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Title: THE EFFECT OF CERTAIN PRODUCTION FACTORS AND RATE OF GAIN ON CARCASS CHARACTERISTICS OF BEEF STEERS

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The purpose of the present study was to determine the association of initial weight, average daily gain, days on feed, percent total digestible nutrients (TDN) and percent digestible protein in the ration with USDA carcass grade, marbling score, conformation score, back fat thickness and area of longissimus dorsi of beef steers.

The source of the data was 1098 beef steers from eight experiments conducted by members of Oregon State University faculty from 1962 through 1966.

The statistical analyses provided simple correlation coefficients between the production factors and carcass characteristics. Also obtained were the multiple regression prediction equations of the carcass characteristics using the production factors as the independent variables.

Initial weight was significantly ($P < .01$) correlated with back

fat thickness (-0. 155), conformation score (-0. 439) and area of longissimus dorsi (0. 394). Days on feed was significantly (P <. 01) correlated with carcass grade (0. 503), marbling score (0. 346), conformation score (0. 413), back fat thickness (0. 149) and area of longissimus dorsi (-0. 261). Average daily gain was significantly (P <. 01) correlated with carcass grade (0. 145), marbling score (0. 121), conformation score (0. 25), back fat thickness (0. 179) and area of longissimus dorsi (0. 188). Percent digestible protein in the ration was significantly (P <. 01) correlated with carcass grade (0. 308), marbling score (0. 347), and back fat thickness (0. 251).

Multiple regression equations using initial weight, average daily gain, days on feed and percent digestible protein as independent variables accounted for 52. 9%, 32% and 30. 9% of the variation in carcass grade, marbling score and conformation score, respectively. The multiple regression equation using initial weight, average daily gain and percent digestible protein as independent variables accounted for 14. 8% of the variation in back fat thickness. The multiple regression equation using initial weight, days on feed and percent total digestible nutrients as independent variables accounted for 21. 3% of the variation in area of longissimus dorsi.

The Effect of Certain Production Factors and Rate of Gain on Carcass Characteristics of Beef Steers

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INTRODUCTION

The need today is for beef steers that can reach a slaughter weight rapidly and economically. When feeding a market steer to a constant slaughter weight the more rapid the gain the fewer number of days the steer will be on feed. This results in greater feed efficiency and lower production costs.

Cartwright et al. (1958) and Knox (1957) stated that rapid gain is advantageous. The rapid gaining animal reaches a given weight sooner and is leaner than a slow gainer. In a study at Missouri Agricultural Experiment Station (1967), a correlation coefficient of -0.26 between fat thickness and rate of gain was obtained. The correlation suggests faster gaining cattle, when fed to a constant weight, have more lean and less fat.

Suess et al. (1966) found a positive relationship between semimembranosus (SM) tenderness and daily gain ($P < .05$). This suggests that animals which grow faster are more tender. However, tenderness of the longissimus dorsi (LD) was not affected by daily gain in the same study by Suess et al. (1966).

Suess et al. (1966) also studied another important variable of overall beef palatability--juiciness. The resulting simple correlation coefficients indicated that neither SM nor LD juiciness is related to daily gain in beef steers.

Daily rate of gain is an important characteristic in selection indexes of beef cattle because of its high heritability. Heritability figures for rate of gain in the feedlot as reported by several researchers are presented in Table 1.

Table 1. Heritability estimates for rate of gain in the feedlot.

Method of Estimation	Heritability %	Investigators
Intra-Sire Correlation	99%	Knapp & Nordskog (1946)
Sire-Progeny Regression	46	Knapp & Nordskog (1946)
Half-Sib Correlation	65	Knapp & Clark (1950)
Sire-Offspring Regression	77	Knapp & Clark (1950)
Sire-Offspring Regression	54	Warwick & Cartwright (1955)
Half-Sib Correlation	38	Warwick & Cartwright (1955)
Half-Sib Correlation	60	Shelby _et al_. (1955)
Half-Sib Correlation	70	Blackwell _et al_. (1957)
Half-Sib Correlation	57	Lickley _et al_. (1960)
Half-Sib Correlation	40	Swiger (1961a)
Half-Sib Correlation	76	Blackwell _et al_. (1962)
Half-Sib Correlation	88	Christians _et al_. (1962)
Half-Sib Correlation	48	Shelby _et al_. (1963)

Bogart (1959) feels that heritability of daily rate of gain can also be high in grass fed steers if they are allowed enough feed to express their genetic capabilities. Francoise et al. (1973) using pasture-reared beef cattle obtained a heritability figure of 44% for rate of gain. This figure compares favorably with the heritability figures in Table 1.

Woodward et al. (1954b) stated that any associations between preslaughter and postslaughter evaluations are of particular importance in a selection program in beef cattle because of slow generation intervals, low reproductive rates and costs of experimentation.

The purpose of the present study was to determine the associations of certain production factors and rate of gain with five selected carcass characteristics.

LITERATURE REVIEW

Production Factors

Rate of gain has a high heritability in beef steers from feedlots where they have the opportunity to express their genetic potential (Table 1). Warwick and Cartwright (1955) stated that the expected heritability of rate of gain is approximately 54 percent.

If beef steers are fed to a constant slaughter weight, those with rapid gains reduce production costs. The reductions result from reduced days on feed and the increased feed efficiency (Bogart, 1959). A relatively close positive association between rate of gain and feed efficiency has been demonstrated by many workers: Winters and McMahon (1933), Black and Knapp (1936), Bogart and Blackwell (1950), Blackwell (1951), Kolhi et al. (1951), Roubicek et al. (1951), Yao et al. (1953), Pierce et al. (1954), Woodward et al. (1954a), McDonald and Bogart (1955), Bogart et al. (1956), Lickley et al. (1960), Ampy and Bogart (1962), Henrickson et al. (1965), Landers et al. (1967) and Bogart and England (1971). The ability of the beef animal to convert feed efficiently is important because about 80 percent of the cost in slaughter beef production is for feed (Bogart, 1959).

The previously determined correlation coefficients between rate of gain and the five selected carcass characteristics used in the present study are presented in Table 2.

Table 2. Correlation coefficients[1] between rate of gain and selected carcass characteristics.

Investigators	Carcass grade	Marble score	Conformation score	Back fat thickness	Area of *longissimus dorsi*
Hankins & Burk (1938)	0.37*	0.38*		0.38*	
Cook *et al.* (1951)	0.17*				
Cook *et al.* (1951)	0.31*				
Durham & Knox (1953)	0.349**				
Woodward *et al.* (1954a)	0.43**			0.57**	0.29**
Woodward *et al.* (1959)	0.27**			0.29**	0.15*
Harwin *et al.* (1961)		0.20*			
Backwell *et al.* (1962)	0.43**				
Shelby *et al.* (1963)	0.37**			0.30**	0.36**
Cundiff *et al.* (1964)	0.16*			0.31**	
Cundiff *et al.* (1972)		0.17**		0.38**	
Crouse *et al.* (1974)	0.02	0.05	0.27**		

[1] *P <.05, ** P <.01.

The correlation coefficients between rate of gain and carcass grade presented in Table 2 indicate there is a tendency for a rapid gaining steer to grade higher than a slow gainer. Crouse et al. (1974) felt the correlation obtained between rate of gain and carcass grade (.02) was low because of the heterogeneous population used in the study.

The researchers (Hankins & Burk, 1938; Harwin et al., 1961; Cundiff et al., 1972; and Crouse et al., 1974) concluded that there is little relationship between marbling score and rate of gain.

When beef steers are fed the same number of days before removal for slaughter there is a slight positive relationship between rate of gain and back fat thickness (Table 2). The Missouri Agricultural Experiment Station (1967) reported a correlation coefficient between rate of gain and back fat thickness of -0.26, suggesting that rapid gaining beef steers fed to a constant slaughter weight tend to have more lean meat and less fat. Woodward et al. (1954a) recorded the same conclusion.

The correlation coefficients between rate of gain and area of longissimus dorsi presented in Table 2 suggest that a rapid gaining beef steer can have a slightly larger longissimus dorsi than a slow gaining steer.

Crouse et al. (1974) felt conformation score, like other carcass characteristics, has a tendency to improve with increased rate of gain.

The results of a study reported in Kansas Ag. Exp. Sta. Bull. 448 (1962) are summarized in Table 3. The purpose of the experiment was to determine the effect of the number of days on feed on marbling score. The results indicate that with each increase in days on feed, marbling score increases, daily rate of gain decreases and USDA carcass grade increases.

Table 3. Effect of days on feed on performance and carcass characteristics of yearling steers.[1]

Days on feed	Initial weight (lbs.)	Average daily gain (lbs.)	Final weight	USDA grade[2]	Marbling score[3]
88	842	3.28	1131	14	7.7
165	842	3.07	1350	15.5	6.3
229	842	2.79	1481	17	4.6

[1] Twelve steers in each experimental period.

[2] Average good = 14, average choice = 17.

[3] Slightly abundant, 4; moderate, 5; modest, 6; small amount, 7; slight amount, 8.

Zinn et al. (1970) studied the effect of number of days on feed on growth characteristics and carcass grade factors. The results are summarized in Table 4.

Zinn et al. (1970) observed average daily gain increased with advancing days on feed, up to 180 days. However, after 120 days on feed there was no significant increase in average daily gain. Up to

150 days on feed, conformation score increased, but after 150 days the conformation score changed little. Zinn et al. (1970) felt the data indicated that score for marbling is not a straight line function, but proceeds in a stepwise manner. The steps Zinn et al. (1970) suggested were from 0 to 30 days, 90 to 120 days, 180 to 210 days and 210 to 240 days on feed. The USDA carcass grade also increased with increasing days on feed and presented a stepwise pattern similar to marbling score.

Table 4. Effect of days on feed on feedlot performance and carcass grade factors of steers.[1]

Days on feed	Initial weight (lbs.)	Average daily gain (lbs.)	Final weight (lbs.)	USDA grade[2]	Marble score[3]	Conformation score[2]
0	468	0.00	468	14.4	1.3	14.2
30	473	1.60	518	15 0	2.5	16.0
60	529	1.70	581	14.5	2.3	14.6
90	460	1.90	620	15.2	2.8	15.6
120	477	2.02	712	17.2	4.4	17.3
150	479	2.02	773	16.8	3.4	18.6
180	487	2.22	874	17.1	4.0	18.3
210	464	2.16	906	19.3	5.0	19.8
240	484	1.96	943	19.1	6.1	19.1
270	471	1.96	975	19.1	5.6	19.4

[1] Ten steers in each experimental period.

[2] Low standard = 13, low good = 16, low choice = 19.

[3] Practically devoid = 2, traces = 3, slight = 4, small = 5.

Ralston et al. (1970) made a study to determine how long a steer should be fed a finishing ration; the results are summarized in Table 5.

Table 5. The effect of time on feed on feedlot performance and carcass characteristics.

Days on feed	Initial weight	Average daily gain	Final weight	Marble score[1]	USDA grade[2]	Back fat	Area of longissimus dorsi
Light Steers	lbs.	lbs.	lbs.			in.	sq. in.
56	638	3. 55	837	6. 9	13. 2	. 20	10. 7
84	637	3 72	950	11. 4	15. 4	. 33	10. 9
112	636	3. 02	974	12. 0	16. 2	. 35	11. 5
140	634	3 09	1, 066	17. 0	17. 5	. 48	11. 8
168	636	3. 00	1, 131	17. 1	17. 0	. 54	12. 2
Heavy Steers							
56	811	3. 67	1, 017	9. 6	14. 8	. 32	12. 0
84	818	3. 64	1, 123	11. 9	16. 0	. 38	11. 9
112	820	3. 39	1, 200	12. 8	16. 3	. 46	13. 2
140	816	3. 30	1, 279	16. 2	17. 5	. 58	13. 4
168	817	3. 21	1, 359	17 1	16. 9	. 67	12. 6

[1] Traces = 6, slight = 9, small = 12, modest = 15.

[2] Good = 14, choice = 17.

As the number of days on feed increased, so did marbling score and back fat. The USDA carcass grade did not advance as dramatically, because as carcass maturity increases the marbling requirements of carcass grade also increase. The area of longissimus dorsi enlarged as the number of days on feed increased with the light steers. The heavy steers presented no trends in the area of *longissimus dorsi*. Ralston *et al.* (1970) presented two possible reasons why average daily gain decreased after 84 days on feed. First, the longer a steer is on a high energy diet, the less feed it consumes when considered as a percentage of its body weight or per unit of metabolically effective size (weight$^{.75}$). Second, the longer a steer is fed the fatter it becomes, and the conversion of its diet to fat is less efficient on a weight basis.

Current studies (Kansas Agric. Exp. Sta. Bull. 448, 1962; Zinn *et al.*, 1970; and Ralston *et al.*, 1970) support the significant ($P < .05$) correlation coefficients obtained by Hankins and Burk (1938) of days on feed with carcass grade (0.48), back fat thickness (0.44) and marbling score (0.40).

Ralston *et al.* (1967) using beef steers with initial weights of 450, 550, 680, 750 and 850 pounds studied the effect of initial weight on the finishing performance of beef steers. The steers placed on the common finishing ration at 450 pounds had significantly ($P < .01$) greater rate of gain and back fat thickness than animals placed on the finishing rations at the heavier weights. USDA carcass grade, marbling score and area of *longissimus dorsi* were similar regardless of the weight of the steers when placed on the finishing ration.

Ralston *et al.* (1966a), Haskins *et al.* (1967), Epley *et al.* (1971), Braman *et al.* (1973) and Greathouse *et al.* (1974) concluded that the percentge of crude or digestible protein in a finishing ration has no effect on a beef steer's carcass characteristics. Thornton et al. (1974) found that a protein supplement at increased levels in a finishing ration for beef steers can result in increased back fat thickness, marbling score and carcass grade.

During the present study no information comparing total digestible nutrients and carcass characteristics was found in the literature reviewed.

Carcass Characteristics

The five carcass characteristics (USDA carcass grade, marbling score, conformation score, back fat thickness and area of *longissimus dorsi*) selected for investigation of their relationship to rate of gain were chosen because they are used by the USDA in quality and yield grading of beef carcasses. The USDA (1965) states that the quality grade of beef carcass is based on separate evaluations of two general considerations: (1) the quality or the palatability-indicating characteristics of the lean and (2) the conformation of the carcass.

The USDA has put into effect changes in the official USDA standards for grades of carcass beef to include mandatory yield grading and the elimination of carcass conformation score. Dual grading evaluates separately the two major factors affecting acceptability and value in beef carcasses. The two factors are, eating quality and cutability. Cutability is defined as: "The indicated percent of trimmed, boneless, major retail cuts to be derived from the carcass."[1]

Hoke and Hedrick (1969) stated that the USDA quality grades, although not infallible, are the only practical guidelines available to the institutional purchaser and consumer today. Bray (1963) stated that USDA carcass grade is one of the simplest and most used research tools for evaluating beef carcasses. Also, it is one of the most meaningless research tools used in meat animal research. The final carcass grade is determined by a balance of quantitative and qualitative evaluations. The balancing of the two factors masks completely the influence of each of these major variables and gives the researchers only a limited description of the carcass characteristics associated with the carcass value. So Bray (1963) favors dual grading because it would more definitively describe carcass characteristics.

Maturity plays an important role in the final carcass grade determination. But all of the steers in the present study had a maturity of A or less, making maturity almost a constant. Therefore, no review of the literature was done on maturity.

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[1] USDA. 1965. Official United States standards for grades of carcass beef. Title 7, Ch. 1, Pt. 53, Sections 53. 102-53. 106. June. U. S. C. & M. S.

USDA carcass grade is made up of various factors: conformation, maturity, marbling, color, firmness and texture of lean. The correlations found in the literature of USDA carcass grade with marbling score, conformation score, back fat thickness and area of longissimus dorsi are presented in Table 6.

Table 6. Correlation coefficients between USDA carcass grade and carcass characteristics.

Investigators	Marbling score	Conformation score	Back fat thickness	Area of longissimus dorsi
Hankins & Burk (1938)	.90*		.95*	
Woodward et al. (1954a)			.54**	.23**
Magee et al. (1958)				.20
Kidwell et al. (1959)	.89**	.35**		
Matthews & Bennett (1962)	.93**		.68**	.10
	.88**		.73**	.21
Hoornbeek et al. (1962)	.66**	.49**		
Shelby et al. (1963)			.44**	.22**
Cundiff et al. (1964)			.33**	.05
Brackelsberg et al.	.96**		.34**	-.06
Campion & Crouse (1975)	.85**			

*Significant at the 5% level.

**Significant at the 1% level.

Marbling score is by far the most important single factor in determining final quality grade (Hankins & Burk, 1938; Kidwell et al., 1959; Matthews & Bennett, 1962; Hoornbeek et al., 1962; Brackelsberg et al., 1971; and Campion & Crouse, 1975). Matthews and Bennett (1962) found marbling score accounted for 77 and 86% of the variation in USDA carcass grade in 1960 and 1961 experiments, respectively, as determined by coefficients of determination (r^2). Marbling score accounted for 79% of the variation in USDA carcass grade in an experiment by Kidwell et al. (1959).

Kidwell et al. (1959) and Campion and Crouse (1975) stated that conformation contributes very little to the USDA carcass grade. Kennick et al. (1969) found a significant ($P < .01$) negative correlation (-0. 502) between conformation score and percent trimmed retail cuts in carcasses of young beef steers fed to a low choice grade. Campion and Crouse (1975) support removal of conformation score from carcass grading as proposed in the regulation changes of the official USDA standards for grades of carcass beef.

Back fat thickness and area of the longissimus dorsi are not used in determining quality grade, but some researchers did determine their correlation with carcass grade; therefore, their results are included. Hankins & Burk (1938), Woodward et al. (1954a), Matthews & Bennett (1962), Shelby et al. (1963), Cundiff et al. (1964) and Brackelsberg et al. (1971) observed a positive relationship between carcass grade and back fat thickness. Hankins and Burk (1938), Woodward et al. (1954a) and McBee and Bowers (1969) found that back fat thickness is highly correlated with marbling score. They concluded that back fat thickness could be useful in predicting the degree of marbling in a beef carcass.

The correlation coefficients between USDA carcass grade and area of the longissimus dorsi presented in Table 6 are small. Two explanations were presented in the literature. First, it is possible that fat measurements receive too much consideration in carcass grading (Woodward et al., 1954b). Second, McBee and Bowers (1969) found that correlations of carcass grade with back fat thickness and area of the longissimus dorsi declined as carcass weight increased. The changes were attributed to the relative rate of muscle and fat deposition as carcass weight increased (Callow, 1948).

> Quality of the lean is evaluated by considering its marbling and firmness as observed in a cut surface in relation to the apparent maturity of the animal from which the carcass was produced. The maturity of the carcass is determined by evaluating the size, shape, and ossification of the bones and cartilages--especially the split chine bones--and the color and texture of the lean flesh. The marbling and other lean flesh characteristics specified for the various grades are based on their appearance in the longissimus dorsi of properly chilled carcasses that are ribbed between the 12th and 13th ribs. [2]

Marbling is the presence of fat in tiny flecks within the muscle. The percentage of ether extract within a muscle is a fair objective measure of marbling. The following researchers observed significant ($P < .01$) correlations between ether extract and marbling of: 0.92 (Walter et al., 1965), 0.92 (Coll et al., 1965), 0.91 (McBee and Wiles, 1967) and 0.77 (Breidenstein et al., 1968). The

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[2]USDA. 1965. Official United States standards for grades of carcass beef. Title 7, Ch. 1, Pt. 53, Sections 53.102-53.106. June. U.S.C. & M.S.

disadvantage of ether extract is that it also measures: (1) Fat deposits along seams of heavy connective tissue, (2) the deposits too small to be seen when estimating marbling, and (3) small amounts of ether soluble substances which are not true fats.

Prior to discussing the work pertaining to marbling and palatability (eating quality of beef), it seems advantageous to mention some of the other factors that also have some influence on palatability. Blumer (1963) composed the following list of possible influencing variables: 1) breeding, 2) age of animal, 3) feeding treatments, 4) meat aging effects, and 5) cooking procedures. Pearson (1966) added another variable to consider in palatability--diversity in consumer demands. The factors that contribute to palatability include optimum tenderness combined with juiciness, aroma, flavor and texture.

The effect of marbling on beef palatability, specifically tenderness, has been well covered in the literature with wide differences of opinion.

The researchers who feel that marbling score has no significant effect on tenderness are: Walter et al. (1965), Romans et al. (1965a), Suess et al. (1966), Breidenstein et al. (1968), and Parrish et al. (1973). Those observing significant ($P < .01$) positive correlations between marbling score and tenderness are: Wellington et al. (1959), Alsmeyer et al. (1959) and Campion et al. (1975). The correlation coefficients obtained by these latter researchers were all small. Cover et al. (1956), Tuma et al. (1962), Goll et al. (1965), Field et al. (1966), McBee and Wiles (1967), Smith et al. (1969) and Juillerat et al. (1971) found that an increase in marbling score can result in increased tenderness. Their results showed low positive relationships or nonsignificant relationships. Cover et al. (1958), Palmer et al. (1958), Alsmeyer et al. (1959), Wellington et al. (1959), Blumer (1963) and Romans et al. (1965a) found that marbling accounts for 10%, 11%, 6.9%, 7%, 5% and 5%, respectively, of the variation in tenderness.

Juiciness refers to "mouth feel" during the chewing of a bite of meat (Pearson, 1966). Juiciness may be evaluated either qualitatively or quantitatively. However, it is probably not possible to separate quality of juice from flavor of meat by taste perception. In fact, Weir (1960) reported that the sensation of juiciness in cooked meat is closely associated with the juices being released more quickly in the more tender meat. Breidenstein et al. (1968) feels that even though tenderness is the most important palatability characteristic, other factors such as juiciness and flavor can easily influence the sensation of tenderness. Evidence for the relationship of marbling and juiciness as evaluated by a taste panel has been observed (Cover et al., 1956; Wellington et al., 1959; Doty et al., 1961; Field et al., 1966; Romans et al., 1965b; Juillerat et al., 1971; and Campion et al., 1975).

From the literature there are many views as to the importance of marbling in quality grading. Bray (1963) feels that since no researcher has found a significant negative relationship between marbling and palatability, marbling will continue to be an important characteristic in quality grading.

Conformation is included in the USDA beef grade standards (1965) because "superior conformation implies a high proportion of meat to bone and a high proportion of the weight of the carcass or cut in the more valuable parts."[3] This trait is measured subjectively and is dependent upon muscle thickness, depth and length and, to a variable extent, upon subcutaneous and intermuscular fat deposits. Conformation as described in the grade standards is an estimate of muscle shape and thickness.

The conclusion reached by researchers (Butler, 1957; Coll et al., 1961; Ramsey et al., 1962; Tyler et al., 1964; Martin et al., 1966; Abraham et al., 1968; Kennick et al., 1969; Kauffman et al., 1973; and Fredeen et al., 1974) is that conformation as measured subjectively today is not a significant factor in determining cut-out value of beef carcasses. Campion et al. (1975) support the removal of conformation score from carcass grading as recently proposed

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[3]USDA. 1965. Official United States standards for grades of carcass beef. Title 7, Ch. 1, Pt. 53, Sections 53.102-53.106. June. U.S.C. & M.S.

by the USDA. In its place will be a cutability figure for the quantitative evaluation of a beef carcass.

Murphey _et al_. (1960), Bray (1963), Fitzhugh _et al_. (1965), Abraham _et al_. (1968), Kennick _et al_. (1969), Epley _et al_. (1970) and Martin _et al_. (1970) stated that the use of the cutability figure has the advantage of measuring the salable portion of the carcass and can rather accurately reflect quantitative differences in beef carcasses. The four carcass characteristics used to determine the cutability figure are: (1) the amount of external fat, (2) the amount of kidney, pelvic and heart fat, (3) the area of _longissimus dorsi_ and (4) the carcass weight. Back fat thickness and area of _longissimus dorsi_ were the only variables from the cutability figure available in the data of the present study to evaluate with the selected production factors.

The use of the area of _longissimus dorsi_ in the cutability figure was supported by Crown and Damon (1960), Cole _et al_. (1960), Murphey _et al_. (1960), Ramsey _et al_. (1962), Hedrick _et al_. (1965), DuBose _et al_. (1967), Busch _et al_. (1968), Abraham _et al_. (1968), Epley _et al_. (1970) and Martin _et al_. (1970).

The importance of including back fat thickness in the cutability equation was supported by Ramsey _et al_. (1962), Fitzhugh _et al_. (1965), Hedrick _et al_. (1965), Abraham _et al_. (1968), Epley _et al_. (1970) and Crouse _et al_. (1974).

DATA SOURCES

The data needed for the present study to determine the effect of the selected production factors and rate of gain on USDA carcass grade, marbling score, conformation score, back fat thickness and area of longissimus dorsi came from eight experiments conducted by members of the Oregon State University faculty. Table 7 contains a list of the researchers who conducted the experiments, their titles and the publications where the results appeared. The variables used from each experiment for the present study are listed in Table 8. A discussion of the purpose, procedures and results of each experiment used for the present study follows.

Experiment 1 was conducted to study the effect of fiber, from various sources and of varying physical states, on steer performance and carcass characteristics. Five trials were conducted during the experiment, but only the third trial provided usable variables for the parent study. In trial 3, 108 steers averaging 761 pounds were randomly allotted to six treatments. The treatments and performance results are listed in Table 9. The high concentrate ration was 85% steam-rolled barley and 15% beet pulp. Two treatments compared a protein supplement based on dry cull peas (OSU) with a recommended protein supplement (Commercial). The treatments varied as to the roughage fed. The trial was terminated at 110 days

Table 7. Researchers of the eight selected experiments.

Experiment number	Researchers	Year	Title	Publication
Experiment 1	Ralston, A. T., D. C. Church, W. H. Kennick, N. O. Taylor and E. N. Hoffman	1962	The effect of "high" concentrate diets upon performance	Proc. West. Sec. An. Sci. XLII
Experiment 2	Ralston, A. T., W. H. Kennick and N. O. Taylor	1964	Effect of barley, corn and/or wheat rations with intraruminal injections of Vitamin A on performance and carcass characteristics of yearling steers	Proc. West. Sec. An. Sci. LIII
Experiment 3	Ralston, A. T. and N. O. Taylor	1965a	The effect of a wheat gluten supplement in a steer finishing ration comprised of varying levels of wheat	Ore. Ag. Exp. Sta. Spec. Rpt. 201
Experiment 4	Ralston, A. T., W. H. Kennick and T. P. Davidson	1965b	The response of beef cattle to varying levels of fat and stilbestrol implants with a wheat ration	J. Animal Sci. 24:599 (Abstr.)
Experiment 5	Ralston, A. T., N. O. Taylor and W. H. Kennick	1966b	The effect of feed grain preparation upon feedlot performance and carcass characteristics of steers	Ore. Ag. Exp. Sta. Spec. Rpt 221
Experiment 6	Ralston, A. T., W. H. Kennick and N. O. Taylor	1966c	The effect of choline chloride, urea and roughage fed at varying levels upon feedlot performance and carcass characteristics of steers	Ore. Ag. Exp. Sta. Spec. Rpt. 228
Experiment 7	Ralston, A. T., W. H. Kennick, T. P. Davidson and K. E. Rowe	1966d	Effect of prefinishing treatment upon finishing performance and carcass characteristics of beef cattle	J. Animal Sci. 25:29
Experiment 8	Ralston, A. T., D. C. Church, T. P. Davidson and W. H. Kennick	1966a	Effect of varying levels of protein, energy and injectable iron upon steer performance and carcass characteristics	J. Animal Sci. 25:595 (Abstr.)

Table 8. Variables used from the eight experiments.

Experiment	Initial weight	Average daily gain	Days on feed	% TDN[1]	% DP[1]	Marble score	USDA carcass grade	Back fat thickness	Area of *longissimus dorsi*	Conformation score
Experiment 1	X	X	X	X	X	X	X	X		X
Experiment 2	X	X	X	X	X	X	X	X		X
Experiment 3	X	X	X	X	X	X	X	X		
Experiment 4	X	X	X	X		X	X	X	X	
Experiment 5	X	X	X	X	X	X	X	X	X	X
Experiment 6	X	X	X	X		X	X	X	X	
Experiment 7	X	X	X	X	X	X	X	X	X	
Experiment 8	X	X	X	X	X	X	X	X	X	

[1] TDN (Total digestible nutrients in the ration), DP (Digestible protein in the ration).

Table 9. Treatment and performance trial 3.

Treatment[1]	Initial weight	Final weight (110 days)	Average daily gain	USDA carcass grade[2]
SRB, 2# daily APEL, OSU	760 lbs	994 lbs	2. 13 lbs	13. 3
SRB, 2# daily DPVS PEL, OSU	761	969	1. 89	13. 3
SRB, BP, OSU	761	999	2. 16	13. 6
SRB, 6# daily PVS, OSU	761	1023	2. 38	13. 5
SRB, OSU	761	971	1. 91	14. 1
SRB, Commercial	761	955	1. 77	13. 5
AVERAGE	761	985	2. 04	13. 6

[1]APEL = alfalfa pellets; DPVS = dehydrated pea vine silage; PVS = pea vine silage; commercial and OSU = 40% protein supplement; SRB = 85% steam rolled barley and 15% beet pulp; BP = dried molasses beet pulp.

[2]Prime = 20, choice = 17, good = 14, standard = 11.

because of an unexpected mud problem. There were no significant differences in daily rate of gain or carcass characteristics due to the various treatments.

Experiment 2 was conducted to determine: (1) The relative value of barley, corn and wheat in a high concentrate ration, (2) the effects of initial intraruminal injections of Vitamin A on feedlot steers that have the recommended level of Vitamin A in a supplement and (3) the value of shade during the summer feeding period. Two hundred sixteen yearling steers averaging 650 pounds were randomly allotted to the experimental design of a 2x4x7 factorial. Also incorporated in the basic design were four pens; two shaded and two without shade. The shaded pens received the same ration as the unshaded pens. The treatment variables were: roughage source (alfalfa hay and peavine silage), seven combinations of concentrates (barley, corn and wheat) and intraruminal injections of Vitamin A at four levels (0; 500,000; 500,000 twice; 1,000,000 I. U.'s). The results of the roughage and concentrate combinations are presented in Table 10. An equal number of steers from each treatment were marketed at 108, 115, 122, 128 and 136 days. The treatments had no significant effect on steer performance or carcass characteristics.

In experiment 3 wheat gluten, as a protein supplement, was compared with the OSU supplement, which is based on cull peas. The percentage of wheat also varied in the rations. Seventy-two steers

Table 10. Barley-corn-wheat performance summary.

10% Roughage		Grain mix containing 25% beet pulp and 5% molasses						
		Wheat 60%	Wheat 40% Barley 20%	Wheat 20% Barley 40%	Barley 60%	Corn 60%	Corn 40% Barley 20%	Corn 20% Barley 40%
Peavine Silage	a	3.08 lbs	2.99	3.21	3.00	3.02	3.22	3.10
	b	12.3	12.9	12.7	14.3	13.1	12.0	12.8
	c	15.4	15.8	15.8	16.1	15.6	15.2	15.4
Alfalfa Hay	a	3.34 lbs	3.04	3.15	3.17	3.09	3.02	3.31
	b	12.5	11.8	12.5	13.2	12.8	14.2	13.3
	c	15.1	15.4	15.8	15.8	15.8	16.2	16.3
No roughage 10% molasses	a	3.09 lbs				2.90		
	b	14.0				11.4		
	c	15.9				14.9		

[a] Average daily gain.

[b] Marbling score 12 = small, 15 = modest.

[c] USDA carcass grade 14 = good, 17 = choice.

averaging 345 pounds were randomly allotted to six pens. Three concentrate rations were used: (1) 85% wheat, 15% beet pulp; (2) 70% wheat, 30% beet pulp; and (3) 50% wheat, 50% beet pulp. Steers in each of two pens received the same ration. The first 97 days on feed the steers were preconditioned using peavine silage fed at a gradually reduced rate. During the preconditioning period all steers received one pound daily of OSU supplement. From 97 days until slaughter one replicate was placed on the wheat gluten supplement and the other continued on the OSU supplement. A summary of the results is presented in Table 11. An equal number of steers from each pen was slaughtered at 168 and 199 days. The results showed no significant differences in steer performance or carcass characteristics due to the protein supplement or percentage of wheat in the concentrate ration.

Table 11. Wheat and wheat gluten performance summary.

	Wheat:Beet Pulp		
	85:15	70:30	50:50
Wheat Gluten			
Average daily gain	2.52 lbs.	2.56	2.48
Marbling score[1]	13.9	13.5	13.8
USDA carcass grade[2]	16.8	16.5	16.0
OSU Supplement:			
Average daily gain	2.57	2.54	2.49
Marbling score	14.4	13.5	12.7
USDA carcass grade	17.1	16.5	16.0

[1] 12 = small, 15 = modest, 18 = moderate.

[2] 14 = good, 17 = choice.

In experiment 4, 120 yearling Hereford steers, from a common background, were used to determine the effect of feeding various levels of fat and implanting diethylstilbestrol on feedlot performance and carcass characteristics. The experimental design was a 3x3x4 factorial with one pen serving as a control. The treatments were: 10% roughage (alfalfa, beet pulp or corn silage), varying levels of fat (0, 3.5 or 7.0%) and steam-rolled wheat the remainder of the ration. The control pen was fed on a ration composed of 90% barley and 10% beet pulp. Within all pens four levels of diethylstilbestrol implants (0, 12, 24 and 36 mg. per head) were given. After 123 days on feed the steers, averaging 1,144 pounds, were slaughtered. The 3.5% fat level and the 12 and 24-mg. diethylstilbestrol implants resulted in significant increases in average daily gain. The various treatments had no significant effect on the carcass characteristics of the steers.

The effects of tempering, dry-rolling and steam-rolling grains on average daily gain, feed efficiency and carcass characteristics were determined in experiment 5. Also, the interactions between grain and its preparation on the production and carcass variables were determined. Averaging 640 pounds, 132 feeder steers from a wintering experiment were stratified as to previous treatment and weight for random placement into one of 12 pens. The experimental design was a 2x3 factorial with two replicates. Each steer was implanted with 12 mg. diethylstilbestrol. The grains processed were soft-white wheat and barley. The ration was 82% concentrate mixture and 18% chopped alfalfa hay. The concentrate mixture was 75% grain (wheat or barley), 15% beet pulp, 5% molasses and 5% OSU supplement. For valid comparisons of the carcass characteristics, an equal number of steers from each pen were removed for slaughter at 140, 154 and 174 days after starting the trial. The results of the treatments are summarized in Table 12. The steam-rolled grain (wheat or barley) resulted in a significant ($P < .01$) increase in average daily gain, compared to dry rolling the grain. There was also a significant ($P < .05$) interaction of grain used with treatment of the grain. The difference suggests that the response of all grains to a particular treatment may not be the same. The carcass characteristics were very similar regardless of the treatment of the grain or which grain was fed.

Experiment 6 was conducted to

> (1) determine the effect of choline chloride upon non-protein nitrogen x roughage interrelationships; (2) compare the finishing performance of beef cattle on two levels of choline (0 and 400 mg. per pound of concentrate), two levels of roughage (10% and 20%) and three levels of urea (0, . 5 and 1. 0%); and (3) determine the effect of the three variables (choline, level of roughage and level of urea) upon carcass characteristics.[4]

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[4]Ralston, A. T., W. H. Kennick and N. O. Taylor. 1966. The effect of choline chloride, urea and roughage fed at varying levels upon feedlot performance and carcass characteristics of steers. Ore. Agric. Exp. Sta. Spec. Rpt. 228.

Table 12. Grain preparation performance summary.

Treatment			Average daily gain[1] (lbs.)	Marbling score[2]	Back fat thickness (in.)	Area of longissimus dorsi (sq. in.)	USDA carcass grade
Wheat:	Steam Rolled	Rep. 1	2.52[ab]	14	.44	11.2	16
		Rep. 2	2.57[a]	15	.46	11.5	17
	Dry Rolled	Rep. 1	2.18[c]	13	.39	11.7	16
		Rep. 2	2.32[bc]	14	.41	11.6	16
	Tempered	Rep. 1	2.39[abc]	14	.42	11.7	16
		Rep. 2	2.45[abc]	15	.47	11.1	17
Wheat Average			2.41	14	.43	11.5	16
Barley:	Steam Rolled	Rep. 1	2.57[a]	15	.52	11.7	17
		Rep. 2	2.40[abc]	14	.54	11.0	17
	Dry Rolled	Rep. 1	2.27[bc]	14	.41	11.5	16
		Rep. 2	2.24[bc]	12	.42	11.3	16
	Tempered	Rep. 1	2.34[abc]	12	.42	11.3	15
		Rep. 2	2.39[abc]	14	.41	11.2	17
Barley Average			2.37	14	.46	11.4	16
Steam Rolled Average			2.52[a]	15	.49	11.4	17
Dry Rolled Average			2.26[b]	14	.41	11.4	16
Tempered Average			2.39[ab]	14	.44	11.4	16

[1] Gains with different superscripts are significantly different (P <.05)

[2] 12 = small, 15 = modest.

[3] 11 = standard, 14 = good, 17 = choice.

One hundred forty-four steers averaging 700 pounds were stratified as to previous treatment and weight and randomly assigned to one of 12 groups in a factorial experiment, with treatments consisting of 10% or 20% roughage, 0 or 400 mg. of choline per pound of concentrate and 0, .5 or 1.0% urea. The concentrate fed consisted of 15% beet pulp, 5% molasses, 39.5% steam rolled wheat, 39.5% steam rolled barley, .5% trace mineralized salt, .5% limestone and 50,000 I. U.'s of Vitamin A. The urea and choline chloride replaced equal amounts of the steam-rolled wheat and barley by weight. The steers were slaughtered at eigher a choice live grade or 1,100 pounds weight, whichever came first. There were no significant differences in steer performance or carcass characteristics due to the various treatments.

In experiment 7, 228 beef steer calves from nine and ten different sources for 1963 and 1964 studies, respectively, were used. The purpose of the studies was to determine whether the source of the feeder steers or their prefinishing ration made a greater contribution to variations in performance and carcass characteristics. The calves averaged 500 pounds when they were randomly allotted to ten different prefinishing treatments consisting of five different roughages (wheat chaff, chopped alfalfa, corn silage, wheat chaff-alfalfa pellets and corn silage-chopped alfalfa) and two levels of concentrate (0 and 1% of body weight). After 110 days on the prefinishing rations, the steers were fed a finishing ration composed of alfalfa pellets, steam-rolled barley, dried beet pulp, molasses, protein supplement and salt. Weight and live grade were the criteria for removing a steer for slaughter. Equal numbers were taken from each treatment so that differences in carcass characteristics would be due to prefinishing treatment and genetic potential and not to the number of days on feed. There were no significant effects on performance or carcass characteristics due to the source of animals or prefinishing treatments.

Experiment 8 was a study of the effects of varying levels of protein, energy and injectable iron on steer performance and carcass characteristics. One hundred eight yearling Hereford steers, of a common background, averaged 634 pounds when randomly allotted to the treatments. The 3x3x2 factorially designed experiment consisted of three levels of digestible protein (6. 8, 8. 7 and 11. 5%), three levels of total digestible nutrients (69, 72 and 78%) and two levels of electrodialyzed iron (0 and 4 ml.). An additional 12 steers were fed a standard diet of 7. 5% digestible protein and 75% total digestible nutrients. The steers were on feed approximately 137 days and averaged 1, 069 pounds at slaughter. The various treatments had no significant effects on steer performance or carcass characteristics.

STATISTICAL PROCEDURES

Multiple linear regression analysis was employed because it can be used to determine which independent variables are related to a single dependent variable, as well as the percentage of variation each contributes to the single dependent variable. Also a prediction equation can be constructed that will express the single dependent variable as a function of the selected independent variables.

The equation used for predicting the single dependent variable was:

$$Y = \alpha + b_1X_1 + b_2X_2 + ... biXi,$$

where α is a constant, b_1 are the standard partial regression coefficients and X_1 are the independent variables selected for the prediction of the dependent variable (Y). The significance of each standard partial regression coefficient was tested with a Student's t-value. The multiple regression coefficient (R^2) gave the percentage of variation of the dependent variable explained by the independent variables. The F-level was used to test the significance of the predication equations.

The data of the present study used for the statistical analyses came from the previously discussed eight experiments conducted by members of the Oregon State University faculty.

RESULTS AND DISCUSSION

The means and standard deviations for certain production factors and the carcass characteristics of beef steers are presented in Tables 13, 14 and 15. The simple correlation coefficients obtained between the certain production factors and the carcass characteristics are presented in Tables 16, 17 and 18.

A significant ($P < .01$) negative correlation, -.252, between initial weight and average daily gain from Table 17 agrees with the statement by Ralston et al. (1967), that animals with lighter initial weights will gain more rapidly than heavier animals. However, the significant ($P < .01$) positive correlations between initial weight and average daily gain presented in Tables 16 and 18 disagree with the statement by Ralston et al. (1967), but agree with results obtained by Knox and Koger (1946).

The significant ($P < .01$) negative correlations between initial weight and days on feed (Tables 16, 17 and 18) indicate that with heavier initial weight, fewer days on feed are required to reach slaughter weight or grade.

The significant ($P < .01$) negative correlations between days on feed and average daily gain (Tables 16 and 18) are supported by the results of the Kansas Agric. Exp. Sta. Bull. 448 (1962), Zinn et al. (1970) and Ralston et al. (1970). Their results indicated that as

Table 13. Means and standard deviations for certain production factors, USDA carcass grade, marble score and back fat thickness.[1]

Variables	Mean	Standard Deviation
Initial weight, lbs.	678	104
Average daily gain, lbs.	2.89	.60
Days on feed	135	43
Carcass grade[2]	16	3.6
Marble score[3]	13.6	5.5
Back fat thickness, in.	.48	.16

[1] 1098 degrees of freedom.

[2] Low standard = 10, low good = 13, low choice = 16.

[3] Traces = 6, slight = 9, small = 12, modest = 15, moderate = 18.

Table 14. Means and standard deviations for certain production factors and conformation score.[1]

Variables	Mean	Standard Deviation
Initial weight, lbs.	672	78
Average daily gain, lbs.	2.56	.59
Days on feed	129	20
Conformation score[2]	16	1.6

[1] 433 degrees of freedom.

[2] Low standard = 10, low good = 13, low choice = 16.

Table 15. Means and standard deviations for certain production factors and longissimus dorsi area.[1]

Variables	Mean	Standard Deviation
Initial weight, lbs.	665	112
Average daily gain, lbs.	2.99	.56
Days on feed	146	37
longissimus dorsi area, sq. in.	11.4	1.1

[1] 717 degrees of freedom.

Table 16. Simple correlation coefficients[1] of certain production factors and USDA carcass grade (CG), marble score (MS) and back fat thickness (BFT).[2]

Variables	ADG	DOF	CG	MS	BFT
Initial weight (IW)	.175**	-.65**	-.036	-.025	-.155**
Average daily gain (ADG)	....	-.173**	.145**	.121**	.179**
Days on feed (DOF)	....	....	.503**	.346**	.149**

[1] **P <.01.

[2] 1098 degrees of freedom.

Table 17. Simple correlation coefficients[1] of certain production factors and conformation score (CS).[2]

Variables	ADG	DOF	CS
IW	-.252**	-.477**	-.439**
ADG	....	-.081	.25**
DOF	....	....	.413**

[1] **P <.01.

[2] 433 degrees of freedom.

Table 18. Simple correlation coefficients[1] of certain production factors and longissimus dorsi area (LD).[2]

Variables	ADG	DOF	LD
IW	.466**	-.882**	.394**
ADG	....	-.559**	.188**
DOF	....	....	-.261**

[1] **P <.01.

[2] 717 degrees of freedom.

days on feed increased average daily gain decreased.

The nonsignificant correlations of initial weight with carcass grade and marbling score (Table 16) support the observations of Hankins and Burk (1938) and Ralston et al. (1967), that initial weight does not affect carcass grade and marbling score.

The significant (P <. 01) negative correlations of initial weight with back fat thickness and conformation score (Tables 16 and 17) indicate that a lighter initial weight can result in increased back fat thickness as suggested by Ralston et al. (1967) and a higher conformation score (Goll et al., 1961).

The significant (P <. 01) positive correlation between initial weight and area of longissimus dorsi (Table 18) disagrees with the results of Ralston et al. (1967), which suggest that there is no relationship between initial weight and area of longissimus dorsi.

The significant (P <. 01) positive correlations of average daily gain with carcass grade, marbling score, conformation score, back fat thickness and area of longissimus dorsi are presented in Tables 16, 17 and 18. The correlations support the statement by Crouse et al. (1974), that when an animal gains rapidly there is a tendency towards an improvement in the carcass characteristics.

The results of Hankins and Burk (1938), the Kansas Agric. Exp. Sta. Bull. 448 (1962), Zinn et al. (1970) and Ralston et al. (1970) support the significant (P <. 01) positive correlations of days on feed with carcass grade, marbling score and back fat thickness (Table 16). The correlation between days on feed and back fat thickness (.149) is lower than the .44 obtained by Hankins and Burk (1938). Ralston et al. (1970) observed increases in back fat thickness as steers were on feed longer before slaughter. The removal for slaughter in the eight experiments used in the present study was when the animal reached a desired pre-selected weight or grade. The criteria for slaughter removal prevented the extremes in back fat thickness as obtained by Ralston et al. (1970), and are a possible explanation why the correlation between days on feed and back fat thickness was lower than the results obtained by Hankins and Burk (1938).

The significant (P <.01) positive correlation between days on feed and conformation score is presented in Table 17. Zinn et al. (1970) observed that up to 150 days on feed, conformation score increased, but after that the conformation score changed very little. The 433 steers of the present study averaged 129 days on feed. Since this average is well below 150 days, the correlation between days on feed and conformation score are supported by the experimental results of Zinn et al. (1970).

The significant (P <.01) negative correlation presented in Table 18 between days on feed and area of longissimus dorsi is -0.261. The correlation is supported by McBee and Bowers (1969), who observed that as the days on feed increased the rate of muscle deposition declined and fat deposition increased.

Initial weight, average daily gain and days on feed are significant ($P < .001$) variables in predicting carcass grade, marbling score and conformation score (equations 1, 2 and 3, Table 19). The amount of variation in carcass grade, marbling score and conformation score accounted for by the three variables (initial weight, average daily gain and days on feed) was 44%, 21.5% and 28.8%, respectively.

Average daily gain is a significant ($P < .001$) variable in the back fat thickness prediction equation. Initial weight ($P < .005$) and days on feed ($P < .01$) are not as important in predicting back fat thickness. The three independent variables (average daily gain, initial weight and days on feed) accounted for 7.4% of the variation in back fat thickness (Table 19, equation 4).

Initial weight and days on feed are significant ($P < .001$) variables in the prediction equation of area of <u>longissimus dorsi</u>. Because of its correlations with initial weight (.466) and days on feed (-.599) (Table 18), average daily gain showed a lower significant level ($P < .01$) in the prediction equation (Table 19, equation 5).

The correlation coefficients of certain production factors and carcass characteristics are presented in Tables 23, 24 and 25. Two production factors have been added, percent total digestible nutrients (TDN) and percent digestible protein in the ration. The correlations for initial weight, average daily gain and days on feed with carcass

Table 19. Multiple regression prediction equations of the carcass characteristics with Student's t-values,[1] multiple regression coefficient of determination (R^2), F-level and degrees of freedom (n)

Prediction Equations[2]	n	F-level	R^2
1. CG = -8.12 + .016 IW + 1.24 ADG + .071 DOF	1094	81.9**	0.44
t-value 16.12**** 9.05**** 28.54****			
2. MS = -12.45 + .017 IW + 1.50 ADG + .074 DOF	1094	36.5**	0.215
t-value 9.27**** 6.04**** 16.61****			
3. CS = 14.32 + (-.0048) IW + .602 ADG + .026 DOF	429	25.3**	0.288
t-value -4.7**** 5.03**** 6.72****			
4. BFT = .389 + (-.00019) IW + .058 ADG + .00039 DOF	1094	7.6**	0.074
t-value -3.24*** 7.38**** 2.76**			
5. LD = 3.36 + .0078 IW + .23 ADG + .015 DOF	713	7.7**	0.198
t-value 10.64**** 2.77** 6.15****			

[1] ** P <.01, *** P <.005, **** P <.001.

[2] CG = carcass grade, MS = marble score, CS = conformation score, BFT = back fat thickness, LD = area of longissimus dorsi, IW = initial weight, ADG = average daily gain, DOF = days on feed.

Table 20. Means and standard deviations for certain production factors, USDA carcass grade, marble score and back fat thickness.[1]

Variables	Mean	Standard deviation
Initial weight, lbs.	664	110
Average daily gain, lbs.	2.74	.56
Days on feed	139	48
% total digestible nutrients in the ration	70.2	8.9
% digestible protein in the ration	6.76	1.82
Carcass grade[2]	16	4
Marble score[3]	13.5	6
Back fat thickness, in.	.48	.16

[1] 843 degrees of freedom.

[2] Low standard = 10, low good = 13, low choice = 16.

[3] Traces = 6, slight = 9, small = 12, modest = 15, moderate = 18.

Table 21. Means and standard deviations for certain production factors and conformation score.[1]

Variables	Mean	Standard deviation
Initial weight, lbs.	672	78
Average daily gain, lbs.	2.56	.59
Days on feed	129	20
% total digestible nutrients in the ration	70.7	4.3
% digestible protein in the ration	6.95	.84
Conformation score[2]	16	1.6

[1] 433 degrees of freedom.

[2] Low standard = 10, low good = 13, low choice = 16.

Table 22. Means and standard deviations for certain production factors and longissimus dorsi area.[1]

Variables	Mean	Standard deviation
Initial weight, lbs.	631	118
Average daily gain, lbs.	2.79	.49
Days on feed	158	40
% total digestible nutrients in the ration	68.7	9.5
% digestible protein in the ration	6.78	2.17
longissimus dorsi area, sq. in.	11.2	1.1

[1] 463 degrees of freedom.

grade, marbling score, conformation score, back fat thickness and area of <u>longissimus dorsi</u> are the same as or similar to those presented in Tables 16, 17 and 18.

The significant ($P < .01$) positive correlations between TDN and initial weight presented in Tables 23 and 25 are different than the significant ($P < .01$) negative correlation presented in Table 24. The sample used to determine the correlations presented in Table 24 had smaller standard deviations for initial weight and TDN (Table 21) when compared with the standard deviations (Tables 20 and 22) of the samples used to determine the correlations presented in Tables 23 and 25. The smaller standard deviations could account for the differences in the correlations between initial weight and TDN. The significant ($P < .01$) positive correlations between TDN and average daily gain presented in Tables 23, 24 and 25 suggest that as the TDN level in the ration increases so does average daily gain. There is also a slight positive relationship between the levels of TDN and digestible protein in the ration, as indicated by the significant ($P < .01$) positive correlations presented in Tables 23, 24 and 25.

In the literature reviewed there were no correlation coefficients between TDN and the carcass characteristics. In the present study significant ($P < .01$) correlations of TDN with carcass grade, marbling score and conformation score were obtained (Tables 23 and 24).

The significant ($P < .01$) correlations of digestible protein with average daily gain and days on feed presented in Tables 24 and 25 are different. The differences can be accounted for by comparing the samples standard deviations for digestible protein presented in Tables 21 and 22. Ralston et al. (1966a), Haskins et al. (1967), Epley et al. (1971), Braman et al. (1973) and Greathouse et al. (1974) observed that the level of protein in a finishing ration has no significant effect on carcass grade, marbling score, conformation score, back fat thickness and area of longissimus dorsi. Thornton et al. (1974) found that increased levels of protein in a finishing ration results in increased carcass grade, marbling score and back fat thickness. The significant ($P < .01$) positive correlations of digestible protein with carcass grade (0.308), marbling score (0.347) and back fat thickness (0.251) of the present study support the results obtained by Thornton et al. (1974).

The prediction equations of the five carcass characteristics using the five production factors as the independent variables are presented in Table 26. The prediction equations include only those independent variables that made a significant ($P < .001$) contribution.

The addition of digestible protein as an independent variable in the prediction equations of carcass grade, marbling score and back fat thickness increased the amount of variation (R^2) of the dependent variable explained by the independent variables (Table 26). The importance of digestible protein in the prediction equations of carcass grade, marbling score and back fat thickness is supported by the study of Thornton _et al._ (1974).

The addition of the independent variables TDN and digestible protein had little effect on the multiple regression coefficient (R^2) of the prediction equations for conformation score and area of _longissimus dorsi_.

Table 23. Simple correlation coefficients[1] of certain production factors and USDA carcass grade (CG), marble score (MS) and back fat thickness (BFT)[2].

Variables	ADG	DOF	TDN	DP	CG	MS	BFT
Initial weight (IW)	.059	-.655**	.397**	.082**	-.044	-.039	-.221**
Average daily gain (ADG)	....	-.107**	.234**	.059	.172**	.149**	.164**
Days on feed (DOF)	....	....	-.647**	.035	.52**	.362**	.178**
% Total digestible nutrients (TDN)	....	....	....	.186**	-.259**	-.202**	.011
% Digestible protein (DP)	....	....	....	....	.308**	.347**	.251**

[1]** P <.01.

[2]843 degrees of freedom.

Table 24. Simple correlation coefficients[1] of certain production factors and conformation score (CS)[2].

Variables	ADG	DOF	TDN	DP	CS
IW	-.252**	-.477**	-.40**	.057	-.439**
ADG	....	-.081	.396**	-.378**	.25**
DOF	....	....	.348**	.495**	.413**
TDN	....	....	....	.198**	.346**
DP	....	....	....	....	-.047

[1]** P <.01.

[2]433 degrees of freedom.

Table 25. Simple correlation coefficients[1] of certain production factors and longissimus dorsi area (LD)[2].

Variables	ADG	DOF	TDN	DP	LD
IW	.354**	-.90**	.493**	.024	.362**
ADG	....	-.467**	.237**	.136**	.045
DOF	....	....	-.636**	-.195**	-.217**
TDN	....	....	....	.368**	-.035
DP	....	....	....	....	-.149**

[1]** $P < .01$

[2]463 degrees of freedom.

Table 26. Multiple regression prediction equations of the carcass characteristics with Student's t-values,[1] multiple regression coefficient of determination (R^2), F-level[1] and degrees of freedom (n).

Prediction Equations[2]	n	F-level[1]	R^2
1. CG = -13.32 + .018 IW + 1.59 ADG + .072 DOF + .502 DP	838	85.8**	0.529
t-values 15.22**** 9.26**** 26.84**** 9.41****			
2. MS = -19 + .016 IW + 1.88 ADG + .071 DOF + .979 DP	838	36.8**	0.32
t-values 7.78**** 6.06**** 14.79**** 10.17****			
3. CS = 15.23 + (-.0039) IW + .468 ADG + .036 DOF + (-.364) DP	428	12.8**	0.309
t-values -3.5**** 3.78**** 7.68**** -3.58****			
4. BFT = .043 + (-.0004) IW + .048 ADG + .024 DP	839	26.2**	0.148
t-values -7.87**** 5.12**** 8.19****			
5. LD = 6.22 + .0076 IW + .011 DOF + (-.021) TDN	459	11.0**	0.213
t-values 8.22**** 3.52**** -3.32****			

[1] **** P <.001, ** P <.01.

[2] CG = carcass grade, MS = marble score, CS = conformation score, BFT = back fat thickness, LD = area of longissimus dorsi, IW = initial weight, ADG = average daily gain, DOF = days on feed, DP = percent digestible protein, TDN = percent total digestible nutrients.

SUMMARY AND CONCLUSIONS

Steers from eight experiments conducted by faculty members of Oregon State University as part of the Oregon Agricultural Experiment Station's research program in beef production provided production information which could be related to carcass characteristics of economic value. The production factors were: initial weight, average daily gain, days on feed, percent total digestible nutrients (TDN) and percent digestible protein (DP). The five carcass characteristics used for analysis were: USDA carcass grade, marbling score, conformation score, back fat thickness and area of the longissimus dorsi.

Multiple regression equations were developed to predict the carcass characteristics. The prediction equations were determined with two sets of independent variables. The first set was composed of: 1) initial weight, 2) average daily gain and 3) days on feed. The second set used the independent variables of the first set plus percent total digestible nutrients (TDN) and percent digestible protein (DP). Also determined from the statistical analyses were the simple correlation coefficients between the production factors and carcass characteristics.

Initial weight was significantly ($P < .01$) correlated with back fat thickness (-.155), conformation score (-.439) and area of the longissimus dorsi (.394). These results were supported by the study done by Ralston et al. (1967).

Days on feed was significantly (P <.01) correlated with carcass grade (.503), marbling score (.346), conformation score (.413), back fat thickness (.149) and area of longissimus dorsi (-.261). The correlations support the belief that as days of feed increase there is a corresponding increase in USDA carcass grade (Hankins and Burk, 1938; Kansas Agric. Exp. Sta. Bull. 448, 1962; Zinn et al., 1970; and Ralston et al., 1970). The negative correlation between days on feed and area of the longissimus dorsi is supported by McBee and Bowers (1969), who observed as days on feed increased the rate of muscle deposition declined and fat deposition increased.

Average daily gain was significantly (P <.01) correlated with carcass grade (.145), marble scoring (.121), conformation score (.25), back fat thickness (.179) and area of the longissimus dorsi (.188). Although the correlations are low they do support the statement by Crouse et al. (1974), that when an animal gains rapidly there is a tendency towards improvement in carcass characteristics. Cundiff et al. (1964) and Cundiff et al. (1972) concluded that selection for rate of gain is desirable because it improves efficiency of production and is accompanied by positive gradual improvements in carcass composition and quality.

The percentage of digestible protein in the finishing ration was significantly (P <. 01) correlated with carcass grade (. 308), marbling score (. 347) and back fat thickness (. 251). These results disagree with the findings of Ralston et al. (1966a), Haskins et al., 1967), Epley et al. (1971), Braman et al. (1973) and Greathouse et al. (1974). They observed no significant effect of protein levels on carcass characteristics. However, the results are supported by Thornton et al. (1974), who observed that increasing protein levels in the ration increases carcass grade, marbling score and back fat thickness.

Initial weight, average daily gain, days on feed and percent digestible protein were significant (P <. 001) independent variables in the multiple regression prediction equations of carcass grade, marbling score and conformation score. The amount of variation the four independent variables accounted for in carcass grade, marbling score and conformation score were: 52. 9%, 32% and 30. 9%, respectively.

The multiple regression prediction equation for back fat thickness was made up of the significant (P <. 001) independent variables, initial weight, average daily gain and percent digestible protein. The independent variables accounted for only 14. 8% of the variation in back fat thickness.

Initial weight, days on feed and percent total digestible nutrients were significant (P <. 001) variables in the multiple regression prediction equation of area of *longissimus dorsi*. The three significant variables accounted for 21.3% of the variation in area of the longissimus dorsi.

The results of the multiple regression predication equations indicate that the significant ($P < .001$) variables account for more of the variation (R^2) in the subjective carcass characteristics (carcass grade, marbling score and conformation score), than they account for in the two objective carcass characteristics (back fat thickness and area of the longissimus dorsi).

The results of the present study indicate that an animal with a heavier initial weight, a rapid daily gain, more days on feed and a higher level of digestible protein in the finishing ration will have a higher USDA carcass grade, marbling score, conformation score and thicker back fat. A larger longissimus dorsi area can be obtained with a heavier initial weight, more days on feed and lower level of TDN in the ration.

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