjected to high or very high levels from birth to 8 months of age. Meyer and Clawson (1964) and Winchester and Howe (1955) obtained similar results.

Effect of Nutritional Level on Carcass Merit

Carcass merit data of calves slaughtered at 8 months of age and at a constant market weight appear in Table V. Results from the calves slaughtered at 8 months of age indicate that slaughter weight, carcass weight, dressing percent, conformation score, marbling score and carcass grade score tended to increase with the level of nutrition.

With one exception, notably, maturity scores, statistical analyses revealed no significant differences in the carcass merit data of calves slaughtered at a constant market weight (Table V). The maturity scores of the very restricted animals were significantly ($P < .05$) lower than those observed for all other treatments. Inasmuch as no definite trend was apparent, the low scores of the very restricted animals might be attributed to a discrepancy in the subjective evaluation of the carcasses. While nonsignificant, the mean values for the dressing percent, conformation score, marbling score, and carcass grade favored those calves which were subjected to the lower planes of nutrition during early life. Palsson and Verges (1952b) observed that marbling in lambs was more dependent on age of the animal than on the plane of nutrition imposed. Similar results were observed in cattle by Hendrickson (1961). Inasmuch as marbling is an important factor in determining carcass grade, it is not surprising that these two factors followed similar patterns.

TABLE V

EFFECT OF TREATMENT ON CARCASS MERIT OF CALVES SLAUGHTERED AT EIGHT MONTHS OF AGE AND AT A CONSTANT MARKET WEIGHT

Item	Treatment Group					EMS[a]
	Very Restricted 1	Restricted 2	Normal 3	High 4	Very High 5	
Eight Months of Age						
Slaughter wt., kg.	191.5[e]	193.0[e]	225.0[f]	249.7[g]	241.6[f,g]	217.069
Carcass wt., kg.	88.2[e]	95.6[e]	113.7[f]	137.0[g]	137.1[g]	92.487
Dressing percent	46.1[e]	49.5[e]	50.5[f]	54.9[g]	56.7[g]	4.273
Conformation score[b]	12.2[e]	12.8[e]	14.2[f]	15.3[f,g]	15.8[g]	0.844
Maturity score[c]	1.0	1.0	1.0	1.0	1.0	0.000
Marbling score[d]	5.0[e]	6.6[e,f]	6.6[e,f]	6.2[e,f]	8.3[f]	2.844
Carcass grade score[b]	13.2[e]	14.6[e,f]	15.0[f,g]	16.2[h,g]	17.0[h]	1.220
Constant Market Weight						
Slaughter wt., kg.	421.0	422.2	428.6	420.3	428.8	290.008
Carcass wt., kg.	262.1	261.2	263.0	259.5	261.6	97.542
Dressing percent	62.2	61.9	61.4	61.7	61.0	2.588
Conformation score[b]	19.8	17.9	18.7	18.5	18.4	3.723
Maturity score[c]	1.8[e]	3.5[f]	3.2[f]	3.3[f]	3.1[f]	0.852
Marbling score[d]	17.3	14.8	12.8	13.3	13.3	10.158
Carcass grade score[b]	20.2	19.1	18.8	18.5	18.1	1.675

[a]Error mean square

[b]Average utility = 1, Average standard = 14, Average good = 17, Average choice = 20.

[c]A− = 1, A = 2, A+ = 3.

[d]Average practically devoid = 5, Average traces = 8, Average slight = 11, Average small = 14, Average modest = 17.

[e, f, g, h]Means on the same line bearing the same superscript do not differ significantly ($P < .05$).

Thus, trends observed in carcass grades and marbling scores may be partially accounted for by differences in animal age.

Effect of Nutritional Level on Carcass Growth and Development

The general growth and development data for the calves slaughtered at 8 months of age (Table VI) show that carcass growth was significantly influenced by the nutritional level imposed. Results from the various skeletal measurements, i.e., length of carcass, leg and depth of body, indicate that as the level of nutrition decreased, there was a decrease in the linear skeletal development. A similar trend was noted for muscular development as suggested by the ribeye area. The effect of the various nutritional levels on fat development is reflected in the amount of kidney and subcutaneous fat (at the 12th thoracic vertebra) produced by the steers in the various treatment groups. As the level of nutrition increased, the amount of fat increased. Collectively, these growth data indicate a definite pattern regarding the effect of nutritional level on the growth of bone, muscle and fat. Accordingly, as nutritional level is decreased, bone development is reduced by the least amount, followed by muscle and fat, respectively. These results are congruent with those of McMeekan (1940a, c) and Palsson and Verges (1952a).

It is apparent from the carcass development data obtained from calves slaughtered at a constant market weight (Table VI), that the nutritional level imposed from birth to 8 months of age had little effect on final carcass size. Although no significant differences were observed in the carcass development data, it might be noted that animals on the lower levels of nutrition during early life, tended to have a

TABLE VI

EFFECT OF TREATMENT ON CARCASS DEVELOPMENT OF CALVES SLAUGHTERED AT EIGHT MONTHS OF AGE AND AT A CONSTANT MARKET WEIGHT

Item	Treatment Group					
	Very Restricted 1	Restricted 2	Normal 3	High 4	Very High 5	EMS[a]
Eight Months of Age						
Length of Carcass, cm.	94.23[c]	93.62[c]	97.74[d]	98.22[d]	98.81[d]	5.212
Length of leg, cm.	60.60[c]	61.34[c]	63.55[d]	64.77[d]	64.44[d]	2.177
Depth of body, cm.	31.19[c]	31.95[c]	31.29[c]	33.02[d]	33.07[d]	1.165
Thickness of shoulder, cm.	14.07[c]	14.35[c,d]	15.01[d]	16.46[e]	16.84[e]	0.458
Thickness of round, cm.	16.26[c]	16.05[c]	17.27[d]	18.34[e]	18.31[e]	0.627
Ribeye area, $cm.^2$	33.23[c]	35.36[c]	37.42[c]	47.36[d]	47.74[d]	32.999
Fat cover (average), cm.	0.30[c]	0.33[c]	0.48[c,d]	0.71[d]	0.71[d]	0.044
Kidney fat wt., kg.[b]	0.89[c]	1.37[c,d]	1.59[d,f]	2.17[e]	1.89[e,f]	0.193
Constant Market Weight						
Length of carcass, cm.	115.77	115.72	114.81	114.50	117.70	4.579
Length of leg, cm.	75.87	74.90	75.61	74.80	75.79	3.080
Depth of body, cm.	39.55	40.39	40.56	39.57	39.34	2.448
Thickness of shoulder, cm.	22.27	22.40	22.55	22.66	22.48	1.083
Thickness of round, cm.	23.34	23.77	23.42	24.13	24.89	1.702
Ribeye area, $cm.^2$	70.13	72.00	74.13	70.13	69.75	35.138
Fat cover (average), cm.	2.44	1.85	2.23	2.23	1.90	0.243
Kidney fat wt., kg.[b]	4.13	4.39	4.50	3.86	4.09	0.762

[a]Error mean square

[b]Actual weight (side basis)

[c, d, e, f]Means on the same line bearing the same superscript do not differ significantly ($P < .05$).

greater amount of subcutaneous fat following a subsequent feeding period to a constant weight. The rate of subcutaneous fat deposition during the feedlot period tended to be greater for those animals on the lower levels of nutrition during early life. This is in agreement with results obtained by McMeekan (1940c), Meyer et al. (1965) and Palsson and Verges (1952b) using swine, cattle and sheep, respectively.

Skeletal measurements, i.e., length of carcass, leg and depth of body indicated, that, on the average, calves slaughtered at 8 months of age had already attained about 82 percent of their market weight scale. The range among group averages was from 79.7 percent for the very restricted calves to 85.3 percent of their final size for the high level calves. Thus, it appears that most of the skeletal development occurred early in the maturation process of the beef calves. The results indicate that bone development is not affected to any great extent by the nutritional treatment imposed during the early phase of postnatal growth. Confirmatory results were obtained by Guenther et al. (1965), McMeekan (1940c) and Palsson and Verges (1952a, b).

Effect of Nutritional Level on Carcass Composition

The effect of nutritional level imposed during early life on the amount of lean, fat and bone in ten standard wholesale cuts from the calves slaughtered at 8 months of age and at a constant market weight is presented in Figures 1, 2 and 3, respectively. The histograms in Figure 1 reveal that the lean content, of cuts from calves slaughtered at 8 months of age, progressively increased as the level of nutrition increased. Nevertheless, no statistically significant differences were observed in the lean content of cuts from animals slaughtered at a

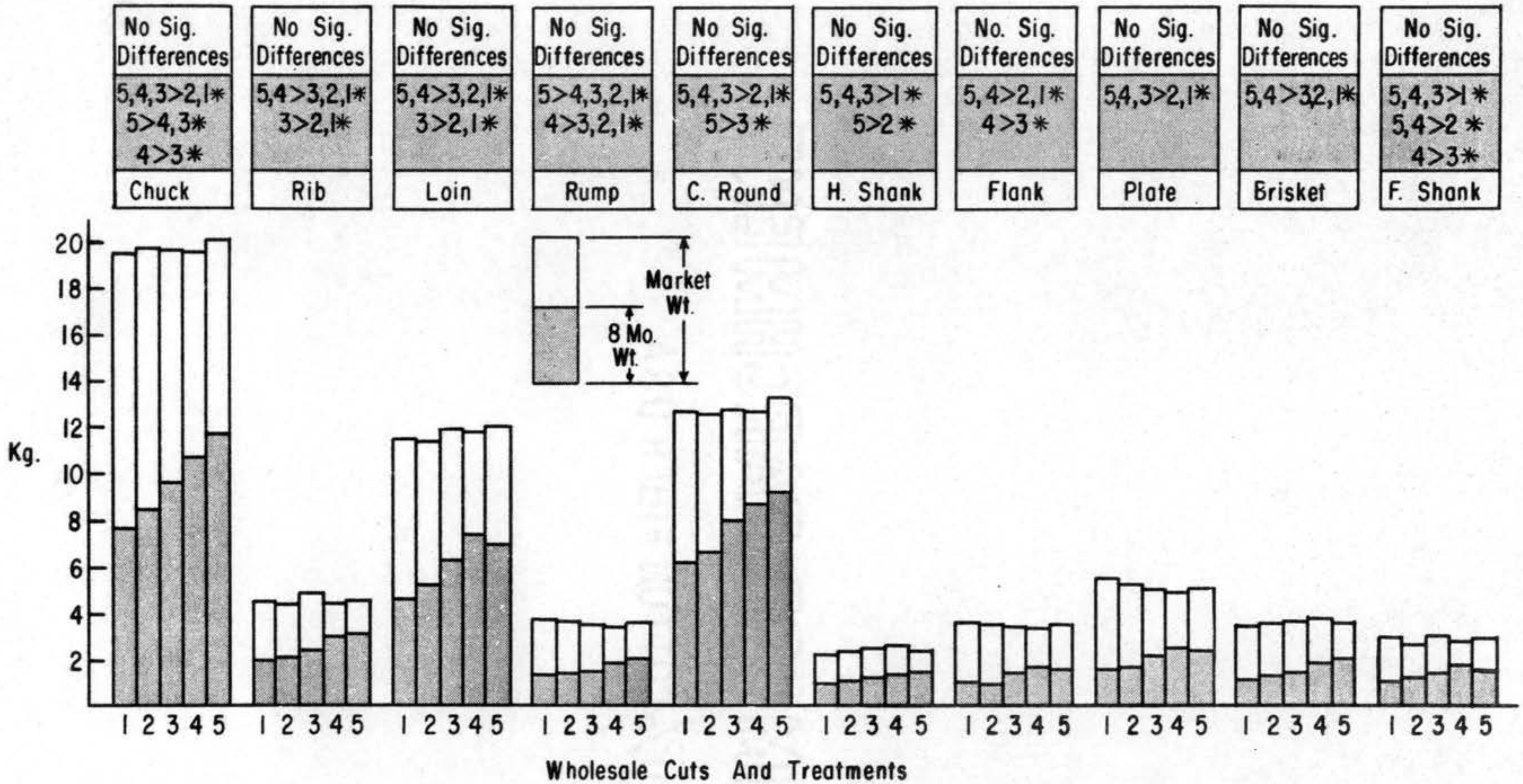

Figure 1. Effect of Nutritional Level Imposed From Birth to 8 Months of Age, on the Amount of Lean in Wholesale Cuts of Beef Calves Slaughtered at 8 Months and at a Constant Market Weight. Tests of significance were conducted at *$P < .05$ level. (Treatments, i.e., 1 = very restricted, 2 = restricted, 3 = normal, 4 = high, 5 = very high).

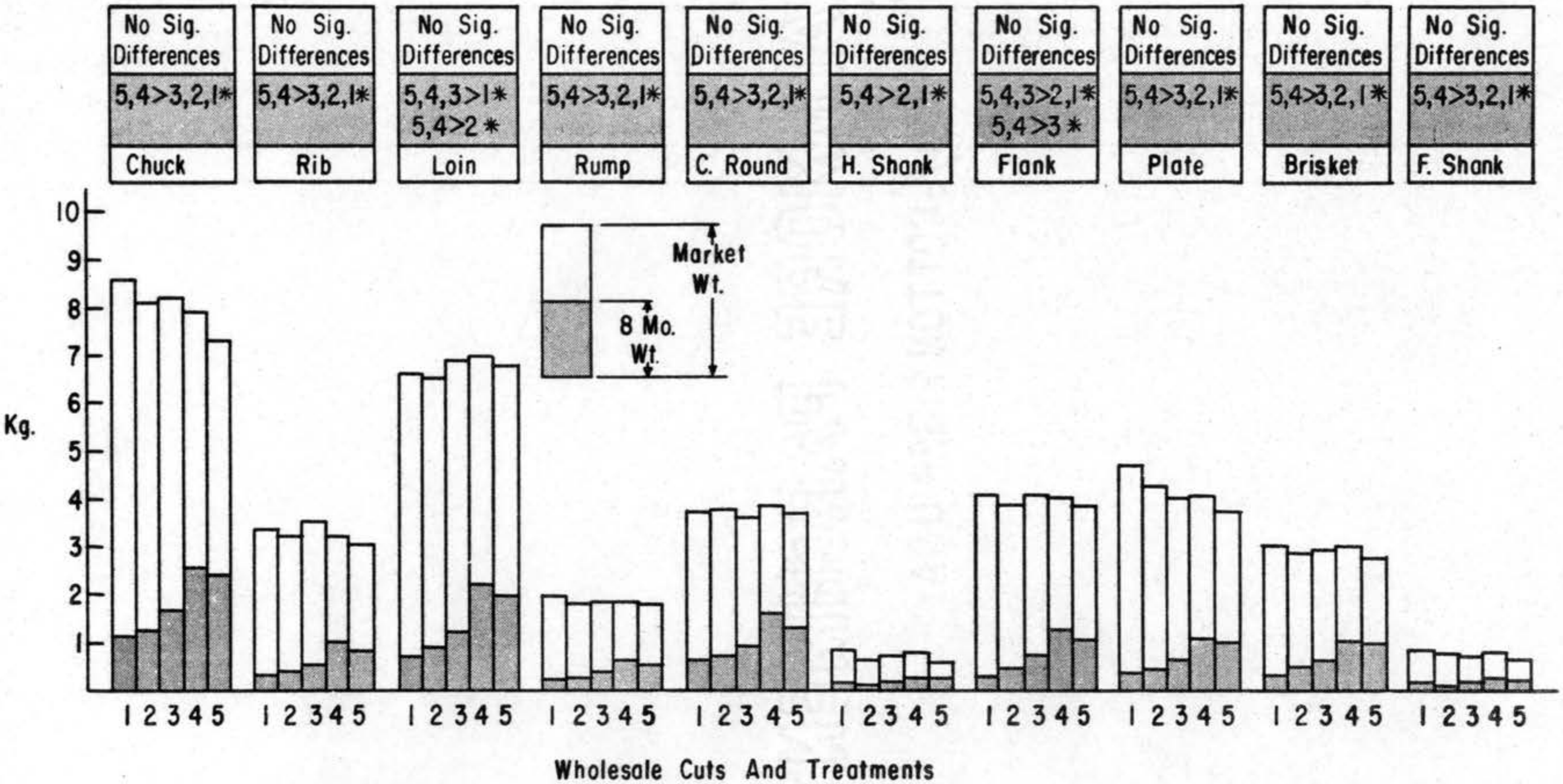

Figure 2. Effect of Nutritional Level Imposed From Birth to 8 Months of Age, on the Amount of Fat in Wholesale Cuts of Beef Calves Slaughtered at 8 Months and at a Constant Market Weight. Tests of significance were conducted at $^*P < .05$ level. (Treatments, i.e., 1 = very restricted, 2 = restricted, 3 = normal, 4 = high, 5 = very high).

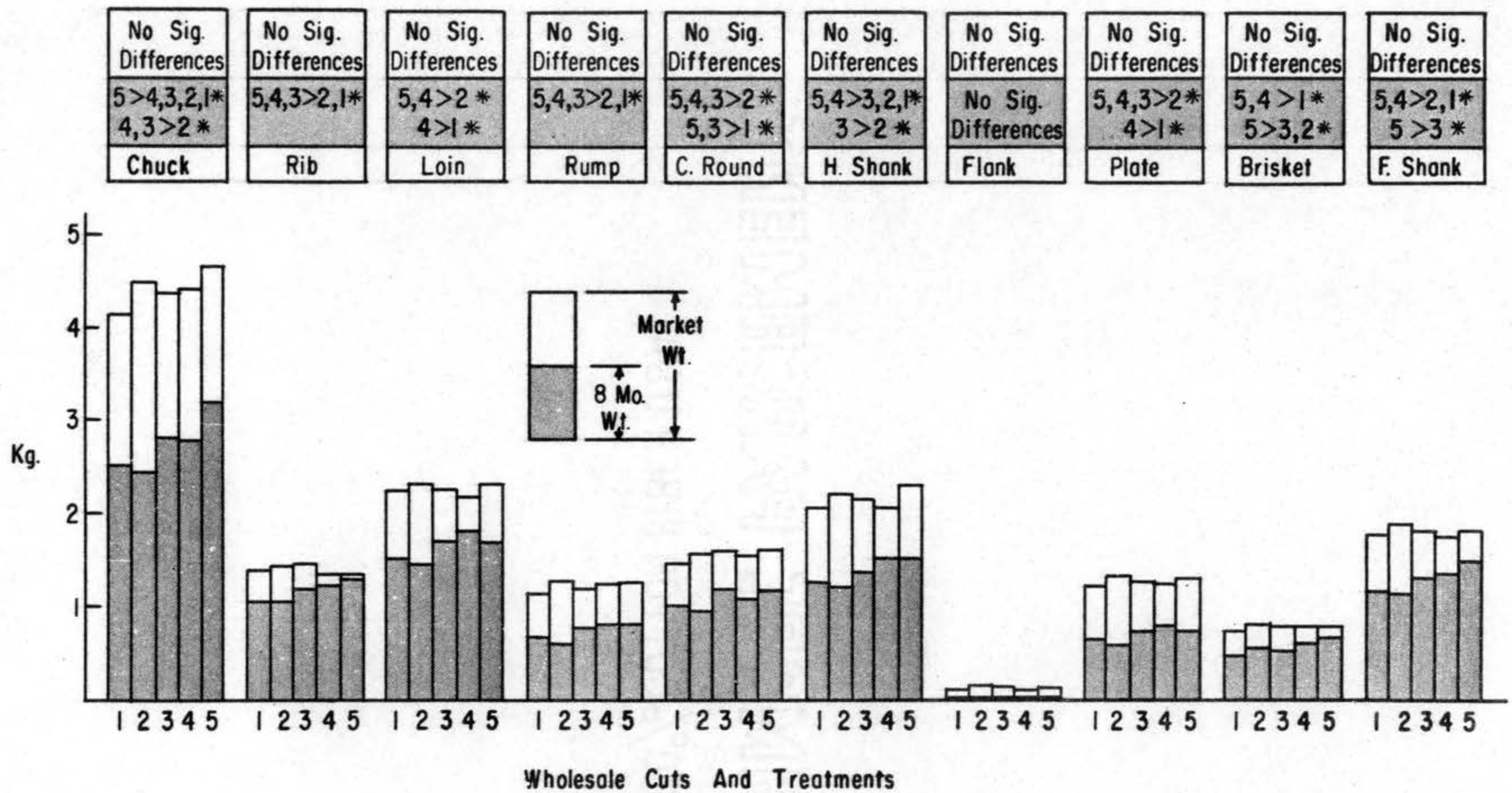

Figure 3. Effect of Nutritional Level Imposed From Birth to 8 Months of Age, on the Amount of Bone in Wholesale Cuts of Beef Calves Slaughtered at 8 Months and at a Constant Market Weight. Tests of significance were conducted at *P$<$.05 level. (Treatments, i.e., 1 = very restricted, 2 = restricted, 3 = normal, 4 = high, 5 = very high).

constant market weight. It can be noted, however, that the chuck, loin and cushion round of the calves on higher levels of nutrition during early life tended to contain the greatest amount of lean. No clear-cut trend was evident in the other cuts.

Results in Figure 2 show that the fat content, of cuts from calves slaughtered at 8 months, increased as the level of nutrition increased. Though large differences were observed at 8 months, no significant differences in fat content were obtained when animals were slaughtered at a constant weight. However, a trend toward decreased fat with higher levels of early life nutrition was evident in the chuck, foreshank, hind shank, flank, plate and brisket.

Bone development (Figure 3) followed a pattern similar to that observed for lean and fat in that the bone content, of cuts from calves slaughtered at 8 months, increased as nutritional level increased. At a constant market weight, differences observed in bone content of the wholesale cuts were not statistically significant. However, the bone content of the chuck, cushion round and hind shank tended to increase as the level of early life nutrition increased.

The effect of nutritional level imposed during early life on total carcass composition (side basis) at 8 months and at a constant market weight are presented in Table VII and shown graphically in Figure 4. Carcass composition, of animals slaughtered at 8 months, was significantly influenced by the level of nutrition imposed during early life. In comparing these results, it can be noted that as the level of nutrition decreased, the relative retardation of growth was greatest in fat tissue followed by lean and bone, respectively. Even though large treatment differences were obtained in the carcass composition of

TABLE VII

CARCASS COMPOSITION OF CALVES SLAUGHTERED AT EIGHT MONTHS OF AGE AND AT A CONSTANT MARKET WEIGHT[a,b]

Item	Treatment Group: Very Restricted 1	Restricted 2	Normal 3	High 4	Very High 5	EMS[c]
Eight Months of Age						
Lean, kg.	28.01[e]	30.63[e]	35.84[f]	41.04[g]	42.49[g]	7.480
Fat, kg.[d]	5.28[e]	6.55[e,f]	8.69[f]	14.09[g]	12.57[g]	5.293
Bone, kg.	10.29[e]	10.00[e]	11.62[f]	12.01[f,g]	12.59[g]	0.490
Protein, kg.	6.26[e]	6.78[e]	8.01[f]	9.25[g]	9.44[g]	0.411
Constant Market Weight						
Lean, kg.	69.71	69.21	70.34	69.39	70.97	6.394
Fat, kg.[d]	41.80	40.21	41.00	40.18	38.25	30.377
Bone, kg.	16.20	17.37	16.93	16.63	17.44	1.365
Protein, kg.	15.33	15.10	15.27	15.22	15.66	0.324

[a] Carcass composition determined by chemical analyses

[b] Right side only

[c] Error mean square

[d] Includes kidney fat

[e, f, g] Means on the same line bearing the same superscript do not differ significantly ($P < .05$).

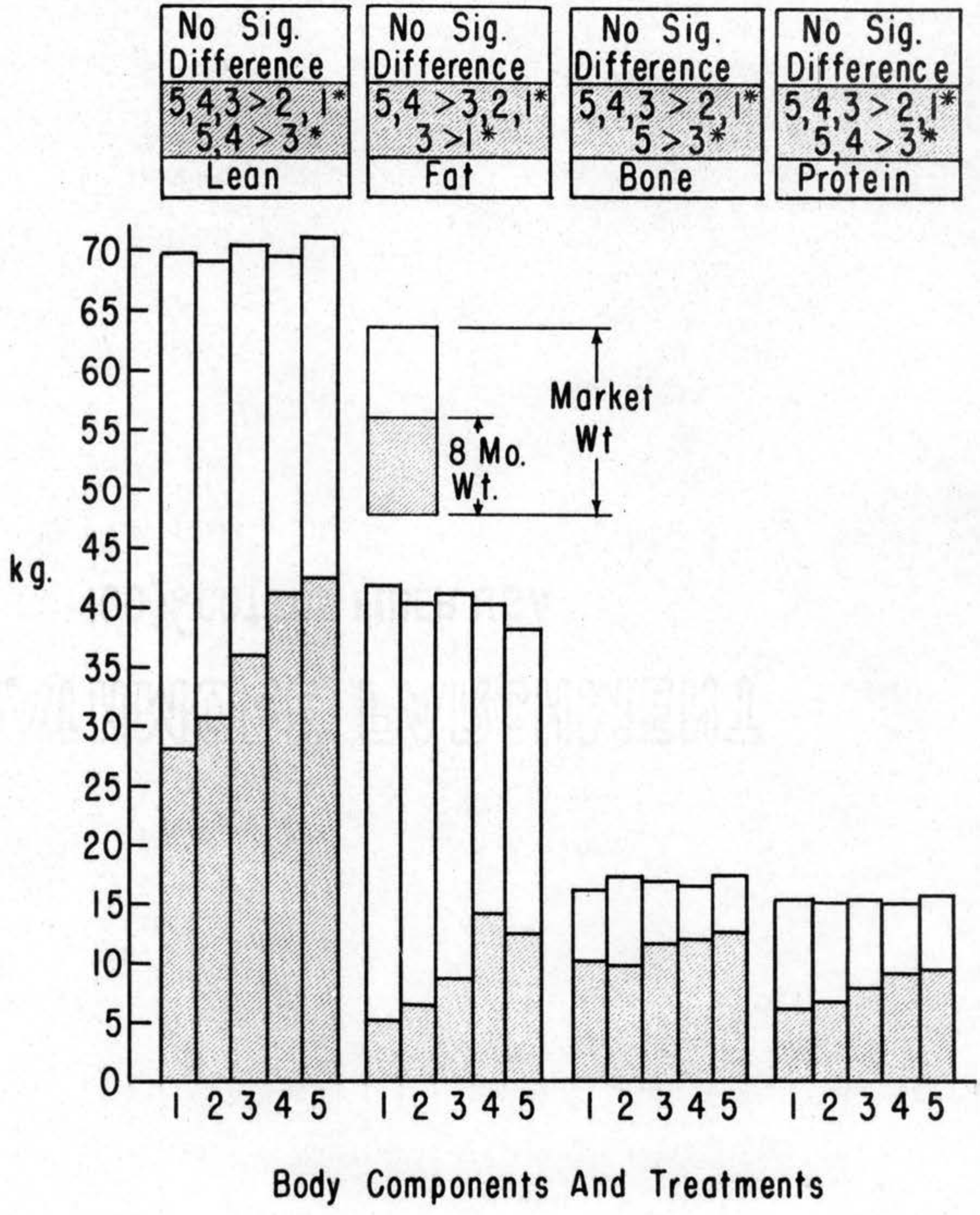

Figure 4. Effect of Nutritional Level Imposed From Birth to 8 Months of Age, on the Carcass Composition of Calves Slaughtered at 8 Months and at a Constant Market Weight. Tests of significance were conducted at *P<.05 level. (Treatments, i.e., 1 = very restricted, 2 = restricted, 3 = normal, 4 = high, 5 = very high).

animals slaughtered at 8 months, no significant differences could be obtained when animals were slaughtered following a feedlot period to a constant market weight. In comparing the relative growth of fat, lean and bone, during the feedlot period, it was observed that the greatest relative growth occurred in fat tissue followed by lean and bone, respectively. Inasmuch as lean and protein are highly related, the patterns exhibited by protein were similar to those observed for lean. Although animals on lower levels of nutrition during early life required a longer period of time to attain a constant market weight, it was noted that these animals exhibited a greater relative rate of lean and fat growth while in the feedlot than did calves on higher levels of early life nutrition. In general, as the level of nutrition increased during early life, carcasses tended to contain a greater percentage of lean and bone, with a lower percentage of fat.

These results are in agreement with those obtained by Wilson (1960) in goats, and Winchester and Ellis (1956) and Winchester and Howe (1955) in cattle. Other investigators (McMeekan 1940a, b, c; Palsson and Verges, 1952a, b) observed that carcasses from animals restricted early in life contained significantly less lean and bone with a greater percentage of fat than animals which were not restricted. The results obtained in this experiment followed a similar pattern, though not as pronounced. This was probably due to the fact that their restricted levels were more severe than those employed in this study. No readily apparent trends could be noted in the lean and bone fraction. However, animals subjected to higher levels of nutrition early in life tended to contain slightly less total carcass fat than those animals on the lower levels of nutrition.

SUMMARY

Sixty Hereford steer calves, from five groups of dams of similar genetic background, were used in this study. From birth to 8 months of age, each of the five groups of calves were subjected to one of the following nutritional levels; very restricted, restricted, normal, high and very high. A random sample of calves from each of the five groups was slaughtered at 8 months and the experimental data retained for subsequent comparisons. Remaining calves were then fed the same finishing ration until attaining a similar market weight of approximately 430 kilograms.

The results clearly indicate that there was a progressive increase in live weight and in total gain, to 8 months, with an increase in nutritional level. Upon slaughter at 8 months of age, it was observed that significant differences, favoring the higher level calves, were obtained in dressing percent, carcass grade and skeletal scale. In addition, the relative amounts of lean, fat and bone tissue produced were directly influenced by the level of nutrition imposed from birth to 8 months. As the level of nutrition decreased, significantly less lean, fat and bone were produced. The relative retardation of growth was greatest in fat tissue, followed by lean and bone, respectively.

In order to reach a constant market weight, more feedlot gain was required of the calves subjected to the lower levels of nutrition from birth to 8 months of age. Average daily feedlot gains of the calves

from the various treatment groups were not significantly different. Therefore, calves subjected to the lower planes of nutrition during early life required more days in the feedlot to attain the desired constant market weight.

Even though significant treatment differences were observed in the carcass merit, skeletal scale and composition of animals slaughtered at 8 months of age, no significant differences were noted when animals were slaughtered following a feedlot period to a constant market weight. Though statistically nonsignificant, carcasses from animals slaughtered at a constant weight tended to contain a greater percentage of lean and bone, with a lower percentage of fat, as the level of nutrition increased during early life.

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APPENDIX

TABLE VIII

REFERENCE POINTS FOR CARCASS MEASUREMENTS

Measurement	Reference Points
Carcass Length	Distance from anterior edge of the first rib, adjacent to the vertebrae, to the anterior edge of the aitchbone
Length of Leg	Distance from anterior edge of the aitchbone to the furthest extremity of the round
Length of Loin	Distance from anterior edge of the aitchbone to the center of the eighth vertebra, counting anteriorly from the last lumbar vertebra
Depth of Body	Distance from the dorsal edge of the spinal canal at the fifth thoracic vertebra to the ventral edge of the sternum, on a line parallel to the floor
Width of Shoulder	Horizontal distance from center of first thoracic vertebra to the exterior surface, perpendicular to the dorsal-ventral midline of the carcass
Width of Round	Horizontal distance from center of aitchbone to the exterior surface, perpendicular to the dorsal ventral midline of the carcass

VITA

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