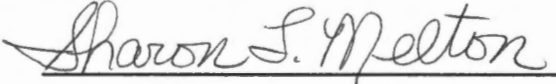
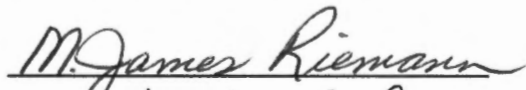
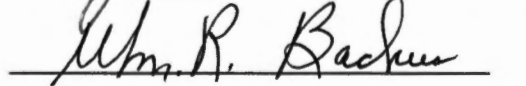


To the Graduate Council:

I am submitting herewith a thesis written by Melanie Jane Huskey entitled "Performance of Steers on Soybean Supplemented Corn Diets With and Without Peanut Skins and the Characteristics of the Beef Produced on Those Diets." I have examined the final copy of this thesis for form and content and recommend that it be accepted in partial fulfillment of the requirements for the degree of Master of Science, with a major in Food Technology and Science.


Sharon L. Melton, Major Professor

We have read this thesis
and recommend its acceptance:

Accepted for Council:


Vice Provost
and Dean of the Graduate School

PERFORMANCE OF STEERS ON SOYBEAN SUPPLEMENTED CORN DIETS WITH AND
WITHOUT PEANUT SKINS AND THE CHARACTERISTICS OF THE BEEF PRODUCED
ON THOSE DIETS

A Thesis
Presented for the
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Degree
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Melanie Jane Huskey
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DEDICATION

This thesis is dedicated to my husband Doug, my parents, Jane Stewart and Jackson Huskey, my sister, Rhonda, and my brothers, Sidney and Steven, whose love, patience, and encouragement have enabled me to complete this study. A special thanks to my parents for teaching me the values of hard work, dedication, and an education.

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ABSTRACT

The objectives of this investigation were (1) to determine the growth and carcass traits of steers fed full fat soybean supplemented diets with and without peanut skins and (2) to evaluate sensory characteristics and chemical composition of beef produced on those diets. Steers (n=35) grazed pasture during the 1987 summer and were fed a maintenance diet (DM) during the fall. After removal from DM, they were divided into 7 groups of 5 steers per group. One group of steers was killed directly off DM (0 DOF). Two groups were fed a control corn diet (D1) ; two groups, a corn + full fat soybeans diet (D2) and two, a corn + full fat soybeans:peanut skins diet (D3). From each diet, one group was killed after 56 days of feeding (56 DOF) and the other at 112 DOF. Steers were weighed at 0, 56 and 112 DOF, and average daily gain (ADG) at 56 DOF calculated. For each steer, selected carcass traits were determined and samples of subcutaneous fat (SF) and the longissimus muscle (LM) were obtained. Total lipids (%) and the fatty acid (FA) composition of lipids in the SF and LM were determined. FA were grouped into types: SAT 10-15C (10:0, 11:0, 12:0, 13:0, 14:0 & 15:0); SAT 16-24C (16:0, 17:0, 18:0, 20:0, 22:0 & 24:0), MONO (14:1, 15:1, 16:1, 17:1, 18:1 & 20:1), PUFA6 (18:2 ω 6, 18:3 ω 6, 20:4 ω 6, 20:5 ω 6 & 22:5 ω 6), PUFA3 (18:3 ω 3, 20:5 ω 3, 22:5 ω 3 & 22:6 ω 3) and UNKNOWNNS (81 FA). Other FA (11) were also measured, and sensory scores and shear values (WB) of LM were determined. All dependent variables were statistically analyzed as a function of DOF and diet. ADG56 and ADG112 were analyzed as a function of diet and ADG period. The FA were also analyzed as a function of sampling site, and the FA of LM were correlated with sensory scores.

The following variables increased in value ($P < .05$) with increasing DOF from 0 to 112: steer wt, 372 to 538 kg; hot carcass wt (HCW), 185 to 316 kg; rib eye area, 56.1 to 79.2 cm²; fat thickness, .22 to 1.25 cm; kidney, pelvic and heart fat, 1.0 to 2.1; yield grade 1.7 to 2.9; quality grade, standard to low choice; lipid in SF, 60.4 to 83.1%, and in LM, 2.6 to 8.0%; MONO in SF, 36.5 to 44.1%; PUFA6 in SF, 1.5 to 2.6%; MONO in LM, 38.4 to 47.4%; taste score, 4.2 to 5.8 and acceptability score, 4.4 to 5.7. Other variables decreased in value ($P < .05$) during the same 112 DOF period: % SAT 16–24C in SF, 48.1 to 42.8%; PUFA in SF, .7 to .3%; SAT 16–24C in LM, 43.1 to 38.7%; PUFA3 in LM, 1.8 to .5%; UNKNOWNS in LM, 4.3 to 2.2%, and WB, 4597 to 2960 g.

All steers fed D1 had a higher ADG56 (1.70 kg/day) than those fed D2 or D3 (1.23 and 1.22). Steers fed D1 through 56 DOF had a significantly heavier HCW (301 kg) than those fed D2 (279 kg) or D3 (272 kg) and a higher ADG, (1.7 versus 1.2 kg/day). Steers fed D2 contained higher levels of MONO and lower levels of 14:0, 16:0 and 18:3 ω 6 in LM than those fed D3 ($P < .05$), and steers fed D1 had lower levels of 18:3 ω 3 in the LM than those fed D2 or D3 ($P < .05$). Compared with the LM, the SF had higher levels of saturated FA and lower % of polyunsaturated and unknown FA ($P < .05$). The highest correlation coefficients between sensory scores and % FA were taste with 15:0, 15:1 top and 18:3 ω 3 (-.71, -.70 and -.64, respectively, $P < .001$).

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I. INTRODUCTION

Due to the high incidence of coronary heart disease in the United States, investigators have examined methods of decreasing the occurrence of the disease by changing the human diet (Kuller, 1983). Saturated fatty acids and cholesterol-containing foods in the diet have been blamed for causing heart disease. Because of this, beef which contains cholesterol and approximately 35% saturated fatty acids in its fat (deMan, 1985) has been placed on the "taboo" list by many dieticians and health associations.

In response to the poor publicity about beef, cattle growers have begun to produce leaner meat, but the level of saturation in the beef fatty acids remains unchanged (Topel, 1986; Utley et al., 1975). It is difficult to alter the fatty acid composition in beef by feeding cattle dietary polyunsaturated fatty acids (PUFA) because the rumen microorganisms hydrogenate these acids (Swenson, 1970). The only successful examples reported in the literature where PUFA in beef were increased significantly by diet were when a polyunsaturated oil coated with a protein-formaldehyde complex was fed to cattle (Cook et al., 1972; Dinius et al., 1974). The resulting beef, however, had undesirable off-flavors and developed oxidative rancidity rapidly. In addition, formaldehyde is a known carcinogen and cannot be fed to cattle at the present time in the United States (Waller, 1989).

Therefore, another way of blocking hydrogenation of dietary PUFA by rumen microorganisms must be found if the fatty acids of beef are to be changed by including PUFA in the cattles' diet. One such way may be to include tannins. Tannins bind with proteins in the same manner as

formaldehyde prohibiting their digestion (Kumar and Singh, 1984; Zelter and Leroy, 1966). It is possible, then, that tannins might also protect dietary PUFA from hydrogenation by rumen microorganisms. Also, in comparison with formaldehyde, high levels of tannins are present in many natural sources. A good economical source of tannins is peanut skins, a by-product of the peanut blanching industry (Hale and McCormick, 1981). The effect of tannins or peanut skins in the cattles' diet on the fatty acids of beef, however, has not been investigated even though peanut skins have been fed to cattle (Hill et al., 1986a; McBrayer et al., 1983; Utley and Hellwig, 1985).

In addition, during recent years there has been increased interest in feeding full-fat soybeans to cattle as a source of increased levels of dietary PUFA, particularly the omega-3 fatty acids such as linolenic acid. Soybeans contain 16 to 20% oil which has approximately 9% linolenic acid (deMan, 1985). The practical limit that full-fat soybeans can be fed to cattle is to provide 6% of the fat in the diet (Rule and Beitz, 1986). However, feeding of full fat soybeans at this level to cattle does not increase the level of polyunsaturated fatty acids in the beef significantly because of hydrogenation of the PUFA in the rumen (Rule and Beitz, 1986).

The effect of feeding a combination of full fat soybeans with tannins or peanut skins to cattle on the growth and characteristics of the resulting beef has not been investigated at the present time. Therefore, the objectives of this present study were (1) to determine the growth and carcass traits of steers fed full fat soybean supplemented diets with and without peanut skins and (2) to determine sensory characteristics and selected chemical components, such as fatty acid composition, of beef

produced on those same diets.

II. LITERATURE REVIEW

Relationship of Dietary Fat to Heart Disease

Today, the diet-heart theory is well accepted by health organizations and many consumers in the United States. This theory holds that cholesterol and/or saturated fat in the diet is the cause of atherosclerosis and heart disease (Kuller, 1983). During the 1970's, much research related the level of serum cholesterol levels to the increased incidence of heart disease but did not differentiate between the different types of cholesterol present (Perkins and Visek, 1983). Total blood cholesterol is made up of high density lipoprotein (HDL) and low density lipoprotein (LDL). Both lipoproteins contain cholesterol, but HDL helps remove the fatty plaques in the arteries that cause heart attacks and strokes while LDL tends to be deposited in the plaques (Perkins and Visek, 1983).

During 1980's, research concerning the relationship of fat to heart disease has been centered on the types of fatty acids and their effects on total serum cholesterol, HDL and LDL levels. Dietary saturated fatty acids, in general, are believed to cause higher levels of LDL (Mattson and Grundy, 1985). Saturated fatty acids contain no double bonds in the carbon chain. On the other hand, consumption of fat, which contain fatty acids with one double bond in the carbon chain or monounsaturated fatty acids, has been shown to decrease the amount of LDL and not affect the level of HDL (Mattson, and Grundy, 1985; Oltjen and Dinius, 1975). Even more recent research has shown that the length of the fatty acid carbon chain influences

the effect that saturated fatty acids have on the LDL levels. Bonanome and Grundy (1988) showed that diets containing stearic acid (18:0) which contains 18 carbons compared to palmitic acid (16:0) which contains 16 carbons reduced the LDL by 21% in humans and did not affect the HDL levels.

The relationship between dietary fatty acids and human serum cholesterol levels becomes even more complex when the effects of the polyunsaturated fatty acids (PUFA) are considered. In general, there are two types of PUFA, the omega-6 and omega-3 (deMan, 1985). The omega-6 PUFA have the first double bond in the carbon chain located between the 6th and 7th carbon from the methyl end of the fatty acid chain and include linoleic acid (18:2 ω 6) and arachidonic acid (20:4 ω 6). The omega-3 PUFA have the first double bond in the carbon chain located between the 3rd and 4th carbons from the methyl end of the fatty acid chain and include linolenic acid (18:3 ω 3) and docosapentenoic acid (22:5 ω 3). Dietary omega-6 PUFA have been shown to decrease both the HDL and LDL levels in man while dietary omega-3 PUFA are believed to decrease only the LDL levels (Perkins and Visek, 1983).

Beef, because of its fat concentration and fatty acid composition, has borne the brunt of being the animal fat that causes heart disease. The level of fat in beef depends on the cut and form sold. Most of the beef sold today in the U.S.A. is choice grade with a fat content of 10 to 15%. Regular ground beef has from 25 to 30% fat. Leaner beef can be purchased but it is more expensive. Beef fat contains approximately 6% myristic acid (14:0), 27% palmitic acid (16:0), 14% stearic acid (18:0), 50% oleic acid (18:1), 3%

18:2 ω 6 and very little 18:3 ω 3 or omega-3 polyunsaturated fatty acids (deMan, 1985).

Beef Cattle Diet and Fat Composition

Because of the poor publicity that beef receives in relation to heart disease, researchers are looking for methods of producing lean acceptable beef with altered fatty acid composition. Alteration of the beef cattle diet is one possibility.

In the United States during the 1900's cattle have been finished primarily on grain diets (Topel, 1986). These diets produce beef with the previously reported fat levels and composition.

Other finishing diets such as grass pasture and forage have been extensively investigated for producing acceptable beef mainly because they might be more economical (Melton et al., 1982; Topel, 1986). Finishing beef on grass pasture becomes more attractive when grain prices soar. This phenomenon last occurred during the 1970's (Melton et al., 1982). During this period, several researchers investigated the characteristics of grass produced beef and found that it generally was much leaner than grain produced beef. Beef produced on grass pastures containing fescue normally contains from 2 to 3% intramuscular fat while beef produced on 140 day grain feeding contains from 10 to 14%.

Compared to a grain diet, the grass diet also altered the beef fat composition. Melton (1983) reported that beef produced on grass had higher levels of saturated and polyunsaturated omega-3 fatty acids and

lower levels of monounsaturated fatty acids than beef produced on grain. Other research at the University of Tennessee has verified this report (Holden, 1985; Mann, 1984; Schell, 1988; Yeo, 1983). Rumsey et al. (1972) also reported that feeding concentrates to beef cattle in comparison with feeding forage diets increased the percentage of unsaturated fatty acids in the beef by 20% with most of the increase being in the monounsaturated fatty acid, oleic acid.

Feeding of soybeans to beef cattle as a source of dietary fat has also been investigated. Soybeans contain 16 to 20% fat with a fatty acid composition of approximately 11% 16:0, 4% 18:0, 25% 18:1, 51% 18:2 ω 6 and 9% 18:3 ω 3 (deMan, 1985). As a dietary fat source, full-fat soybeans are fed to cattle at a level to supply 6% dietary fat. According to Rule and Beitz (1986), this is the practical upper limit of dietary fat for finishing beef cattle. Inclusion of soybeans in the diet of beef cattle provide a source of the omega-3 PUFA that are not found in conventional grain diets used to finish cattle. The cattle that are fed diets including soybeans tend to have a higher proportion of 18:3 ω 3 in the resulting beef (Rule and Beitz, 1986; Rule et al., 1986; Skelly et al., 1973;). Rule and Beitz (1986) reported that compared to steers fed a conventional corn diet, those fed a soybean supplemented corn diet had a significantly higher level of 18:3 ω 3 (0.57 versus 0.37%) in the perirenal adipose tissue. However, they did not find a significant difference due to diet in the 18:3 ω 3 content in muscle lipids of the steers. The fatty acid composition of the intramuscular beef lipids in steers fed the soybean supplemented corn diet was very similar to that

previously given.

Supplementing corn diets of cattle with soybeans, however; could be detrimental to producing lean beef. Rule et al. (1986) reported that supplementing a high-energy finishing diet for beef steers with full fat soybeans to provide a 6% dietary fat intake increased the amount of intramuscular fat in the beef.

Fate of Dietary Unsaturated Fatty Acids in Ruminants

Beef cattle contain microorganisms in their rumen which prevent passage of large amounts of dietary unsaturated fatty acids into the abomasum and intestinal area. The rumen contains oligotrich protozoa and ruminal bacteria which hydrogenate the unsaturated fatty acids (Chalupa and Kutches, 1968; Polan et al., 1964). Swenson (1970) reported that only a small amount of unsaturated fatty acids left the rumen even though 67.8% of the fatty acids ingested by cattle were unsaturated. Rule and Beitz (1986) reported that in steers fed a dietary fat that contained 2.7% 18:0, 19.9% 18:1, 55.1% 18:2 ω 6 and 5.7% 18:3 ω 3, the duodenal ingesta fat contained 56.7% 18:0, 19.1% 18:1, 5.3% 18:2 ω 6, and 1.0% 18:3 ω 3. These results show the extent of hydrogenation and type of fatty acids hydrogenated by rumen microorganisms in beef cattle.

Protected Lipids in the Beef Cattles' Diet

If the fatty acid composition of beef is to be altered by feeding large

amounts of dietary unsaturated fatty acids, these fatty acids must be protected from hydrogenation by the rumen microorganisms. The most successful way of protecting fatty acids from hydrogenation in the rumen utilizes formaldehyde. An emulsion of protein and oil is reacted with formaldehyde and then spray dried (Scott et al., 1971). The formaldehyde forms bonds with the protein that are resistant to hydrolysis by rumen microorganisms, thus protecting the embedded fat from microbial attack. This protein-formaldehyde bond, however, is hydrolyzed, by the acid pH in the abomasum releasing the fat for digestion (Johnson, 1974; Oltjen and Dinius, 1975; Scott et al., 1971; Tracy, 1975). In a study by Hood and Thornton (1976), steers fed formaldehyde-casein protected sunflower oil retained more 18:2 ω 6 in their depot fat than steers fed the unprotected sunflower oil. Steers fed formaldehyde protected casein and sunflower oil had 11.1% 18:2 ω 6 in their intramuscular lipid while those fed unprotected sunflower oil only had 2.9%.

The high levels of 18:2 ω 6 in the beef, however, resulted in problems. The beef had decreased storage life because of the oxidation of the PUFA present and developed oxidative rancidity and off-flavors (Johnson, 1974).

Johnson (1974) also reported that the elaborate method of preparing a protein coated polyunsaturated oil using formaldehyde was too expensive for commercial use. In addition, although formaldehyde is used as a preservative in some foods, it is carcinogenic (Waller, 1989), and is not acceptable as an additive to cattle feed for production of beef.

Since a protein complex with formaldehyde protected polyunsaturated

oils from rumen microbial attack, it is feasible that reactions of proteins with other chemical reagents besides formaldehyde could also. Protein reacted with formaldehyde is also resistant to hydrolysis by rumen microorganisms (Ferguson et al., 1967; Peter, 1971; Zelter et al., 1970). Researchers have found that protein can be protected from proteolysis by rumen microflora by coating agents (Sibbald et al., 1968), heating (Chalmers et al., 1954), and tannin (Zelter and Leroy, 1966). These methods of blocking protein hydrolysis by rumen microflora also need to be investigated as possible protectants for dietary fatty acids from hydrogenation by the rumen microorganisms.

Tannin Effect on Protein Digestion in Ruminants

As previously stated, tannins have the ability to protect protein from proteolysis in the rumen (Kumar and Singh, 1984; Zelter and Leroy, 1966). When soybean meal was complexed with increasing tannin levels from 10 to 25%, the *in vitro* ammonia production by rumen liquor was reduced 92%.

Characteristics of Tannins and Their Reactions With Proteins

The term tannin originally referred to substances capable of tanning leather. A more modern definition is, "any substance with a molecular weight of 500 to 3000 that contains many phenolic hydroxyl groups and is capable of forming bonds with proteins and other molecules" (Swain and Kleiman, 1979).

The reactions between tannins and proteins are not completely understood. It is known, however, that both hydrophobic and hydrogen bonding is involved (Goldstein and Swain, 1965; Hagerman and Butler, 1980, Hoon et al., 1980; Loomis, 1974). The bonding between the protein and tannic acid may render the protein soluble or insoluble depending upon the pH and the concentration of tannic acid. Hagerman and Butler (1978) and Van Buren and Robinson (1969) reported that stronger bonds between the protein and tannic acid were formed when more gelatin was present by weight than tannin.

Haslam et al. (1977) suggested that tannins may be in the form of a helical structure, which may explain why some proteins have a greater affinity for tannins than others. Proteins with a high content of proline are especially reactive with tannins (Hagerman and Butler, 1978; Kumar and Singh, 1984). There is some evidence that the amino acids, glycine and glutamic acid, also react with tannin. Eggum and Christensen (1975) reported that the availability of these two amino acids from the diet were reduced when they were fed in combination with tannins to rats.

Effects of Dietary Tannins on Beef Cattle

The addition of dietary tannins to cattle feed generally results in lower dry matter digestibility (Burns and Cope, 1974; Donnelly and Anthony, 1970, Hawkins, 1955), increased nitrogen excretion (Musha and Eugenia, 1970; Van Soest, 1984; Vohra et al., 1965), reduced metabolizable energy of diets and increased cholesterol level in the blood (Vohra et al., 1965).

Tannins in feed also reduces voluntary feed intake in cattle, probably due to the astringent flavor (Kumar and Singh, 1984; Musha and Eugenia, 1970; Vohra et al., 1965). The low palatability of sericea is attributed to its tannin content (Hawkins, 1955). At a level of 20 mg tannins/g of dry matter, feed is rejected (Kumar and Singh, 1984). Whether or not the tannins make the feed unpalatable, however, may be dependent on the tannin compound. For example, powdered gallotannin does not significantly affect feed intake or lower weight gains in cattle (Hawkins, 1955).

The detrimental effects of dietary tannins on cattle also may be reduced by increasing the dietary protein content. Lease and Mitchell (1940) observed that increasing the protein level in a tannic acid containing diet counteracted the detrimental effects of tannic acid. Increasing the protein content seems to saturate the tannin present negating its effects (Van Buren and Robinson, 1969). Soybean meal is one source of protein fed to overcome the effects of tannins (Hill et al., 1986a). Soybean meal added to tannin containing diets to increase the crude protein content from 10.5 to 15.5% increased the digestion of total digestible nutrients as well as crude fiber and neutral detergent fiber.

Cattle exhibit toxic reactions to 3 to 5% tannins in their diet. The tannins cause degenerative changes in the intestines, liver, spleen and kidney (Gupta et al., 1977), mucus in the urine (Mudgal and Sampath, 1969) and constipation (Lohan et al., 1979).

Tannins also affect the animals ability to utilize food in other ways. Tannins bind digestive enzymes resulting in limited digestion of cellulose (Kumar and Singh, 1984). Tannins also react with the outer cellular layer of

the gut wall restricting movement of nutrients from the gut into the body (Kumar and Singh, 1984). Furthermore, tannins reduce the availability of iron because tannins complex with divalent metal ions (Narasinga and Prabhavathi, 1982; Radhakrishna and Sivaprasad, 1980).

Because of the many reactions of tannins with proteins, it is possible that tannins fed at a low level in combination with a protein supplement containing an unsaturated oil to beef cattle might interfere with the hydrogenation of the unsaturated fatty acids. No reports of studies were found, however, of the effect of tannin-protein complexes on the hydrogenation of unsaturated fatty acids by rumen microorganisms.

An Economical Source of Tannins

One of the limiting factors in producing special cattle feed is the cost. Tannins are naturally present in many plants such as peanuts, sorghum, oak trees and lespedza with some grains containing up to 2.5% tannin on a dry weight basis (Hagerman and Butler, 1978). A cheap source of tannins exists in the form of peanut skins which are by products of peanut butter production. Peanut skins contain 16 to 19.6% tannins, and the peanut industry produces over 30,000 metric tons of peanut skins per year (Hale and McCormick, 1981).

Peanut Skins in the Cattles' Diet

Peanut skins have been fed to cattle. Peanut skins fed to steers at 10%

or less did not affect their performance in a study by McBrayer et al. (1983). Utley and Hellwig (1985) observed that 10% peanut skins added to a bermuda grass pellet diet actually improved the performance of steers. Peanut skins added to cattle diets increased digestible energy (Hill et al., 1986b; Utley and Hellwig, 1985) and fecal nitrogen excretion (Hill et al., 1986b); and decreased food intake (McBrayer et al., 1983).

Cattle Diets Containing Tannins and Full Fat Soybeans

No reports of studies were found in which a combination of tannins from any source and full fat soybeans had been fed to cattle. A combination of full fat soybeans and tannin from peanut skins added to a conventional corn finishing diet for cattle could possibly increase the levels of PUFA in beef. After entering the rumen, tannins could react with the protein in the bean coating the oil which is dispersed in the protein before the rumen microorganisms could hydrogenate the PUFA. These PUFA could then pass into the abomasum and intestinal area, be absorbed in the blood stream and deposited in the beef muscle and fat depots of the animal. The possibility that this could happen needs to be investigated. In addition, the effects of such a diet on beef cattle performance and other characteristics of the resulting beef need to be studied.

III. MATERIALS AND METHODS

Experimental Plan and Diet Composition

In this experiment 35 yearling Angus, Hereford and Angus x Hereford yearling steers were grazed on fescue-clover pasture during the 1987 spring and summer until August 10, 1987. The steers were removed from the pasture and fed a maintenance diet of mixed grass-clover hay and limited concentrate until November 5, 1987. The steers were then divided into 7 groups of five steers per group. Each group in comparison with the other groups contained similar steers in body size and weight.

Each of these 7 groups were randomly allocated to one of 7 treatments. Treatment 1 steers were slaughtered after removal from the maintenance diet or at 0 days (DOF) of a grain diet. The other 6 groups of steers were each placed in individual feeding pens at the University of Tennessee Plateau Experiment Station at Crossville, TN. A 14 day adjustment period was allowed for each group of steers to become accustomed to an assigned grain diet. Two groups of steers were adjusted to a control corn diet, two groups of steers were adjusted to a corn + soybeans diet and the remaining two groups of steers were adjusted to a corn + soybeans: peanut skins diet. The ingredients, proximate composition, mineral content and cost of each of these diets are given in Table 1. After the adjustment period, steers in Treatments 2 and 3 were fed the control corn diet for 56 and 112 days, respectively, before slaughter; steers in Treatments 4 and 5 were fed the corn + soybeans diet for 56 and 112 days, respectively, before slaughter,

Table 1. Composition of diets fed to steers from 0 to 112 days (DOF).

Item	Diets		
	Control corn	Corn + soybeans	Corn+soybeans: peanuts skins
<u>Ingredients</u>			
Whole-shelled corn, %	92.81	89.65	78.31
Tend-R-Lean ^a , %	7.19	-	-
Soybeans, roasted ^b , %	-	9.33	-
Soybeans:peanut skins, roasted ^c , %	-	-	20.72
Limestone, %	-	1.02	.97
<u>Proximate composition</u>			
Dry matter, %	86.45	86.63	87.21
Crude protein, %	12.39	13.13	17.03
Fat, %	3.97	5.67	7.50
Crude fiber, %	3.82	3.27	3.63
Acid detergent fiber, %	2.76	3.67	4.53
Neutral detergent fiber, %	8.28	8.98	9.11
<u>Mineral content</u>			
Calcium, %	.22	.50	.50
Phosphorus, %	.35	.32	.36
Potassium, %	.37	.54	.71
<u>Cost</u>			
Dollars/ton fed	117.80	129.25	146.19

^aPurchased from TN Farmers Co-op with no rumensin added.

^bSoybeans were extruded.

^cThe soybeans:peanut skins ratio was 1.00.

and steers in Treatments 6 and 7 were fed the corn + soybeans:peanut skins diet, respectively, for 56 and 112 days before slaughter.

The full fat soybeans were purchased from and extruded in a Triple F Extruder at Dicksey Farm Supply in Manchester, TN. The peanut skins were obtained from JFG Coffee Company in Knoxville, TN, and were included without further treatment in the diet.

Treatment and Performance of Steers

All 35 steers were individually weighed at 0-DOF. Thirty steers (Treatments 2 through 7) were each weighed after the adjustment period, and at 28 and 56 DOF. Fifteen steers (Treatment 3, 5, and 7) were each weighed at 84 and 112 DOF. The weight of feed eaten per day by each group of steers was also measured throughout the adjustment period and for each group of steers until slaughtered. From these data, an average daily gain (ADG) in kg gain/day for each steer was calculated across 56 DOF (ADG₅₆) for all steers in Treatments 2 through 7. ADG from 57 to 112 DOF (ADG₁₁₂) was also calculated for the steers in Treatments 3, 5 and 7. A percentage increase in body weight was also calculated for each steer in Treatments 2 through 7 for the feeding period from 0-DOF to slaughter. An average feed conversion rate (kg of feed/kg gained) for steers on each diet from 0 to 56 DOF and from 57 to 112 DOF was also calculated.

Slaughter and Carcass Characteristics and Sampling

Steers were transported from the Plateau Experiment Station to Lay's Packing Company in Knoxville, TN, by truck prior to slaughter. After slaughter, the hot carcass weight was determined for each steer and the carcass was stored at 5 to 6 C for 48 hours prior to collection of other carcass data. For each steer carcass, the adjusted fat thickness in cm was measured over the 12-13th rib; the rib eye area (cm²) was determined by tracing the rib eye on acetate paper placed over a grid on the rib eye and measuring the area with a planimeter; the % kidney, pelvic and heart (KPH) fat estimated; and the yield grade and quality grade were determined.

After the carcass data was collected at Lay's Packing Company, a hindquarter from each steer carcass was transported to the University of Tennessee Meats Lab. Upon arrival, approximately 100 g of the longissimus muscle and 50 g of subcutaneous fat from over the sirloin area were removed from each steer hindquarter for chemical analyses. Each longissimus and fat sample was placed in separate, closed Whirl-Pak polyethylene bags (Nasco) and stored at -35 C prior to being frozen in liquid nitrogen and shattered in a 1 quart stainless steel jar of a Waring blender. Each powdered sample was then stored at -35 C in a Whirl-Pak bag no longer than 6 weeks until analyzed.

After removal of the chemical samples, the remainder of each hindquarter was aged at 5 to 6 C for 10 additional days. After aging, four steaks (2.54 cm thick) were removed from the anterior end of the loin of each hindquarter. Steaks from each steer were wrapped individually in

polyethylene coated freezer paper and stored at -35 C until analyzed for sensory characteristics and Warner Bratzler shear values.

Chemical Analyses

Total lipids were extracted from 40 g of the longissimus muscle sample and 4 g of the subcutaneous fat sample for each steer and quantitated (% total lipids) by the chloroform-methanol method of Melton et al. (1979). After quantitation, the remaining lipid extract from each sample was dried to dryness at 45 C under a vacuum with a slight flow of nitrogen on a rotary evaporator. The dried residue was dissolved in 25-ml of chloroform and stored under nitrogen in a covered, 25-ml Erlenmeyer flask at -18 C for further analysis.

The fatty acid composition of the total lipids from the longissimus muscle sample and subcutaneous fat sample from each steer was determined according to the method of the AOCS (1975). The total lipids were saponified by heating in a 0.5 N methanol KOH solution for 10 min and the methyl esters of the fatty acids were made using boron trifluoride in methanol. The fatty acid methyl esters were analyzed on a 0.25 mm i.d. by 30 meter long fused silica SP-2330 capillary column (Supelco, Inc., Bellefonte, PA). The temperature program for analysis was from 150 to 220 C at 2 degrees/min on a Shimadzu Model 6AM gas chromatograph equipped with flame ionization detector and a Shimadzu Model E-1A data processor. A helium carrier gas was used at a flow rate of 40 ml/min and the split ratio for the capillary column was 30:1.

Individual fatty acid methyl esters were identified by matching their relative retention times with those of standard fatty acid methyl esters analyzed under exactly the same conditions. The percentage of each fatty acid was determined according to AOCS (1975) Method Ce-1-62 using the average correction factors given in Table 2. These correction factors were determined from multiple analyses of standard fatty acid mixture RM-6 (Supelco, Inc.), the recommended standard for animal fat analysis. The correction factor of all fatty acids not listed in Table 2 was assumed to be 1.00. The percentages of the following fatty acids were determined: capric (10:0), undecanoic (11:0), lauric (12:0), tridecanoic (13:0), myristic (14:0), 14-methyl tetradecanoic (A15:0), myristoleic (14:1), pentadecanoic (15:0), palmitic (16:0), 16-methyl hexadecanoic (A17:0), palmitoleic (16:1), an isomer of 16:1 (16:1 ISO), margaric (17:0), heptadecenoic (17:1), stearic (18:0), oleic (18:1 ω 9), isomer 1 of oleic (18:2 ISO1), isomer 2 of oleic (18:1 ISO2), an isomer of linoleic (18:2 ISO), linoleic (18:2 ω 6), isomer 1 of linoleic (18:2 ISO1), isomer 2 of linoleic (18:2 ISO2), isomer 3 of linoleic (18:2 ISO3), an isomer of linolenic (18:3 ω 6), eicosanoic (20:0), linolenic (18:3 ω 3), eicosenoic (20:1), eicosadienoic (20:2), eicosatrienoic (20:3), doeicosanoic (22:0), arachidonic (20:4 ω 6), 2,5,8, 11,14- eicosapentenoic (20:5 ω 6), tetraeicosanoic (24:0), 5,8,11,14,17- eicosapentenoic (20:5 ω 3), 4,7,10,13,16-doeicosapentenoic (22:5 ω 6), 7,10,13, 16,19-doeicosapentenoic (22:5 ω 3) and 4, 7, 10, 13, 16, 19-doeicosahexenoic acid (22:6 ω 3).

Percentages of the following fatty acid types were also calculated: SAT 10-15C (%10:0+%11:0+%12:0+%13:0+%14:0+%15:0), SAT 16-24C (%16:0+

Table 2. Correction for calculation of fatty acid percentages in lipids of beef longissimus muscle and subcutaneous fat lipids.

Fatty acid	Percentage in standard ^a	Correction factor ^b
14:0	2.0	.9684
16:0	30.0	1.0000
16:1	3.0	.9334
18:0	14.0	.9871
18:1	41.0	.9998
18:2 ω 6	7.0	.9526
18:3 ω 3	3.0	.8989

^aAOAC Standard No. 6.

^bEach correction factor is an average of 6 determinations.

%17:0+%18:0+%20:0+%22:0+%24:0), MONO (%14:1+%15:1+%16:1+ %17:1+ %18:1+ %20:1), PUFA6 (%18:2 ω 6+%18:3 ω 6+%20:4 ω 6+%20:5 ω 6+%22:5 ω 6), PUFA3 (%18:3 ω 3+ %20:5 ω 3+%22:5 ω 3 +%22:6 ω 3) and UNKNOWNNS, a group of unknown fatty acids represented by 81 gas chromatographic peaks with retention times ranging from 4.14 to 38.80 min were also determined. The sum of percentages of the unknown fatty acids plus the sum of the percentages of the known fatty acids equalled 100 for the longissimus muscle lipid sample and subcutaneous lipid sample, respectively, of each steer.

Sensory Evaluation

Steaks from five steers at a time were evaluated by a 56-member untrained panel per sitting from 1:30 to 4:30 pm 7 days out of a two week period.. Each sitting represented a block and the steaks from the five steers per sitting were selected at random.

Steaks from the five steers were removed from the freezer and thawed overnight at 5 C. The thawed steaks were placed on broiler pans and broiled in a 204.4 C Rotary Despatch oven to an internal temperature of 21.1 C. The longissimus muscle from the steaks of each steer was sliced into 1.25 cm cubes which were kept warm in ceramic dishes on a warming tray (55 C) until evaluated by the panelists. Samples from each of the 5 steers per panel sitting were presented one at a time in a random order to each panelist. Each panelist evaluated a sample from each steer for aroma, flavor and overall acceptability on an 8-point scale where 8=like

extremely, 7=like very much, 6=like moderately, 5=like slightly, 4=dislike slightly, 3=dislike moderately, 2=dislike very much and 1=dislike extremely.

Warner-Bratzler Shear

Sections of the longissimus muscle from the steaks broiled to an internal temperature of 21.1 C as described previously were stored overnight at 5 C. Six 1.27 cm cores were removed from these sections and were bisected on a Warner-Bratzler shear tester. The average force required to shear the samples from each steer was determined in grams.

Statistical Analyses

Dependent variables from the steers performance on the different diets and analyses of the resulting beef produced on the different diets from 0 to 112 days (DOF) were analyzed as a function of treatment as shown in Table 3. Treatment sum of squares were partitioned by orthogonal comparisons, C1 through C6, shown in Table 4, and these specific comparisons were used to test for significant differences among treatment means. Either linear or quadratic equations were obtained using the General Linear Model of Statistical Analysis System (SAS, 1985) to explain the significant ($P<.05$) DOF effects on each dependent variable. These dependent variables included weight of steer at 0 DOF, hot carcass weight, rib-eye area, % kidney, pelvic, heart fat, fat thickness over the

Table 3. Analysis of variance for dependent variables as a function of treatments for 35 steers grazed on pasture and then fed different diets from 0 to 112 days (DOF).

Source	Degrees of freedom
Treatment	6
C1 ^a	1
C2 ^a	1
C3 ^a	1
C4 ^a	1
C5 ^a	1
C6 ^a	1
Error	28
Total	34

^aOrthogonal comparisons are shown in Table 4.

Table 4. Orthogonal comparisons for separation of treatment sum of squares for characteristics of 35 steers grazed on pasture and then fed different diets for 112 days.

Orthogonal comparison	Treatment ^a						
	1	2	3	4	5	6	7
C1 ^b	-3	0	1	0	1	0	1
C2 ^b	3	-2	1	-2	1	-2	1
C3 ^b	0	0	0	-1	-1	1	1
C4 ^b	0	0	0	-1	1	1	-1
C5 ^b	0	0	0	-1	1	-1	1
C6 ^b	0	2	2	-1	-1	-1	-1

^aTreatment 1=0 days on feed (DOF); 2=control corn diet for 56 DOF; 3=control corn diet for 112 DOF; 4=corn + soybeans (SB) diet for 56 DOF; 5=corn + SB diet for 112 DOF; 6=corn + soybeans:peanut skin (SB:PS) diet for 56 DOF; 7=corn + SB:PS diet for 112 DOF.

^bC1 is a linear DOF effect; C2 is a quadratic DOF effect; C3 compares corn + SB diet with corn + SB:PS diet; C4 is the interaction of the SB containing diets; C5 compares 56 DOF with 112 DOF for SB containing diets; and C6 compares control corn diet with corn + SB and corn + SB:PS diets.

12-13th rib, yield grade, quality grade, slaughter weight, % intramuscular lipid in the longissimus muscle, % lipid in the subcutaneous fat over the sirloin, and the percentages of the following fatty acids, both in subcutaneous fat and intramuscular fat: 10:0, 11:0, 12:0, 13:0, 14:0, 15:0, 14:1, 15:0 15:1, 16:0, 17:0, 16:1, 16:1 ISO, 17:0 17:1, 18:0, 18:1, 18:1 ISO1, 18:1 ISO2, 18:2 ISO, 18:2 ω 6, 18:2 ISO11, 18:2 ISO2, 18:2 ISO3, 18:3 ω 6, 20:0, 18:3 ω 3, 20:1, 20:2, 20:3, 20:4 ω 6, 20:5 ω 6, 20:5 ω 3, 24:0, 22:5 ω 6, 22:5 ω 3, and 22:6 ω 6. In addition, the percentages of the fatty acid types, SAT 10-15C, SAT 16-24C, MONO, PUFA6, PUFA3, and UNKNOWNS were also analyzed.

The ADG56 and percentage increase in body weight for the 30 steers in Treatments 2 through 7 were also statistically analyzed as a function of treatments (6) as shown in Table 5. The treatment sums of squares were partitioned by orthogonal comparisons, CA through CE, given in Table 6.

In addition, ADG at 56 DOF and ADG at 112 DOF for the fifteen steers in Treatments 3, 5 and 7 were statistically analyzed as shown in Table 7, and significant differences among diets and ADG periods were identified by orthogonal comparisons, Contrast 1 through Contrast 5, shown in Table 8.

The concentration of each of the fatty acids and fatty acid types previously listed were also analyzed as a function of their carcass site (subcutaneous versus intramuscular), treatment and site x treatment interaction as shown in Table 9. Only significant differences between sites were determined for each dependent variable from these statistical analyses since the treatment effects were statistically analyzed for each

Table 5. Analysis of variance for the dependent variables analyzed for the 30 steers in Treatments 2 through 7.

Source	Degrees of freedom
Treatment	5
C-A ^a	1
C-B ^a	1
C-C ^a	1
C-D ^a	1
C-E ^a	1
Error	24
Total	29

^aOrthogonal comparisons are given in Table 6.

Table 6. Orthogonal comparisons for the dependent variables analyzed for the 30 steers in Treatments 2 through 7.

Comparison	Treatments ^a					
	2	3	4	5	6	7
C-A	0	0	-1	-1	1	1
C-B	0	0	-1	1	1	-1
C-C	0	0	-1	1	-1	1
C-D	2	2	-1	-1	-1	-1
C-E	-1	1	-1	1	-1	1

^aTreatments 2 and 3 were the control corn diet fed 56 and 112 DOF, respectively; treatments 4 and 5 were corn + soybeans diet fed 56 and 112 DOF, respectively, and treatments 6 and 7 were corn + soybeans:peanut skins fed 56 and 112 DOF, respectively.

Table 7. Analysis of variance for average daily gain at 56 DOF (ADG56) and from 57 to 112 DOF (ADG112) for fifteen steers fed different diets for 112 days before slaughter.

Source	Degrees of freedom
Treatment (T)	2
Period of ADG (P)	1
T x P	2
Contrast 1 ^a	1
Contrast 2 ^a	1
Contrast 3 ^a	1
Contrast 4 ^a	1
Contrast 5 ^a	1
Error	9
Total	14

^aOrthogonal comparisons are given in Table 8.

Table 8. Orthogonal comparisons for partitioning main effect sums of squares for average daily gain of 15 steers fed different diets for 112 days before slaughter.

Comparison	Control corn ^a		Corn + soybeans ^a		Corn + soybeans: peanut skins ^a	
	ADG56 ^b	ADG112 ^b	ADG56	ADG112	ADG56	ADG112
Contrast 1	1	-1	1	-1	1	-1
Contrast 2	2	2	-1	-1	-1	-1
Contrast 3	0	0	-1	1	0	0
Contrast 4	0	0	0	0	-1	1
Contrast 5	0	0	1	1	-1	-1

^aDescription of diets fed.

^bADG56 is the average daily gain of these steers for 56 days of full diet feeding and ADG112 is the average daily gain of the same steers fed the same diets from 57 to 112 days.

Table 9. Analysis of variance for site differences in percentages of fatty acid and fatty acid types.

Source	Degrees of freedom
Site	1
Treatment	6
Site x treatment	6
Error	56
Total	69

site separately.

The sensory characteristics, aroma, taste and acceptability and shear value were analyzed as shown in Table 10. The orthogonal contrasts C1 through C6 shown in Table 4, p. 25, were used to partition the sums of squares for each dependent variable and to identify significantly different treatment means.

Correlation coefficients of the percentage of each fatty acid and fatty acid type in the intramuscular lipids of the longissimus muscle with each of the sensory scores for aroma, flavor and overall acceptability were determined. Selected correlation coefficients, mainly those that were significant, are presented.

Table 10. Analysis of variance for sensory characteristics of the longissimus from steers grazed on pasture and fed different diets for 112 days (DOF).

Source	Degrees of freedom
Treatment	6
C1 ^a	1
C2 ^a	1
C3 ^a	1
C4 ^a	1
C5 ^a	1
C6 ^a	1
Error (T*block)	22
Residual	6
Total	34

^aOrthogonal comparisons are given in Table 4, p.25.

IV. RESULTS AND DISCUSSION

Steer Weights and Carcass Characteristics

The analyses of variance for weight of steers and carcass characteristics as a function of treatment are given in Table 11. The hot carcass weight, rib-eye area, % KPH fat, fat thickness, yield grade, and quality grade were all significantly affected by treatment. Beginning weight of steers was not affected by treatment ($P>.05$). When treatment sum of squares was partitioned by orthogonal comparisons, the slaughter weight, hot carcass weight, rib-eye area, % KPH fat, fat thickness, yield grade, and quality grade were found to be significantly affected by DOF (C1 and/or C2, Table 11). The main differences among treatments for all of these characteristics were due to the DOF effect (C1 and C2 comparisons). The only other significant comparison for any characteristic was C6 for hot carcass weight which compared control diet with diets containing soybeans.

Average values for steer weight and carcass characteristics for each diet and DOF are presented in Table 12. Hot carcass weight, rib-eye area, fat thickness, quality grade and slaughter weight increased quadratically from 0 to 112 DOF as shown in Tables 11 and 13. The % KPH fat and yield grade increased linearly from 0 to 112 DOF as shown in those same tables, respectively. These results are consistent with those from Bidner et al. (1981), Bowling et al. (1978), Hancock et al. 1987, Hidiroglou et al. (1987), Leander et al. (1978), Newsome et al. (1985), Reagan et al. (1983), Schroeder et al. (1980), Tatum et al. (1980), and Utley et al. (1975) who

Table 11. Sums of squares^a from analyses of variance of steer weights and carcass characteristics for steers grazed on grass and then fed different diets from 0 to 112 days (DOF).

Source	Degrees of freedom	Beginning weight	Hot carcass weight	Rib-eye area	%KPH fat
Treatment	6	3344	382236.**	64.63**	5.471*
C1 ^b	1	2535	311184.**	48.06**	4.537**
C2 ^b	1	72	41406.**	11.67*	.273
C3 ^b	1	71	2712.	.30	.018
C4 ^b	1	125	769.	.02	.313
C5 ^b	1	33	1480.	.12	.067
C6 ^b	1	508	24685.*	4.46	.264
Error	28	239320	126800.	46.25	3.700
Total	34	242664	509037.	110.88	9.171

		Fat thickness	Yield grade	Quality grade	Slaughter weight
Treatment	6	.6869*	5.911*	133.5**	610450.
C1 ^b	1	.6202**	5.52**	114.8**	499594.**
C2 ^b	1	.0425*	.11	8.4*	85020.*
C3 ^b	1	.0080	.07	.2	4247
C4 ^b	1	.0048	.06	4.1	6661
C5 ^b	1	.0000	.06	5.1	673
C6 ^b	1	.0114	.09	1.0	14255
Error	28	.2195	4.308	32.0	360860.
Total	34	.9064	10.219	165.5	971310.

^a* $p < .05$; ** $p < .01$ level.

^bC1 is a linear DOF effect; C2 is a quadratic DOF effect; C3 compares the diet containing soybeans (SB) with the diet containing SB:peanut skins; C4 is the interaction of soybean diets with 56 and 112 DOF; C5 compares 56 versus 112 DOF for diets containing SB; and C6 compares the control diet to both diets containing SB.

Table 12. Average values for steer weights and carcass characteristics for steers grazed on pasture and then fed different diets from 0 to 112 day (DOF) for type of diet and DOF.

Variable	Beginning steer weight (kg)	Hot car- cass weight (kg)	Rib-eye area (cm ²)	Fat thickness ^a (cm)	KPH fat ^b (%)
DIET					
Control corn (n=10)	362	301 ^c	80.6	1.17	1.9
Corn + soybeans (n=10)	362	279 ^d	72.9	.99	1.9
Corn + soybeans: peanut skins (n=10)	364	272 ^d	70.3	.99	1.8
DOF^e					
0 (n=5)	372	185	56.1	.22	1.0
56 (n=15)	365	252	68.4	.86	1.6
112 (n=15)	360	316	79.2	1.25	2.1

	Yield grade	Quality grade ^f	Slaughter weight (kg)
DIET			
Control corn (n=10)	2.7	11.6	528
Corn + soybeans (n=10)	2.6	11.5	493
Corn + soybeans: peanut skins (n=10)	2.6	10.8	481
DOF^e			
0 (n=5)	1.7	7.0	372
56 (n=15)	2.4	10.0	464
112 (n=15)	2.9	12.0	538

^aMeasured at the 12th to 13th rib.

^bEstimate of kidney, pelvic and heart fat.

^{c,d}For DIET, means in a column followed by different superscripts are significantly different at the $P < .05$ level.

^eHot carcass weight, rib-eye area, fat thickness, quality grade and slaughter weight were significantly affected quadratically by DOF, and yield grade and KPH were significantly affected linearly by DOF.

^f7=Standard, 8=High Standard, 9=Low Good, 10=Good, 11=High Good and 12=Low Choice.

Table 13. Equations showing significant DOF effects on steer weights and carcass characteristics for steers grazed on pasture and then fed different diets from 0 to 112 days (DOF).

Charac- teristic	R ²	Equation ^a
Hot carcass weight	.694	$Y = 185 + 1.195(\text{DOF}) - .000256 (\text{DOF})^2$
Rib-eye area	.485	$Y = 56.1 + .2238(\text{DOF}) - .000157(\text{DOF})^2$
Fat thickness	.710	$Y = .22 + .0137(\text{DOF}) - 3.99 \times 10^{-5}(\text{DOF})^2$
KPH fat	.540	$Y = 1.04 + .0096(\text{DOF})$
Yield grade	.554	$Y = 1.8 + .0103(\text{DOF})$
Quality grade	.754	$Y = 7.0 + .0601(\text{DOF}) - 9.57 \times 10^{-5}(\text{DOF})^2$
Slaughter weight	.560	$Y = 820 + 3.955(\text{DOF}) - .00622 (\text{DOF})^2$

^ay = Characteristic.

reported that grass fed cattle (0 DOF) had lower hot carcass weights, rib eye areas, fat thickness, quality grades, slaughter weights, % KPH fat, and yield grade than did grain fed cattle. Bidner et al. (1981), however, found feeding grain to cattle did not affect yield or quality grades in their study.

The beginning weight of the steers prior to grain feeding ranged from 360 to 372 kg (Table 12). The average slaughter weight of the steers killed at 0-DOF was the same as their beginning weight since they were the base line group. The average slaughter weight of steers fed 56 DOF was 464 kg and of steers fed 112 DOF, 538 kg. The average 0 DOF steer carcass weighed 185 kg when hot, had a 56.1 cm² rib-eye area, a 0.22 cm fat thickness over the 12-13th rib, 1.0% KPH fat, a 1.7 yield grade and a standard quality grade (Table 12). The average 56-DOF steer carcass had a hot weight of 252 kg, a rib-eye area of 68.4 cm², a fat thickness of 0.86 cm, a KPH% of 1.6, a yield grade of 2.4, a quality grade of Good. Finally, the average 112 DOF carcass weighed 316 kg hot, had a 79.2 cm² rib-eye area, a 1.25 cm fat thickness, 1.6% KPH fat, a 2.4 yield grade, and a low choice quality grade (Table 12).

The only significant difference among the different diets was in the hot carcass weight. Steers fed the control diet had a heavier mean hot carcass weight (301 kg) than the 272 and 279 kg mean hot carcass weight of the steers fed soybean supplemented corn diets, with and without peanut skins, respectively (Table 12). Contrary to the results observed in this study, Rule et al. (1986) showed that compared to feeding cattle a corn diet only, feeding cattle a corn and full fat soybean diet did not result in differences in the carcass weights ($P>.05$). Also, although cattle fed the soybean supplemented corn diets had a 19% greater fat thickness and 29% greater

KPH fat, as well as a larger rib eye area and USDA yield and quality grades, than cattle fed the corn diet in the study of Rule et al. (1986), these differences were not significant ($P>0.05$). In the present study steers fed the soybean supplemented corn diets tended to have less fat thickness and % KPH fat and lower yield and quality grades than steers fed the corn diet only.

Steer Performance

Since five of the 35 steers in this experiment were slaughtered at 0 DOF, it was impossible to calculate the ADG at 56 days or % weight increase for 0 to 56 DOF for those steers. The analyses of variance for these variables as a function of treatment for the remaining 30 steers are given in Table 14. The percentage weight increase from 0 to 56 DOF was significantly affected by treatment and after treatment sums of squares were partitioned for ADG-56 DOF, the orthogonal comparison C-D was found to be significant (Table 14). C-D compared the control corn diet to the soybean supplemented diets (Table 6, p. 27).

Steers fed the control corn diet gained an average of 1.70 kg per day which was significantly greater than the 1.22 or 1.23 kg/day gained by steers fed the soybean supplemented diets (Table 15). The average feed conversion rate for the control corn, corn + soybeans and the corn + soybeans:peanut skins diets, respectively, for 56 DOF was 6.68, 7.49 and 7.68 kg feed/kg gain, and from 56 to 112 DOF was 7.70, 5.66 and 9.01. Again, as previously noted, the results of Rule et al. (1986) do not coincide with

Table 14. Sums of squares^a from analyses of variance for average daily gain through 56 DOF and percentage weight increase for steers from 0 up to 112 days (DOF) of feeding different diets.

Source	Degrees of freedom	ADG-56 DOF ^b	Weight increase, %
Treatment	5	7.234	1342.**
C-A ^c	1	.007	21.
C-B ^c	1	.010	33.
C-C ^c	1	.018	635.**
C-D ^c	1	7.196**	225.**
C-E ^c	1	.001	428.**
Error	24	18.399	298
Total	29	25.633	1640

^a*p<.05; **p<.01;

^bAverage daily gain through 56 days on diets.

^cSee Table 6, p. 27, for definition of orthogonal comparisons.

Table 15. Means for average daily gain through 56 days of feeding on different diets and percentage weight increase in steers from 0 up to 112 days (DOF) of feeding different diets for type of diet and DOF.

Variable	Average daily gain (ADG56) (kg gain/day)	Weight increase (%)
<u>DIET</u>		
Control corn (n=10)	1.70 ^a	30.9 ^a
Corn + soybeans (n=10)	1.23 ^b	26.1 ^b
Corn + soybeans: peanut skins (n=10)	1.22 ^b	24.1 ^b
<u>DOF</u>		
56 (n=15)	1.37	21.1 ^c
112 (n=15)	1.39	32.9 ^d

^{ab}For DIET, means in a column followed by different superscript letters are significantly different at the $P<0.05$ level.

^{cd}For DOF, means in a column followed by different superscript letters are significantly different at the $P<0.05$ level.

the results of the present study. Rule et al. (1986) showed that soybeans added to a corn diet did not affect ADG ($P>.05$).

When the sums of squares for percentage weight increase were partitioned for 15 steers fed 0 to 112 days, the comparisons C-C, C-D, and C-E were significant (Table 14). Steers fed the control corn diet had a weight increase of 30.9% averaged across DOF, which was significantly greater than the steers fed diets containing soybeans or soybeans + peanut skins. Steers fed the latter two diets had a mean weight increase of 26.1 and 24.1%, respectively. One would expect the opposite to be true, due to the fat content of soybeans and the results from previous research (Rule et al., 1986). Furthermore, when comparing ADG₅₆ between steers slaughtered after 56 DOF and those slaughtered after 112 DOF, the 56 DOF steers gained 21.1% in weight which was less than 32.9 % increase of the 112 DOF steers ($P<.05$). The reason why the 112 DOF steers gained more weight than the 56 DOF steers during the first 56 days of feeding is not known at the present time.

Table 16 shows the analysis of variance for the average daily gain during two periods (0 to 56 DOF and 57 to 112 DOF) for the 15 steers fed the three diets for 112 days. The orthogonal contrasts used to separate diet, period and diet x period interaction are defined in Table 8, p. 28. The only significant difference found was defined by Contrast 3 which compared average daily gain from 0 to 56 DOF with average daily gain from 57 to 112 DOF for steers fed the corn + soybeans diet. Steers on this diet gained 1.51 kg/day from 57 to 112 DOF compared with 1.24 kg/day from 0 to 56 DOF (Table 17).

Table 16. Sums of squares^a from analysis of variance for the average daily gains of the 15 steers grazed on grass and then fed different diets 0 to 112 days (DOF) before slaughter.

Source	Degrees of freedom	Average daily gain
Diet (D)	2	4.115
Period of ADG (P)	1	.070
D X P	2	1.943
Contrast 1 ^b	1	.070
Contrast 2 ^b	1	2.383
Contrast 3 ^b	1	3.050*
Contrast 4 ^b	1	.379
Contrast 5 ^b	1	.245
Error	24	16.567
Total	29	22.694

^a* $p < .05$.

^bSee Table 8, p. 28, for the definition of each orthogonal comparison Contrast 1 through Contrast 5.

Table 17. Average daily gain from 0 to 56 DOF and from 56 to 112 DOF of the 15 steers grazed on pasture and then fed different diets from 0 to 112 days (DOF) for type of diet.

Diet	Average daily gain (kg/day)	
	0 to 56 DOF	57 to 112 DOF
Control corn (n=5)	1.70	1.45
Corn + soybeans (n=5)	1.24 ^a	1.51 ^b
Corn + soybeans: peanut skins (n=5)	1.25	1.09

^{ab} Means followed in a row followed by different superscripts are significantly different at the $P < 0.05$ level.

Fat Level and Fatty Acid Composition of Two Sampling Sites

The analyses of variance for the percentage lipid in samples from the longissimus muscle and the subcutaneous fat over the sirloin area are given in Table 18. The orthogonal contrasts C1 through C6 in Table 18 are defined in Table 4, p. 25. Significant treatment effects were found for the percentage lipid in both samples. The percentage lipid in the longissimus muscle increased quadratically from 2.58% at 0 DOF to 8.03% at 112 DOF (Table 19). The percentage of lipid in the subcutaneous fat over the sirloin also increased quadratically from 60.4% to 83.1% as DOF increased from 0 to 112 (Table 19).

Table 20 gives the analyses of variance for the percentage of fatty acids and fatty acid types in the fat as a function of the different sampling sites. Treatment effects and the treatment by site interaction on the fatty acids are also given in Table 20; however, treatment effects on each fatty acid will be analyzed for each site and will be discussed later. The percentage of the fatty acids 11:0, 12:0, 14:0, 15:0, 14:1, 15:1, 16:0, 16:1, 16:1 ISO, 17:1, 18:1 ω 9, 18:2 ISO, 18:2 ω 6, 18:2 ISO 2, 18:3 ω 6, 18:3 ω 3, 20:3, 20:4 ω 6, 24:0, 20:5 ω 3, 22:5 ω 3, and 22:6 ω 3 were all significantly affected by sampling site. The levels of the fatty acid types: Sat 10-15C, SAT 16-24C, PUFA6, PUFA3 and UNKNOWNS were also significantly affected by sampling site.

The percentages of 11:0, 12:0, 14:0, 15:0, 14:1, 15:1, 16:0, 16:1, 16:1 ISO, 17:1, 18:2 ISO, 18:2 ISO 2 and 24:0 were all higher ($P < .05$) in

Table 18. Sums of squares^a from analyses of variance for percentage lipid in the longissimus muscle intramuscular and the subcutaneous fat over the sirloin area of steers grazed on pasture and then fed different diets from 0 to 112 days (DOF).

Source	Degrees of freedom	Intramuscular lipid	Subcutaneous fat
Treatment	6	141.5**	2031.1**
C1 ^b	1	3.9	1150.8**
C2 ^b	1	125.0**	827.2**
C3 ^b	1	1.1	3.7
C4 ^b	1	4.6	48.3
C5 ^b	1	0.8	0.5
C6 ^b	1	6.2	0.6
Error	26	163.5	1331.7
Total	32	305.1	3362.8

^a** $p < 0.01$.

^bC1 is a linear DOF effect; C2 is a quadratic DOF effect; C3 compares the diet containing soybeans (SB) with the diet containing SB:peanut skins; C4 is the interaction of soybean diets with 56 and 112 DOF; C5 compares 56 versus 112 DOF for diets containing SB; and C6 compares the control diet to both diets containing SB.

Table 19. Average percentage lipid in the intramuscular lipid of the longissimus muscle and subcutaneous fat over the sirloin of steers grazed on pasture and then fed different diets from 0 to 112 day (DOF) for type of diet and DOF.

Variable	Intramuscular lipid	Subcutaneous fat
	-----% Lipid-----	
<u>DIET</u> ^a		
Control corn (n=10)	7.03	81.6
Corn + soybeans (n=10) ^b	6.50	81.7
Corn + soybeans: peanut skins (n=10)	5.87	80.8
<u>DOF</u> ^c		
0 (n=5) ^d	2.58	60.4
56 (n=15) ^d	4.80	79.6
112 (n=15)	8.03	83.1

^aNo significant differences were found among the diets for the percentage fat in the two fat depot sites.

^bn=9 for the intramuscular lipid.

^cSignificant quadratic DOF effects were found both fat depot sites; for the intramuscular lipid, % fat = $2.58 + .03064(\text{DOF}) + .000161(\text{DOF})^2$ and for the subcutaneous fat, % fat = $60.4 + .4841(\text{DOF}) - .00251(\text{DOF})^2$.

^dFor the intramuscular lipid, n=4 for 0 DOF and n=14 for 56 DOF.

Table 20. Sums of squares^a from analyses of variance for levels of fatty acids and fatty acid types from different sites in steers grazed on grass pasture and then fed different diets from 0 to 112 days (DOF).

Source	Degrees of freedom	Fatty acids			
		10:0	11:0	12:0	13:0
Site (S)	1	27.5	.010**	.0044**	.0006
Treatment (T)	6	53.1	.069**	.0014	.0063*
S x T	6	17.4	.094**	.0008	.0003
Error	54	461.9	.081	.0166	.0214
Total	67	559.9	.255	.0231	.0287

		14:0	15:0	14:1	15:0
Site (S)	1	14.06**	.0755**	2.84**	.92**
Treatment (T)	6	6.04**	.4584**	.75	1.85*
SxT	6	1.73	.0349**	.50	.07
Error	54	15.01	.0747	3.56	5.76
Total	67	36.84	.6434	7.65	8.60

		15:1	16:0	17:0	16:1
Site (S)	1	.0238**	175.**	.063	14.18**
Treatment (T)	6	.2419**	45	.745**	12.82*
SxT	6	.0092	87	.157	3.99
Error	54	.0552	749	1.020	48.23
Total	67	.3301	1057	1.985	79.23

Table 20 (Continued)

Source	Degrees of freedom	Fatty acids			
		16:1 ISO	17:0	17:1	18:0
Site (S)	1	1.292**	1.04	.97*	1
Treatment (T)	6	.854**	6.62*	8.66**	278.**
SxT	6	.208	.78	1.08	9
Error	54	1.580	20.87	11.34	176
Total	67	3.934	29.31	22.04	464

		18:1 ~~ISO~~	18:1 ISO1	18:1 ISO2	18:2 ISO
Site (S)	1	248.*	.0022	.020	.0170**
Treatment (T)	6	425	.0365	.145	.0166
SxT	6	161	.0322	.024	.0022
Error	54	2691	.3348	.903	.0901
Total	67	3525	.4058	1.091	.1260

		18:2 ~~ISO~~	18:2 ISO1	18:2 ISO2	18:2 ISO3
Site (S)	1	17.15**	.0032	.0185*	.0026
Treatment (T)	6	8.38*	.1924**	.1130**	.0894**
SxT	6	2.34	.0615	.0138	.0070
Error	54	28.81	.3808	.2442	.1382
Total	67	56.68	.6380	.3896	.2373

Table 20 (Continued)

Source	Degrees of freedom	Fatty acids			
		18:3 ω 6	20:0	18:3 ω 3	20:1
Site (S)	1	.0078**	.0029	.053**	.058
Treatment (T)	6	.0022	.0528**	1.628**	.773
SxT	6	.0024	.0096	.228**	.313
Error	54	.0281	.0737	.278	5.454
Total	67	.0405	.1390	2.187	6.598

		20:2	20:3	22:0	20:4 ω 6
Site (S)	1	.0029	.2065**	.0018	3.832**
Treatment (T)	6	.0693	.0287	.0087	.340**
SxT	6	.0250	.0189	.0028	.325**
Error	54	.3630	.2136	.0692	.872
Total	67	.4603	.4677	.0825	5.369

		20:5 ω 6	24:0	20:5 ω 3	22:5 ω 6
Site (S)	1	.0008	.0122*	.2365**	.057
Treatment (T)	6	.0196	.0134	.1462**	.122
SxT	6	.0083	.0101	.1180*	.147
Error	54	.0894	.1191	.4157	1.444
Total	67	.1180	.1548	.9164	1.771

Table 20 (Continued)

Source	Degrees of freedom	Fatty acids			
		22:5 _{ω3}	22:6 _{ω3}	SAT 10-15C ^b	SAT 16-24C ^b
Site (S)	1	.922**	.0099*	99.*	178.**
Treatment (T)	6	.364*	.0098	49.	255
SxT	6	.215	.0191	14	152
Error	54	1.170	.0913	516	1283
Total	67	2.671	.1301	678	1868

		MONO ^b	PUFA6 ^b	PUFA3 ^b	UNKNOWN ^b
Site (S)	1	80	41.7**	3.153**	57.2**
Treatment (T)	6	559.*	7.2*	4.798**	6.7**
SxT	6	120	2.1	1.687**	9.5**
Error	54	2068	33.1	3.397	13.6
Total	67	2827	85.8	13.035	87.0

^a*p<.05; **p<.01.

^bFatty acids grouped into types of fatty acids.

the subcutaneous fat over the sirloin than in the intramuscular fat from the longissimus muscle (Table 21). The levels of the fatty acids: 18:1 ω 9, 18:2 ω 6, 18:3 ω 6, 18:3 ω 3, 20:3, 20:4 ω 6, 20:5 ω 3, 22:5 ω 3, and 22:6 ω 3, were significantly lower in the subcutaneous fat over the sirloin than in the intramuscular fat of the longissimus muscle (Table 21). These results tend to agree with Westerling and Hedrick (1979) in that they showed subcutaneous fat to have higher percentages of 16:0 and 18:1 ω 9 and lower percentages of 18:2 ω 6, 18:3 ω 3, and 20:4 ω 6 than intramuscular fat, while 20:1 was not significantly affected.

Table 22 illustrates that the subcutaneous fat contained a higher percentage of saturated fatty acids than the intramuscular fat ($P < .05$). However, the intramuscular fat of the longissimus muscle had higher levels of PUFA6, PUFA3, and UNKNOWNS than did the subcutaneous fat over the sirloin ($P < .05$). Intramuscular lipids generally contain a higher level of phospholipids than the subcutaneous lipids, and these phospholipids have a greater percentage of polyunsaturated fatty acids than the neutral lipids (Yeo, 1983). This is probably the reason that the intramuscular lipids contain higher levels of the polyunsaturated fatty acids than the subcutaneous lipids in this study. In disagreement with the present results, Westerling and Hedrick (1979) found no differences in levels of total saturated and unsaturated fatty acids between subcutaneous and intramuscular fat sampling sites.

Table 21. Average percentages of fatty acids in the subcutaneous fat and the intramuscular lipids of the longissimus muscle from steers grazed on pasture and then fed different diets from 0 to 112 days (DOF).

Fatty acid	Site	
	Subcutaneous fat	Longissimus intra-muscular lipid
10:0	3.114	1.841
11:0	.079 ^a	.054 ^b
12:0	.075 ^a	.059 ^b
13:0	.031	.025
14:0	3.801 ^a	2.891 ^b
A15:0	.171 ^a	.104 ^b
14:1	1.155 ^a	.746 ^b
15:0	1.016 ^a	.784 ^b
15:1	.160 ^a	.122 ^b
16:0	27.554 ^a	24.340 ^b
A17:0	.412	.352
16:1	4.027 ^a	3.114 ^b
16:1 ISO	.814 ^a	.538 ^b
17:0	2.165	1.918
17:1	1.790 ^a	1.551 ^b
18:0	12.705	12.978
18:1 ω 9	35.310 ^b	39.132 ^a
18:1 ISO1	.018	.029
18:1 ISO2	.346	.322
18:2 ISO	.132 ^a	.100 ^b
18:2 ω 6	2.357 ^b	3.362 ^a
18:2 ISO1	.096	.082
18:2 ISO2	.178 ^a	.145 ^b

Table 21 (Continued)

Fatty acid	Site	
	Subcutaneous fat	Longissimus intra-muscular lipid
18:2 IS03	.079	.092
18:3 ω 6	.017 ^b	.039 ^a
20:0	.104	.091
18:3 ω 3	.273 ^b	.329 ^a
20:1	.733	.674
20:2	.084	.096
20:3	.073 ^b	.183 ^a
22:0	.031	.021
20:4 ω 6	.062 ^b	.537 ^a
20:5 ω 6	.027	.033
20:5 ω 3	.035 ^b	.153 ^a
24:0	.047 ^a	.020 ^b
22:5 ω 6	.049	.107
22:5 ω 3	.058 ^b	.291 ^a
22:6 ω 3	.016 ^b	.040 ^a

^{ab} Average percentages in the same row followed by different superscript letters are significantly different at the $P < .05$ level.

Table 22. Average percentages of fatty acid types in different sites in steers fed different grain diets from 0 to 112 days (DOF) after grazing pasture.

Fatty acid type ^a	Site	
	Fat over Sirloin area	Longissimus intra-muscular lipid
SAT 10-15 C	8.09 ^b	5.68 ^c
SAT 16-24 C	42.61 ^b	39.37 ^c
MONO	43.17	45.34
PUFA6	2.51 ^c	4.08 ^b
PUFA3	.38 ^c	.81 ^b
UNKNOWN	.84 ^c	2.67 ^b

^aSAT 10-15C=10:0+11:0+12:0+13:0+14:0+15:0; SAT 16-24C=16:0+17:0+18:0+20:0+22:0+24:0; MONO=14:1+15:1+16:1+17:1+18:1+20:1; PUFA6= 18:2 ω 6+18:3 ω 6+20:4 ω 6+20:5 ω 6+22:5 ω 6; PUFA3=18:3 ω 3+20:5 ω 3+22:5 ω 3+22:6 ω 3 and UNKNOWN is composed of 81 fatty acids with retention time from 4.14 to 38.80 min.

^{bc}Average percentages in a row followed by different superscript letters are significantly different at the P<.05 level.

Fatty Acid Composition of the Subcutaneous Fat

The analysis of variance for the fatty acids and fatty acid types in the subcutaneous fat over the sirloin area as a function of treatment are given in Table 23. The orthogonal comparisons used to separate significant treatment effects are given in Table 4, p. 25. The levels of the following fatty acids: A15:0, 15:1, A17:0, 16:1 ISO, 17:1, 18:2 ISO1, 18:2 ISO3, 20:0, 18:3 ω 3, and 20:1, and the fatty acid type, PUFA3, were all significantly affected by treatment (Table 23). When the treatment sums of squares were partitioned by orthogonal comparisons, the percentages of the fatty acids: 10:0, 16:1, 18:0, 18:2 ISO2, 18:2 ω 6, 18:2 ISO2 and 22:5 ω 3 also were significantly affected by DOF (C1 and C2 comparisons, Table 23). In addition, partitioning treatment sums of squares also showed that the fatty acid types: SAT 16-24C, MONO, PUFA6 and UNKNOWNNS were affected by DOF (C1 and C2, Table 23). The levels of A17:0 and 22:5 ω 3 had a significant C3, and the percentage of C20:1 had a significant C5 (Table 23).

Table 24 shows that levels of fatty acids: 10:0, A15:0, 15:1, A17:0, 16:1 ISO, 18:0, 20:0 and 18:3 ω 3, decreased quadratically with an increase in DOF from 0 to 112, while percentages of fatty acids: 16:1, 17:1, 18:2 ISO1, and 18:2 ISO3, increased quadratically ($P < .05$) in the fat over the sirloin. Levels of fatty acids, 18:1 ISO2 and 18:2 ISO2 decreased linearly with increasing DOF but that of 18:2 ω 6 increased linearly in percentage. The equations showing the DOF effects for each of these fatty acids are given in

Table 23. Sums of squares^a from analyses of variance of percentages of fatty acids and fatty acid types in subcutaneous fat of steers grazed on pasture and then fed different diets 0 to 112 days (DOF).

Source	Degrees of freedom	Fatty acid			
		10:0	11:0	12:0	13:0
Treatment	6	49.33	.0017	.0016	.0047
C1 ^b	1	.32	.0004	.0002	.0022
C2 ^b	1	40.56*	.0000	.0001	.0001
C3 ^b	1	2.29	.0001	.0003	.0010
C4 ^b	1	1.11	.0001	.0000	.0002
C5 ^b	1	4.56	.0005	.0001	.0002
C6 ^b	1	.48	.0005	.0008	.0010
Error	28	288.60	.0086	.0103	.0159
Total	34	337.93	.0103	.0118	.0206

		14:0	15:0	14:1	15:0
Treatment	6	3.70	.3823**	.9786	1.037
C1 ^b	1	.08	.2059**	.0597	.377
C2 ^b	1	1.14	.1723**	.0004	.000
C3 ^b	1	.27	.0000	.2692	.179
C4 ^b	1	.63	.0012	.3267	.096
C5 ^b	1	.04	.0025	.0044	.094
C6 ^b	1	1.53	.0004	.3182	.291
Error	28	12.09	.0528	2.7779	3.2689
Total	34	15.79	.4350	3.7565	4.3061

Table 23 (Continued)

Source	Degrees of freedom	Fatty acid			
		15:1	16:0	17:0	16:1
Treatment	6	.1720**	107.78	.4737**	9.92
C1 ^b	1	.0860**	35.93	.2289**	.10
C2 ^b	1	.0805**	28.14	.0858*	4.83*
C3 ^b	1	.0003	12.48	.0855*	.04
C4 ^b	1	.0015	11.63	.0359	1.69
C5 ^b	1	.0004	19.16	.0214	.49
C6 ^b	1	.0033	.44	.0162	2.76
Error	28	.0399	652.37	.6109	33.09
Total	34	.2119	760.16	1.0847	43.01

		16:1 ISO	17:0	17:1	18:0
Treatment	6	.939**	4.354	6.6028**	169.70
C1 ^b	1	.557**	1.993	1.999*	99.57**
C2 ^b	1	.267*	2.118	3.671**	58.24**
C3 ^b	1	.004	.099	.057	2.61
C4 ^b	1	.055	.028	.057	2.16
C5 ^b	1	.000	.038	.584	.26
C6 ^b	1	.056	.079	.234	6.86
Error	28	1.102	16.741	9.240	101.88
Total	34	2.041	21.095	15.843	271.58

Table 23 (Continued)

Source	Degrees of freedom	Fatty acid			
		18:1 ω 9	18:1 ISO1	18:1 ISO2	18:2 ISO
Treatment	6	372.58	.0283	.1239	.00719
C1 ^b	1	207.97	.0002	.0741*	.00002
C2 ^b	1	9.22	.0141	.0057	.00003
C3 ^b	1	1.97	.0068	.0115	.00030
C4 ^b	1	48.68	.0068	.0014	.00380
C5 ^b	1	103.98	.0024	.0310	.00000
C6 ^b	1	.77	.0002	.0002	.00304
Error	28	2366.73	.1398	.4768	.05336
Total	34	2739.31	.1682	.6007	.06054

		18:2 ω 6	18:2 ISO1	18:2 ISO2	18:2 ISO3
Treatment	6	6.43	.1471*	.0460	.0372*
C1 ^b	1	5.06**	.006	.022*	.010*
C2 ^b	1	.63	.124**	.003	.016*
C3 ^b	1	.13	.003	.012	.007
C4 ^b	1	.47	.000	.000	.000
C5 ^b	1	.03	.012	.000	.000
C6 ^b	1	.11	.002	.009	.004
Error	28	14.77	.2403	.1089	.0587
Total	34	21.21	.3874	.1549	.0959

Table 23 (Continued)

Source	Degrees of freedom	Fatty acid			
		18:3 ω 6	20:0	18:3 ω 3	20:1
-----Sums of squares ^a -----					
Treatment	6	.0015	.0293**	.3965**	.4290*
C1 ^b	1	.0006	.0020	.1847**	.0867
C2 ^b	1	.0001	.0182**	.1991**	.0972
C3 ^b	1	.0004	.0021	.0023	.0725
C4 ^b	1	.0000	.0001	.0078	.0021
C5 ^b	1	.0001	.0014	.0015	.1698*
C6 ^b	1	.0002	.0055	.0010	.0006
Error	28	.0141	.0655	.1865	1.0613
Total	34	.0156	.0948	.5830	1.4904

		20:2	20:3	22:0	20:4 ω 6
Treatment	6	.0797	.0292	.0102	.0140
C1 ^b	1	.0001	.0042	.0004	.0001
C2 ^b	1	.0223	.0010	.0026	.0002
C3 ^b	1	.0256	.0111	.0005	.0104
C4 ^b	1	.0162	.0085	.0019	.0001
C5 ^b	1	.0124	.0043	.0002	.0010
C6 ^b	1	.0031	.0002	.0045	.0021
Error	28	.3277	.1478	.0663	.0993
Total	34	.4074	.1770	.0765	.1133

Table 23 (Continued)

Source	Degrees of freedom	Fatty acid			
		20:5 ω 6	20:5 ω 3	24:0	22:5 ω 6
Treatment	6	.0085	.0253	.0219	.0292
C1 ^b	1	.0032	.0037	.0041	.0014
C2 ^b	1	.0000	.0053	.0019	.0000
C3 ^b	1	.0002	.0015	.0020	.0063
C4 ^b	1	.0005	.0011	.0003	.0091
C5 ^b	1	.0042	.0056	.0131	.0033
C6 ^b	1	.0003	.0081	.0006	.0091
Error	28	.0618	.1668	.1027	.1164
Total	34	.0703	.1922	.1247	.1456

		22:5 ω 3	22:6 ω 3	SAT10-15C ^b	SAT16-24C ^b
Treatment	6	.0463	.0228	43.6	293.6
C1 ^b	1	.0039	.0000	0.2	212.1**
C2 ^b	1	.0159	.0082	28.5	1.0
C3 ^b	1	.0205*	.0083	6.3	29.6
C4 ^b	1	.0000	.0047	.4	21.6
C5 ^b	1	.0019	.0004	6.9	24.5
C6 ^b	1	.0041	.0011	1.4	4.9
Error	28	.1246	.0652	323.6	1061.9
Total	34	.1709	.0880	367.1	1355.5

Table 23 (Continued)

Source	Degrees of freedom	Fatty acid type			
		MONO ^C	PUFA6 ^C	PUFA3 ^C	UNKNOWN ^S ^C
Treatment	6	362	6.07	.690**	.658
C1 ^b	1	216.*	5.03**	.311**	.158
C2 ^b	1	43	.62	.308**	.306*
C3 ^b	1	7	.02	.050	.024
C4 ^b	1	28	.33	.016	.122
C5 ^b	1	68	.03	.002	.000
C6 ^b	1	1	.03	.002	.049
Error	28	1820	14.47	.762	2.188
Total	34	2182	20.55	1.451	2.846

^a* $p < .05$; ** $p < .01$.

^bC1 is a linear DOF effect; C2 is a quadratic DOF effect; C3 compares the diet containing soybeans (SB) with the diet containing SB:peanut skins; C4 is the interaction of soybean diets with 56 and 112 DOF; C5 compares 56 versus 112 DOF for diets containing SB; and C6 compares the control diet to both diets containing SB.

^cFatty acids were grouped together into types of fatty acids.

Table 24. Average percentages of fatty acids in the subcutaneous fat of steers grazed on pasture and then fed different diets from 0 to 112 days (DOF) for DOF.

Fatty acid	DOF		
	0 (n=5)	56 (n=15)	112 (n=15)
10:0 ^a	4.555	3.854	1.894
11:0	.047	.058	.052
12:0	.072	.079	.072
13:0	.016	.039	.028
14:0	3.488	3.704	4.001
A15:0 ^a	.417	.158	.102
14:1	1.249	1.122	1.158
15:0	.794	1.108	.999
15:1 ^a	.322	.153	.112
16:0	28.721	25.992	28.728
A17:0 ^a	.644	.380	.367
16:1 ^a	3.710	3.697	4.461
16:1 ISO ^a	1.187	.771	.732
17:0	1.366	2.184	2.412
17:1 ^a	.901	1.749	2.126
18:0 ^a	17.834	12.229	11.470
18:1 ω 9	29.414	37.029	35.546
18:1 ISO1	.000	.000	.041
18:1 ISO2 ^b	.471	.326	.348
18:2 ISO	.129	.132	.133
18:2 ω 6 ^b	1.380	2.583	2.456
18:2 ISO1 ^a	.000	.061	.162
18:2 ISO2 ^b	.243	.163	.172
18:2 ISO3 ^a	.019	.078	.101

Table 24 (Continued)

Fatty acid	DOF		
	0 (n=5)	56 (n=15)	112 (n=15)
18:3 ω 6	.006	.019	.019
20:0 ^a	.147	.115	.079
18:3 ω 3 ^a	.517	.268	.197
20:1	.901	.730 ^c	.679 ^d
20:2	.116	.102	.055
20:3	.055	.086	.065
22:0	.049	.035	.022
20:4 ω 6	.069	.062	.059
20:5 ω 6	.048	.019	.028
24:0	.015	.051	.054
20:5 ω 3	.072	.036	.023
22:5 ω 6	.036	.055	.047
22:5 ω 3	.105	.065	.035
22:6 ω 3	.000	.003	.033

^aA significant quadratic DOF effect was found for the percentage of this acid.

^bA significant linear DOF effect was found for the percentage of this acid.

^{cd}Contrast 5 is significant comparing 56 and 112 DOF for diets containing soybeans.

in Table 25.

The only other significant DOF effect observed was the significant C5 found for 20:1 (Table 23). This contrast compared 56 DOF with 112 DOF for steers fed the corn diet containing soybeans with and without peanut skins. The percentage of 20:1 in the subcutaneous fat was lower at 112 DOF than at 56 DOF.

The percentage of SAT 16-24C fatty acid type decreased linearly with increasing DOF from 0 to 112, but the percentage of SAT 10-15C was not affected by DOF (Tables 24 and 26, respectively). Tables 24 and 26 also show that the levels of MONO and PUFA6 increased linearly across DOF, but the percentage of PUFA3 decreased quadratically. The percentage of UNKNOWNS first decreased from 0 to 56 DOF and then increased from 56 to 112 DOF (Table 26). Equations showing the significant DOF effects on levels of fatty acid types in the subcutaneous fat are given in Table 25.

In summary, the subcutaneous fat from 0-DOF steers contained 8.97% SAT 10-15C, 48.13% SAT 16-24C, 36.54% MONO, 1.54% PUFA6, .69% PUFA3 and .87% UNKNOWNS, while that from 112-DOF steers contained 7.05% SAT 10-15C, 42.76% 16-24C, 44.08% MONO, 2.61% PUFA6, .29% PUFA3, and .95% UNKNOWNS. The 0 DOF steers represent the grass fed steers while the 112 DOF represent the grain fed steers.

In agreement with the results of the present study, Hidiroglou et al. (1987) also showed that feeding grain to steers compared with 0 DOF steers increased the proportion of 18:1 ω 9 in the subcutaneous fat. The results of Sumida et al. (1972) also agree with the results of the present study. Sumida and coworkers reported that the level of 18:0 was higher and

Table 25. Equations showing significant DOF effects on percentages of fatty acids and fatty acid types in the subcutaneous fat of steers grazed on pasture and then fed different diets from 0 to 112 days (DOF).

Fatty acid	R ²	Equation ^a
10:0	.121	$Y = 4.555 - .00130 (DOF) - .00020 (DOF)^2$
A15:0	.869	$Y = .417 - .00644 (DOF) + 3.23 \times 10^{-5} (DOF)^2$
15:1	.786	$Y = .322 - .00414 (DOF) + 2.03 \times 10^{-5} (DOF)^2$
A17:0	.290	$Y = .644 - .00696 (DOF) + 4.01 \times 10^{-5} (DOF)^2$
16:1	.115	$Y = 3.72 - .00743 (DOF) + 1.25 \times 10^{-4} (DOF)^2$
16:1 IS0	.404	$Y = 1.187 - .0108 (DOF) + 6.00 \times 10^{-5} (DOF)^2$
17:1	.358	$Y = .901 + .0194 (DOF) - 7.51 \times 10^{-5} (DOF)^2$
18:0	.581	$Y = 17.83 - .1434 (DOF) + .000773 (DOF)^2$
18:1 IS02	.123	$Y = .408 - .000719 (DOF)$
18:2 ω 6	.239	$Y = 1.879 + .00664 (DOF)$
18:2 IS01	.336	$Y = .000 + .000736 (DOF) + 6.36 \times 10^{-6} (DOF)^2$
18:2 IS02	.142	$Y = .209 - .000433 (DOF)$
18:2 IS03	.266	$Y = .019 + .00137 (DOF) - 5.66 \times 10^{-6} (DOF)^2$
20:0	.214	$Y = .147 - .000534 (DOF) - 6.27 \times 10^{-7} (DOF)^2$
18:3 ω 3	.658	$Y = .517 - .00604 (DOF) + 2.84 \times 10^{-5} (DOF)^2$
Fatty acid type ^b		
SAT 16-24 C	.157	$Y = 44.50 - .0263 (DOF)$
MONO	.098	$Y = 39.66 + .0487 (DOF)$
PUFA6	.242	$Y = 2.038 + .00659 (DOF)$
PUFA3	.427	$Y = .694 - .00781 (DOF) + 3.79 \times 10^{-5} (DOF)^2$
UNKNOWN	.163	$Y = .873 - .00669 (DOF) + 6.601 \times 10^{-5} (DOF)^2$

^aY=average percentage of each fatty acid or fatty acid type and DOF = days steers were fed grain.

^bSAT 10-15C=10:0+11:0+12:0+13:0+14:0+15:0; SAT 16-24C=16:0+17:0+18:0+20:0+22:0+24:0; MONO=14:1+15:1+16:1+17:1+18:1+20:1; PUFA6=18:2 ω 6+18:3 ω 6+20:4 ω 6+20:5 ω 6+22:5 ω 6; PUFA3=18:3 ω 3+20:5 ω 3+22:5 ω 3 and UNKNOWN is composed of 81 fatty acids with retention time from 4.14 to 38.80 min.

Table 26. Average percentages of fatty acid types in subcutaneous fat of steers grazed on pasture and fed different diets from 0 to 112 days (DOF) for DOF.

Fatty acid type ^a	DOF		
	0 (N=5)	56 (N=15)	112 (N=15)
SAT 10-15 C	8.97	8.84	7.05
SAT 16-24 C ^b	48.13	40.61	42.76
MONO ^b	36.54	44.48	44.08
PUFA6 ^b	1.54	2.74	2.61
PUFA3 ^c	.69	.37	.29
UNKNOWN ^c	.87	.71	.95

^aSAT 10-15C=10:0+11:0+12:0+13:0+14:0+15:0; SAT 16-24C=16:0+17:0+18:0+20:0+22:0+24:0; MONO=14:1+15:1+16:1+17:1+18:1+20:1; PUFA6=18:2 ω 6+18:3 ω 6+20:4 ω 6+20:5 ω 6+22:5 ω 6; PUFA3=18:3 ω 3+20:5 ω 3+22:5 ω 3+22:6 ω 3 and UNKNOWN^c consist of 81 fatty acids with retention times from 4.14 to 38.80 min.

^bA significant linear DOF effect was found on the percentage of the fatty acid type at the P<.05 level.

^cA significant quadratic DOF effect was found on the percentage of the fatty acid type at the P<.05 level.

levels of 18:2 ω 6 and 18:3 ω 3 were lower in the subcutaneous fat from 0 DOF cattle than in that from grain fed cattle. In contrast to the present results, Sumida et al. did not find any difference in the level of 16:1 in the subcutaneous fat between their 0-DOF and grain-fed cattle. Also, in agreement with the present study, Westerling and Hedrick (1979) found that the percentage of 18:2 ω 6 in the subcutaneous fat increased with increasing days of grain feeding cattle; however, they did not report any 18:3 ω 3 in the subcutaneous fat of their steers.

Generally, forage fed or grass fed cattle (0-DOF) have greater concentrations of 16:0, 18:0, and 18:3 ω 3 and lower concentrations of 18:1 ω 9 fatty acids in their fat depots than grain-fed cattle (Greathouse et al., 1974; Melton, 1983; Miller et al., 1967; Westerling and Hedrick, 1979). According to Melton (1983), the reason for the greater amount of 18:3 ω 3 in the fat of grass fed cattle compared with grain fed cattle is that the rumen does not hydrogenate all of the 18:3 ω 3 in the grass lipid. Grass from a pasture has approximately 2.5% lipid which contains from 50 to 70% 18:3 ω 3.

As shown in Table 23, the only fatty acids significantly affected by diet were A17:0 and 22:5 ω 3 (C3, $P < .05$). In addition, no fatty acid types were affected by the diet (Table 23). The average percentages of fatty acids and fatty acid types in the subcutaneous fat of steers fed each diet are given in Tables 27 and 28, respectively. Feeding steers the corn and soybean diet instead of the corn and soybeans:peanut skin diet resulted in significantly more A17:0 (.423 versus .292%, respectively) and less 22:5 ω 3 (.026 versus .091%, respectively) in the subcutaneous fat. The data in the present study show that the tannins in the peanut skins were not able to inhibit the

Table 27. Average percentages of fatty acids in the subcutaneous fat from steers grazed on pasture and then fed different diets for type of diet.

Fatty acid	Diets		
	Control corn (n=10)	Corn + soybeans (n=10)	Corn + soybeans: peanut skins (n=10)
10:0	3.053	2.446	3.123
11:0	.049	.057	.060
12:0	.069	.076	.083
13:0	.026	.031	.045
14:0	3.533	3.896	4.129
15:0	.125	.133	.131
14:1	.994	1.097	1.329
15:0	.914	1.028	1.217
15:1	.118	.144	.136
16:0	27.189	28.235	26.656
17:0	.407	.423 ^a	.292 ^b
16:1	3.650	4.245	4.340
16:1 ISO	.691	.767	.797
17:0	2.370	2.332	2.191
17:1	2.063	1.822	1.928
18:0	12.526	11.873	11.150
18:1 ω 9	36.514	35.860	36.487
18:1 ISO1	.024	.037	.000
18:1 ISO2	.341	.359	.311
18:2 ISO	.118	.143	.135
18:2 ω 6	2.605	2.559	2.395
18:2 ISO1	.122	.094	.119
18:2 ISO2	.192	.130	.179
18:2 ISO3	.106	.062	.100
18:3 ω 6	.023	.013	.022
20:0	.116	.077	.097
18:3 ω 3	.224	.247	.225

Table 27 (Continued)

Fatty acid	Diets		
	Control corn (n=10)	Corn + soybeans (n=10)	Corn +soybeans: peanut skins (n=10)
20:1	.711	.247	.225
20:2	.064	.050	.122
20:3	.072	.054	.101
22:0	.011	.032	.042
20:4 ω 6	.049	.044	.089
20:5 ω 6	.019	.022	.029
24:0	.046	.065	.046
20:5 ω 3	.052	.009	.026
22:5 ω 6	.027	.046	.081
22:5 ω 3	.034	.026 ^a	.091 ^b
22:6 ω 3	.100	.002	.043

^{ab}Means in a row followed by different superscript letters are significantly different at the $P < .05$ level.

Table 28. Average percentages of fatty acid types in the subcutaneous fat from steers grazed on pasture and then fed different diets for type of diet.

Fatty acid type ^a	Diets		
	Control corn (n=10)	Corn + soybeans (n=10)	Corn + soybeans: peanut skins (n=10)
SAT 10-15C	7.64	7.53	8.66
SAT 16-24C	42.26	42.61	40.18
MONO	44.05	43.81	44.98
PUFA6	2.72	2.65	2.62
PUFA3	.32	.28	.38
UNKNOWNNS	.77	.82	.89

^aSAT 10-15C=10:0+11:0+12:0+13:0+14:0+15:0; SAT 16-24C=16:0+17:0+18:0+20:0+22:0+24:0; MONO=14:1+15:1+16:1+17:1+18:1+20:1; PUFA6=18:2 ω 6+18:3 ω 6+20:4 ω 6+20:5 ω 6+22:5 ω 6; PUFA3=18:3 ω 3+20:5 ω 3+22:5 ω 3+22:6 ω 3, and UNKNOWNNS consist of 81 fatty acids with retention times from 4.14 to 38.80 min.

hydrogenation of the dietary PUFA in the soybeans, specifically because of the lack of increased levels of 18:3 ω 3 in the subcutaneous fat of cattle fed the corn + soybeans:peanut skins compared to those fed the corn + soybeans diet. Any increased levels of 18:3 ω 3 in the lipids of the cattle fed soybean supplemented diets would have to come from the soybean because the lipids in corn and in peanuts do not contain any 18:3 ω 3 (deMan, 1985). Rule and Beitz (1986) reported that a corn diet supplemented with full-fat soybeans which provided 6% dietary fat had 3.29% 18:0, 21.7% 18:1 ω 9, 54.5% 18:2 ω 6 and 6.17% 18:3 ω 3 in the dietary lipid. In their study, after this diet passed from the rumen into the abomasum of cattle, the duodenal ingesta lipid contained 58.8% 18:0, 17.7% 18:1 ω 9, 5.5% 18:2 ω 6 and 0.78% 18:3 ω 3. These data show the extent hydrogenation of dietary PUFA by the rumen micro-organisms.

Fatty Acid Composition of the Intramuscular Lipid

The analyses of variance for the percentages of fatty acids and fatty acid types in the intramuscular lipid of the longissimus muscle as a function of treatment are shown in Table 29. Concentrations of the following fatty acids and fatty acid types were significantly affected by treatment: 11:0, 14:0, 15:0, 15:1, 17:0, 17:1, 18:0, 18:2 ISO1, 20:0, 18:3 ω 3, 20:4 ω 6, 20:5 ω 6, 20:5 ω 3, MONO, PUFA3, and UNKNOWN5. However, when the treatment sums of squares were partitioned by orthogonal comparisons C1 through C6 (Table 4, p, 24) significant DOF effects (C1 and C2) were found

Table 29. Sums of squares^a from analyses of variance for levels of fatty acids and fatty acid types in the intramuscular lipids of the longissimus muscle from steers grazed on pasture and then fed different diets 0 to 112 days (DOF).

Source	Degrees of freedom	Fatty acid			
		10:0	11:0	12:0	13:0
Treatment	6	21.15	.162**	.00065	.00188
C1 ^b	1	1.94	.102**	.00000	.00077
C2 ^b	1	1.76	.052**	.00018	.00000
C3 ^b	1	1.88	.003	.00023	.00037
C4 ^b	1	1.34	.003	.00001	.00024
C5 ^b	1	14.01	.001	.00022	.00004
C6 ^b	1	.21	.001	.00000	.00045
Error	26	173.29	.072	.00629	.00554
Total ^c	32	194.44	.234	.00694	.00742

		14:0	15:0	14:1	15:0
Treatment	6	4.07**	.1109**	.2669	.8831
C1 ^b	1	1.02**	.0379**	.1333*	.2032
C2 ^b	1	1.83**	.0692**	.0079	.0000
C3 ^b	1	.81**	.0005	.0818	.2101
C4 ^b	1	.01	.0002	.0000	.2742
C5 ^b	1	.38	.0002	.0270	.0011
C6 ^b	1	.02	.0029	.0168	.1946
Error	26	2.91	.0219	.7864	2.4920
Total ^c	32	6.98	.1328	1.0532	3.3752

Table 29 (Continued)

Source	Degrees of freedom	Fatty acid			
		15:1	16:0	17:0	16:1
Treatment	6	.0791**	23.90	.4284	6.898
C1 ^b	1	.0239**	.38	.0925	.991
C2 ^b	1	.0512**	2.41	.3110**	4.469**
C3 ^b	1	.0005	15.86*	.0042	.000
C4 ^b	1	.0004	1.05	.0060	.319
C5 ^b	1	.0000	3.56	.0059	1.082
C6 ^b	1	.0030	.72	.0088	.036
Error	26	.0153	97.03	.4094	15.14
Total ^c	32	.0944	121.02	.8378	22.04

		16:1 ISO	17:0	17:1	18:0
Treatment	6	.1225	3.048*	3.132**	117.59**
C1 ^b	1	.0475	.972*	1.170**	59.78**
C2 ^b	1	.0362	1.052*	1.332**	53.78**
C3 ^b	1	.0000	.167	.045	.94
C4 ^b	1	.0062	.842*	.503	1.09
C5 ^b	1	.0319	.015	.058	.54
C6 ^b	1	.0007	.001	.024	1.45
Error	26	.4773	4.124	2.100	73.66
Total ^d	32	.5999	7.172	5.232	191.25

Table 29 (Continued)

Source	Degrees of freedom	Fatty acid			
		18:1 ω 9	18:1 IS01	18:2 IS0	18:1 IS02
Treatment	6	213.28	.040	.0116	.0448
C1 ^b	1	58.73*	.002	.0001	.0255
C2 ^b	1	91.67**	.003	.0016	.0056
C3 ^b	1	57.65	.014	.0021	.0052
C4 ^b	1	4.73	.003	.0022	.0028
C5 ^b	1	.50	.017	.0000	.0000
C6 ^b	1	.00	.001	.0056	.0058
Error	26	324.66	.195	.0368	.4260
Total ^c	32	537.93	.235	.0484	.4780

		18:2 ω 6	18:2 IS01	18:2 IS02	18:2 IS03
Treatment	6	4.286	.1069**	.0808	.0593
C1 ^b	1	2.435*	.0050	.0584*	.0124
C2 ^b	1	1.550	.0517**	.0043	.0396*
C3 ^b	1	.053	.0156	.0078	.0009
C4 ^b	1	.216	.0048	.0063	.0001
C5 ^b	1	.028	.0231*	.0021	.0046
C6 ^b	1	.003	.0067	.0018	.0016
Error	26	14.033	.1405	.1353	.0795
Total ^c	32	18.319	.2474	.2162	.1380

Table 29 (Continued)

Source	Degrees of freedom	Fatty acid			
		18:3 ω 6	20:0	18:3 ω 3	20:1
Treatment	6	.0031	.0331**	1.459**	.6569
C1 ^b	1	.0001	.0141**	.522**	.0492
C2 ^b	1	.0021	.0154**	.883**	.0398
C3 ^b	1	.0005	.0026**	.000	.0001
C4 ^b	1	.0000	.0000	.003	.0084
C5 ^b	1	.0004	.0002	.001	.2688
C6 ^b	1	.0000	.0007	.050**	.2906
Error	26	.0140	.0083	.0921	4.3925
Total ^c	32	.0171	.0413	1.5510	5.0494

		20:2	20:3	22:0	20:4 ω 6
Treatment	6	.0147	.0183	.00124	.6512*
C1 ^b	1	.0041	.0011	.00028	.0833
C2 ^b	1	.0087*	.0136*	.00072*	.4297**
C3 ^b	1	.0000	.0005	.00000	.0005
C4 ^b	1	.0006	.0003	.00003	.0334
C5 ^b	1	.0005	.0026	.00003	.0152
C6 ^b	1	.0008	.0002	.00018	.0891
Error	26	.0353	.0658	.00290	.7724
Total ^c	32	.0500	.0842	.00414	1.4236

Table 29 (Continued)

Source	Degrees of freedom	Fatty acid			
		20:5 _{w6}	20:5 _{w3}	24:0	22:5 _{w6}
Treatment	6	.0194*	.00159	.2389**	.2401
C1 ^b	1	.0096**	.00002	.0401*	.0037
C2 ^b	1	.0048*	.00006	.1628**	.0784
C3 ^b	1	.0034	.00010	.0090	.0022
C4 ^b	1	.0000	.00075	.0002	.0022
C5 ^b	1	.0001	.00030	.0007	.0839
C6 ^b	1	.0015	.00037	.0262	.0696
Error	26	.0276	.01635	.2489	1.3282
Total ^c	32	.0470	.01794	.4878	1.5683

		22:5 _{w3}	22:6 _{w3}	SAT10-15C ^b	SAT16-24C ^b
Treatment	6	.5326	.00611	19.55	113.1
C1 ^b	1	.0711	.00004	.05	39.1*
C2 ^b	1	.3650**	.00090	.04	24.0
C3 ^b	1	.0068	.00206	7.95	29.4
C4 ^b	1	.0416	.00002	.25	8.8
C5 ^b	1	.0120	.00091	10.06	7.0
C6 ^b	1	.0361	.00221	1.21	4.0
Error	26	1.0456	.02690	192.58	220.8
Total ^c	32	1.5782	.03220	212.13	333.9

Table 29 (Continued)

Source	Degrees of freedom	Fatty acid			
		MONO ^d	PUFA6 ^d	PUFA3 ^d	UNKNOWN ^d
Treatment	6	317.6**	5.00	5.80**	15.50**
C1 ^b	1	94.7**	1.22	1.43**	4.37**
C2 ^b	1	166.5**	3.01*	3.91**	9.78**
C3 ^b	1	50.1*	.11	.04	.37
C4 ^b	1	3.6	.35	.02	.10
C5 ^b	1	2.7	.30	.01	.84
C6 ^b	1	0.0	.00	.39	.04
Error	26	248.1	18.59	2.64	11.40
Total ^c	32	565.8	23.59	8.43	26.90

^a* $p < .05$; ** $p < .01$.

^bC1 is a linear DOF effect; C2 is a quadratic DOF effect; C3 compares corn + SB diet with Corn + SB:PS diet; C4 is the interaction of the SB containing diets; C5 compares 56 DOF with 112 DOF for SB containing diets and C6 compares control corn diet with corn + SB and corn + SB:PS diets.

^cThe reason for 2 less degrees freedom in the intramuscular lipids compared with subcutaneous fat was that chemical analyses samples of the longissimus muscle from two steers were lost and could not be replaced.

^dThese fatty acids were grouped into fatty acid types.

for the concentrations of 14:1, 17:0, 16:1, 18:1 ω 9, 18:2 ω 6, 18:2 ISO2, 18:2 ISO3, 20:2, 20:3, 22:0, 20:4 ω 6, 22:5 ω 3, SAT 15-24C and PUFA6. Levels of the fatty acids, 14:0, 16:0, and 20:0, and of the fatty acid type, MONO, had a significant comparison, C3; the level of 17:0 had a significant C5 and the % 18:3 ω 3 had a significant comparison, C6 (Table 29). Significant C3, C4 and C6 comparisons indicate that the concentrations of fatty acids in the intramuscular lipids were different among the diets. The fatty acid, 18:2 ISO1 also had a significant C5 indicating that there was a significant difference among 56 and 112 DOF in cattle fed diets containing soybeans.

In general, in the intramuscular lipid as DOF increased from 0 to 112, the percentages of 11:0, 15:0, 15:1, 17:0, 16:1, 18:0, 20:0, 18:3 ω 3, 20:2, 20:3, 22:0, 20:4 ω 6, 20:5 ω 6, 20:5 ω 3, and 22:5 ω 3 decreased quadratically, and the percentages of 14:0, 17:0, 17:1, 18:1 ω 9, 18:2 ISO1, and 18:2 ISO3 increased quadratically as shown in Tables 29, 30 and 31, respectively. In addition, the level of 18:2 ISO2 decreased linearly and the levels of 14:1, and 18:2 ω 6 increased linearly as DOF increased from 0 to 112. Steers fed diets containing soybeans for 56 DOF also had lower %18:2 ISO1 in their intramuscular lipid than did steers fed the same diets for 112 DOF.

As the DOF increased from 0 to 112, the levels of the fatty acid types: PUFA6, PUFA3 and UNKNOWNs decreased quadratically and the % MONO increased quadratically in the intramuscular lipid as shown in Tables 29, 32 and 33. The level of SAT 16-24C also decreased linearly across DOF from 0 to 112 as shown in these same tables.

The percentages of fatty acids and fatty acid types in the intramuscular

Table 30. Average percentages of fatty acids in intramuscular lipids of the longissimus muscle from steers grazed on pasture and then fed different diets from 0 to 112 days (DOF) for DOF.

Fatty acid type ^a	DOF		
	0 (n=4)	56 (n=14)	112 (n=15)
10:0	2.718	1.807	1.640
11:0 ^a	.262	.061	.047
12:0	.055	.058	.062
13:0	.014	.029	.024
14:0 ^a	2.163	2.864	3.110
15:0 ^a	.245	.109	.061
14:1 ^b	.577	.790	.751
15:0	.601	.852	.768
15:1 ^a	.238	.129	.085
16:0	23.724	24.226	24.611
17:0 ^a	.606	.380	.257
16:1 ^a	2.214	2.982	2.076
16:1 ISO	.671	.530	.510
17:0 ^a	1.277	1.930	2.076
17:1 ^a	.841	1.561	1.731
18:0 ^a	17.835	12.784	11.862
18:1 ^{ω9a}	33.776	39.015	40.760
18:1 ISO1	.000	.028	.037
18:1 ISO2	.404	.308	.313
18:2 ISO	.114	.104	.093
18:2 ^{ω6b}	3.028	3.766	3.075
18:2 ISO1 ^a	.000	.062	.122
18:2 ISO2 ^b	.259	.117	.141
18:2 ISO3 ^a	.000	.081	.125
18:3 ^{ω6}	.054	.043	.031
20:0 ^a	.168	.090	.072

Table 30 (Continued)

Fatty acid	DOF		
	0 (N=4)	56 (N=14)	112 (N=15)
18:3 ω 3 ^a	.842	.345	.177
20:1	.717	.614	.719
20:2 ^a	.145	.100	.082
20:3 ^a	.224	.194	.162
22:0 ^a	.034	.022	.017
20:4 ω 6 ^a	.808	.581	.424
20:5 ω 6 ^a	.090	.028	.024
24:0	.017	.020	.022
20:5 ω 3 ^a	.329	.177	.084
22:5 ω 6	.066	.060	.162
22:5 ω 3 ^a	.541	.331	.187
22:6 ω 3	.049	.043	.034

^aA significant quadratic DOF effect was found for the percentage of the fatty acid.

^bA significant linear DOF effect was found for the percentage of the fatty acid.

Table 31. Equations showing the significant DOF effect on percentage fatty acids in intramuscular lipids of the longissimus muscle from steers grazed on pasture and then fed different diets from 0 to 112 days (DOF).

Fatty acid	R ²	Equation ^a
11:0	.657	$Y = .262 - .00526(\text{DOF}) + 2.98 \times 10^{-5}(\text{DOF})^2$
14:0	.408	$Y = 2.163 + .0166(\text{DOF}) - 7.23 \times 10^{-5}(\text{DOF})^2$
A15:0	.807	$Y = .245 - .00319(\text{DOF}) + 1.38 \times 10^{-5}(\text{DOF})^2$
14:1	.134	$Y = .577 + .00604(\text{DOF}) - 4.02 \times 10^{-5}(\text{DOF})^2$
15:1	.796	$Y = .238 - .00253(\text{DOF}) + 1.04 \times 10^{-5}(\text{DOF})^2$
A17:0	.482	$Y = .606 - .00495(\text{DOF}) + 1.64 \times 10^{-5}(\text{DOF})^2$
16:1	.248	$Y = 2.214 + .0162(\text{DOF}) - 4.35 \times 10^{-5}(\text{DOF})^2$
17:0	.282	$Y = 1.277 + .0162(\text{DOF}) - 8.08 \times 10^{-5}(\text{DOF})^2$
17:1	.478	$Y = .841 + .0178(\text{DOF}) - 8.76 \times 10^{-5}(\text{DOF})^2$
18:0	.594	$Y = 17.84 - .1271(\text{DOF}) + .000658(\text{DOF})^2$
18:1 ω 9	.280	$Y = 33.78 + .1255(\text{DOF}) - .000571(\text{DOF})^2$
18:2 ω 6	.133	$Y = 3.617 - .00342(\text{DOF})$
18:2 ISO1	.229	$Y = .000 + .00113(\text{DOF}) - 3.43 \times 10^{-7}(\text{DOF})^2$
18:2 ISO2	.270	$Y = .190 - .000601(\text{DOF})$
18:2 ISO3	.375	$Y = .000 + .00181(\text{DOF}) - 6.17 \times 10^{-6}(\text{DOF})^2$
20:0	.713	$Y = .168 - .00195(\text{DOF}) + 9.70 \times 10^{-6}(\text{DOF})^2$
18:3 ω 3	.906	$Y = .842 - .0118(\text{DOF}) + 5.25 \times 10^{-5}(\text{DOF})^2$
20:2	.255	$Y = .145 - .00105(\text{DOF}) + 4.31 \times 10^{-6}(\text{DOF})^2$
20:3	.176	$Y = .224 - .000536(\text{DOF}) - 1.41 \times 10^{-7}(\text{DOF})^2$
22:0	.241	$Y = .034 - .000273(\text{DOF}) + 1.04 \times 10^{-6}(\text{DOF})^2$
20:4 ω 6	.360	$Y = .808 - .00467(\text{DOF}) + 1.11 \times 10^{-5}(\text{DOF})^2$
20:5 ω 6	.306	$Y = .090 - .00161(\text{DOF}) + 9.14 \times 10^{-6}(\text{DOF})^2$
20:5 ω 3	.416	$Y = .329 - .00325(\text{DOF}) + 9.53 \times 10^{-6}(\text{DOF})^2$
22:5 ω 3	.276	$Y = .541 - .00432(\text{DOF}) + 1.03 \times 10^{-5}(\text{DOF})^2$

^aY=Average percentage of each fatty acid and DOF=days steers were fed grain diets.

Table 32. Average percentages of fatty acid types in intramuscular lipids of the longissimus muscle from steers grazed on pasture and then fed different diets from 0 to 112 days (DOF) for DOF.

Fatty acid type ^a	DOF		
	0 (n=4)	56 (n=10)	112 (n=10)
SAT 10-15C	5.81	5.67	5.65
SAT 16-24C ^b	43.06	39.07	38.66
MONO ^c	38.36	45.09	47.43
PUFA6	3.23	3.90	3.29
PUFA3 ^c	1.76	.90	.48
UNKNOWN ^c	4.25	2.77	2.16

^aSAT 10-15C=10:0+11:0+12:0+13:0+14:0+15:0; SAT 16-24C=16:0+17:0+18:0+20:0+22:0+24:0; MONO=14:1+15:1+16:1+17:1+18:1+20:1; PUFA6=18:2 ω 6+18:3 ω 6+20:4 ω 6+20:5 ω 6+22:5 ω 6; PUFA3=18:3 ω 3+20:5 ω 3+22:5 ω 3+22:6 ω 3, and UNKNOWN^c consist of 81 fatty acids with retention times from 4.14 to 38.80 min.

^bA significant linear DOF effect was found for this type fatty acids.

^cA significant quadratic DOF effect was found for this type fatty acids.

Table 33. Equations showing the significant DOF effect on percentage fatty acid types in intramuscular lipids of the longissimus muscle from steers grazed on pasture and then fed different diets from 0 to 112 days (DOF).

Fatty acid type ^a	R ²	Equation ^b
SAT 16-24C	.117	$Y = 41.57 - .0295(\text{DOF})$
MONO	.462	$Y = 38.36 + .1592(\text{DOF}) - .000699(\text{DOF})^2$
PUFA6	.179	$Y = 4.038 + .01862(\text{DOF}) - .000192(\text{DOF})^2$
PUFA3	.633	$Y = 1.76 - .01949(\text{DOF}) + 7.20 \times 10^{-5}(\text{DOF})^2$
UNKNOWN	.526	$Y = 4.25 - .0342(\text{DOF}) + .000138(\text{DOF})^2$

^aSAT 10-15C=10:0+11:0+12:0+13:0+14:0+15:0; SAT 16-24C=16:0+17:0+18:0+20:0+22:0+24:0; MONO=14:1+15:1+16:1+17:1+18:1+20:1; PUFA6=18:2 ω 6+18:3 ω 6+20:4 ω 6+20:5 ω 6+22:5 ω 6; PUFA3=18:3 ω 3+20:5 ω 3+22:5 ω 3+22:6 ω 3, and UNKNOWN consist of 81 fatty acids with retention times from 4.14 to 38.80 min.

^bY=Average percentage of fatty acid type and DOF = days steers were fed grain diet.

lipids of steers fed the different diets are given in Tables 34 and 35, respectively. Steers fed the corn + soybeans:peanut skins diet contained higher levels of the fatty acids, 14:0, 16:0, and 18:3 ω 6 (Table 34) and lower levels of the MONO fatty acid type (Table 35) in their intramuscular lipids than did steers fed the corn + soybeans diet. In addition, steers fed the control corn diet without soybeans had less 18:3 ω 3 in their intramuscular lipids than did steers fed any diet containing soybeans (Table 34). The higher levels of saturated fatty acids, the lower levels of monounsaturated fatty acids and the lack of significant higher levels of PUFA in the intramuscular lipids of cattle fed the diets containing the peanut skins compared to those fed the other diets indicate that the tannins in the peanut skins may have slightly enhanced the hydrogenation of the dietary PUFA by rumen microorganisms instead of protecting them from hydrogenation. Since no other reports of studies were found in which the effects of diets containing peanut skins on the fatty acid composition of beef has been studied, this may be the first time this result has been reported.

Melton (1983) also reported that grass fed steers (0-DOF) contained higher concentrations of 17:0, 18:3 ω 3, 20:3, 20:4 ω 6, and 22:5 ω 3 in their intramuscular lipids than grain fed steers (56 and 112 DOF). This is in agreement with the results of the present study. Montgomery and Bidner (1979) and Westerling and Hedrick (1979) also reported that the percentage of 18:2 ω 6 in intramuscular lipids of cattle increased with increasing DOF which is in agreement with the present study. The higher levels of

Table 34. Average percentages of fatty acids in the intramuscular lipids of the longissimus muscle from steers fed different diets after grazing on pasture for each type of diet.

Fatty acid	Diets		
	Control corn (n=10)	Corn + soybeans (n=10)	Corn +soybeans: peanut skins (n=10)
10:0	1.624	1.437	2.070
11:0	.046	.044	.070
12:0	.060	.056	.063
13:0	.021	.025	.034
14:0	2.937	2.811 ^a	3.208 ^b
15:0	.072	.085	.098
14:1	.734	.719	.851
15:0	.690	.762	.971
15:1	.093	.107	.119
16:0	24.584	23.386 ^a	25.202 ^b
17:0	.294	.341	.317
16:1	3.180	3.287	3.251
16:1 ISO	.513	.322	.524
17:0	1.985	1.923	2.101
17:1	1.597	1.631	1.716
18:0	12.610	11.878	12.391
18:1 ω 9	39.937	41.717	38.142
18:1 ISO1	.040	.000	.055
18:1 ISO2	.291	.339	.305
18:2 ISO	.080	.110	.098
18:2 ω 6	3.442	3.426	3.359
18:2 ISO1	.113	.114	.055
18:2 ISO2	.138	.108	.143
18:2 ISO3	.113	.093	.105
18:3 ω 6	.036	.031 ^a	.042 ^b
20:0	.073	.071	.095

Table 34 (Continued)

Fatty acid	Diets		
	Control corn (n=10)	Corn + soybeans (n=10)	Corn +soybeans: peanut skins (n=10)
18:3 ω 3	.204 ^a	.279 ^b	.293 ^b
20:1	.806	.592	.599
20:2	.083	.092	.096
20:3	.182	.169	.181
22:0	.016	.021	.021
20:4 ω 6	.428	.540	.534
20:5 ω 6	.017	.045	.018
20:5 ω 3	.026	.016	.020
24:0	.090	.171	.130
22:5 ω 6	.180	.090	.067
22:5 ω 3	.210	.298	.266
22:6 ω 3	.027	.056	.035

^{abc}Means in a row followed by different superscript letters are significantly different at the P<.05 level.

Table 35. Average percentages of fatty acid types in intramuscular lipids of longissimus muscle from steers fed different diets after grazing on pasture for each type diet.

Fatty acid type ^a	Diets		
	Control corn (n=10)	Corn + soybeans (n=10)	Corn +soybeans: peanut skins (n=10)
SAT 10-15C	5.38	5.14	6.42
SAT 16-24C	39.29	37.30	39.83
MONO	46.35	48.05 ^b	44.68 ^c
PUFA6	3.68	3.59	3.49
PUFA3	.53	.80	.72
UNKNOWNNS	2.43	2.60	2.35

^aSAT 10-15C=10:0+11:0+12:0+13:0+14:0+15:0; SAT 16-24C=16:0+17:0+18:0+20:0+22:0+24:0; MONO=14:1+15:1+16:1+17:1+18:1+20:1; PUFA6=18:2 ω 6+18:3 ω 6+20:4 ω 6+20:5 ω 6+22:5 ω 6; PUFA3=18:3 ω 3+20:5 ω 3+22:5 ω 3+22:6 ω 3, and UNKNOWNNS consist of 81 fatty acids with retention times from 4.14 to 38.80 min.

^{b,c}Means in a row followed by different superscripts are significantly different at the P<.05 level.

levels of 18:3 ω 3 in the intramuscular lipids of cattle fed diets containing full fat soybean than in those of cattle fed the control corn diet agree with the results of Skelley et al. (1973) who reported that including soybeans in diets fed to cattle generally results in more unsaturation of the intramuscular fatty acids. In contrast to these results, Rule and Beitz (1986) found no difference between the 18:3 ω 3 contents of the intramuscular lipids in steers fed a control grain diet and in steers fed the diet supplemented with full fat soybeans to supply 6% dietary fat content ($P>.05$).

Sensory Characteristics and Tenderness

The analyses of variance for the sensory characteristics, aroma, taste, and acceptability, and tenderness of cooked longissimus muscle as a function of treatment are shown in Table 36. For each steer, the sensory scores were averaged only for the 28 panelists who attended each evaluation session. The treatment sum of squares was partitioned by orthogonal contrasts C1 through C6 given in Table 4, p. 25. Significant treatment effects were found for taste, acceptability and tenderness, but not for the aroma. The sensory scores for taste and acceptability increased quadratically across DOF as shown by the significant comparisons C1 and C2 for each characteristic in Table 36 and by the averages at 0, 56 and 112 DOF and equations given in Table 37. The score for taste increased from 4.2 at 0 DOF to 5.8 at 112 DOF while the acceptability score increased from 4.4 to

Table 36. Sums of squares^a from analyses of variance for sensory scores and shear value of longissimus muscle samples from steers grazed on pasture and then fed different diets from 0 to 112 days (DOF).

Source	Degrees of freedom	Sensory scores			Shear value
		Aroma	Taste	Acceptability	
Treatment (T)	6	2.00	11.21**	7.15**	45.88**
C1 ^b	1	.03	5.06**	2.70**	27.30**
C2 ^b	1	.93	4.40**	3.16**	13.39**
C3 ^b	1	.19	.31	.26	3.42
C4 ^b	1	.24	1.05*	.72	1.31
C5 ^b	1	.57	.02	.05	.44
C6 ^b	1	.03	.37	.25	.01
Error (T x block) ^c	22	5.54	4.53	5.05	38.54
Residual	6	1.84	2.62	2.21	17.45
Total	34	9.38	18.36	14.41	101.86

^a* $p < .05$; ** $p < .01$.

^bC1 is a linear DOF effect; C2 is a quadratic DOF effect; C3 compares the diet containing soybeans (SB) with the diet containing SB:peanut skins; C4 is the interaction of soybean diets with 56 and 112 DOF; C5 compares 56 versus 112 DOF for diet containing SB and C6 compares the control diet to both diets containing SB. See Table 4, p. 25.

^cFor definition of this error term, see Table 10, p. 29.

Table 37. Average sensory scores and shear values for cooked longissimus muscle samples from steers grazed on pasture and then fed different diets from 0 to 112 days (DOF) for each type of diet and DOF.

Variable	Sensory scores ^a			Shear value (g)
	Aroma	Taste	Acceptability	
DIET ^b				
Control corn (n=10)	5.2	5.8	5.6	3197
corn + soybeans (n=10)	5.2	5.7	5.6	3405
Corn + soybeans: peanut skins (n=10)	5.0	5.4	5.3	3029
DOF ^c				
0 (n=5)	4.8	4.2	4.4	4597
56 (n=15)	5.0	5.5	5.4	3274
112 (n=15)	5.3	5.8	5.7	2960

^aThe scores were from an 8-point scale where 4=dislike slightly, 5=like slightly and 6=like moderately, and each sample was evaluated by 28 panelists.

^bNo significant differences were found among the diets for the sensory scores or shear value.

^cTaste, acceptability and shear value were significantly affected by DOF as shown by the following equations: Taste = $4.2 + .0319(\text{DOF}) - .000159(\text{DOF})^2$; Acceptability = $4.4 + .0230(\text{DOF}) - .000106(\text{DOF})^2$; and shear value = $4597 - 34.23(\text{DOF}) + .190(\text{DOF})^2$.

5.7 during the same period. The scores at 0-DOF were between dislike slightly and like slightly and at 112 DOF between like slightly and like moderately. In addition the tenderness of the longissimus as measured by the Warner-Bratzler shear increased quadratically with increasing DOF from 0 to 112 ($P<.05$) as shown in tables 36 and 37. The longissimus at 0 DOF required 4597 g force to shear a 1.27 cm diameter core compared with 2960 g force for the same size core at 112 DOF.

There were no significant differences among diets for aroma, acceptability or shear value. However, there was a significant C4 for taste indicating an interaction among diets containing soybeans with 56 and 112 DOF. Longissimus samples from steers fed the corn + soybeans diet had a taste score of 5.8 at 56 DOF and 5.6 at 112 DOF, while samples from steers fed the corn + soybeans:peanut skin diet had a taste score of 5.1 at 56 DOF and 5.8 at 112 DOF.

The improvement in taste and acceptability scores with increasing DOF has been found in several studies at the University of Tennessee and by other researchers (Melton, 1983). The fact that grain-produced beef has more desirable flavor than grass produced beef is reported to be due to a higher intensity of a cooked beef fat flavor and a lower intensity of milky-oily flavor in the grain produced beef (Melton, 1983). This difference in flavor between grass and grain produced beef also may be due to a higher level of pentanal, toluene and alkyl benzenes that have been found in higher concentration in grass produced beef than in grain produced beef (Bolton, 1987).

Relationship of Flavor to Intramuscular Lipid Fatty Acid Levels

Table 38 shows correlation coefficients of the taste and acceptability scores of the cooked beef with the selected fatty acid concentrations in the raw beef. A negative correlation coefficient indicates that higher concentrations of the fatty acid in the intramuscular lipids contributed to a less desirable taste and lower acceptability score. Higher levels of the fatty acids: 11:0, A15:0, 15:1, A17:0, 16:1 ISO, 18:0, 18:2 ISO1, 18:2 ISO2, 18:3 ω 3, 20:0, 20:2, 22:0 and 22:5 ω 3 as well as the fatty acid types: PUFA3 and UNKNOWNs, were significantly correlated negatively with taste score. Therefore, these fatty acids and types in some way may have contributed to the less desirable taste of the beef. The percentages of 18:2 ISO1 and 18:2 ISO3 and of MONO were significantly positively correlated with the taste score and may have in some manner contributed to a more desirable beef taste. The correlation coefficients of the fatty acids and fatty acid types with the acceptability score were generally the same as those with the taste score with the following exceptions. The level of 14:1 was significantly negatively correlated with the acceptability score but not the taste score and the levels of 18:0, 22:5 ω 3 and MONO were not significantly correlated with the acceptability score. Also, the correlation coefficients of the fatty acids and types of fatty acids with the acceptability score were generally lower than those with the taste score. The highest correlation coefficients found were between taste score and A15:0 (-.71), taste score and 15:1 (-.70) and taste score and 18:3 ω 3 (-.64) as shown in Table 38.

Table 38. Selected correlation coefficients^a of sensory characteristics of cooked steak with fatty acid concentrations in intramuscular lipid of the longissimus muscle from steers grazed on grass and then fed different diets from 0 to 112 days (DOF).

Fatty acid	Sensory characteristics	
	Taste	Acceptability
11:0	-.53**	-.49**
15:0	-.71***	-.67***
14:1	-.30	-.36*
15:1	-.70***	-.68***
17:0	-.52**	-.44**
16:1 ISO	-.63***	-.50**
18:0	-.37*	-.31
18:2 ISO1	.39*	.33
18:2 ISO2	-.41*	-.39*
18:2 ISO3	.52**	.54**
18:3 ω 3	-.64***	-.60***
20:0	-.43*	-.36*
20:2	-.41*	-.42*
22:0	-.38	-.38
22:5 ω 3	-.40*	-.25
<u>Fatty acid type</u>		
MONO	.35*	.29
PUFA3	-.56***	-.50**
UNKNOWN	-.46**	-.40*

^a* $p < .05$; ** $p < .01$; *** $p < .001$; (n=33).

Several investigators have found that higher levels of the omega-3 fatty acids and the odd carbon number, branch chain fatty acids such as A15:0 are highly correlated with higher intensities of undesirable flavors and/or lower taste desirability scores (Holden, 1985; Mann, 1983; Melton et al., 1982; Melton, 1983; Schell, 1988) which are in agreement with results found in the present study. Melton (1983) also reported that higher levels of the monounsaturated fatty acids were generally correlated with higher levels of desirable flavors in beef and more desirable taste scores which was also found in the present study. The exact manner in which these fatty acids are related to the desirability of beef flavor has still not been determined.

V. SUMMARY

The objectives of this investigation were (1) to determine the growth and carcass traits of steers fed full fat soybean supplemented diets with and without peanuts skins and (2) to evaluate the sensory characteristics and chemical composition of beef produced on those diets. Thirty-five steers grazed fescue-clover pasture during the 1987 spring-summer and then were fed a maintenance diet of mixed grass-clover hay and limited concentrate from Aug. to Nov., 1987, at which time they were divided into 7 groups of 5 steers per group. Each group was randomly allotted to one of 7 treatments (T). T1 steers were slaughtered directly off maintenance diet and were the 0 DOF steers. The other 6 groups were adjusted to grain diets for 14 days before full feeding began. Two groups were adjusted to a control corn diet (D1); two groups, to a full fat soybean supplemented corn diet (D2) and two groups, to a corn diet supplemented with full fat soybeans:peanut skins, 1:1 ratio (D3). For each of these diets, one group of steers was slaughtered after 56 days of full feeding (56 DOF) and another after 112 days (112 DOF). T2 was D1-56 DOF; T3, D1-112 DOF; T4, D2-56 DOF; T5, D2-112 DOF; T6, D3-56 DOF and T7, D3-112 DOF. Steers were weighed at 0, 56 and 112 DOF; daily consumption of grain per each group was determined and average daily gain (ADG) from 0 to 56 DOF calculated for each steer except those in T1. ADG from 57 to 112 DOF (ADG112) for the steers in T3, T5, and T7 was also determined, and the feed conversion rate (FCR) for each diet and DOF calculated. After slaughter, for each steer, the hot carcass weight, adjusted fat thickness, rib eye area, % kidney, pelvic and heart fat (KPH), and USDA yield and

quality grades were determined, and samples of subcutaneous fat from over the sirloin and of the longissimus muscle were obtained. Level of total lipids and the fatty acid (FA) composition of these lipids in the subcutaneous fat and longissimus muscle were determined. FA were grouped into FA types: SAT 10–15C (10:0, 11:0, 12:0, 13:0, 14:0, and 15:0); SAT 16–24C (16:0, 17:0, 18:0, 20:0, 22:0 and 24:0), MONO (14:1, 15:1, 16:1, 17:1, 18:1 and 20:1), PUFA6 (18:2 ω 6, 18:3 ω 6, 20:4 ω 6, 20:5 ω 6, and 22:5 ω 6), PUFA3 (18:3 ω 3, 20:5 ω 3, 22:5 ω 3 and 22:6 ω 3) and UNKNOWN (81 FA). Eleven other FA composed of isomers (16:1 ISO, 18:1 ISO, 18:1 ISO1, 18:1 ISO2, 18:2 ISO1, 18:2 ISO2 and 18:2 ISO3), unsaturated FA of unknown ω position (20:2 and 20:3) and 2 branched chain FA (A15:0 and A17:0) were also measured. Also, the aroma, taste and acceptability of cooked longissimus muscle from each steer were scored by an untrained panel on an 8-point scale where 4=dislike slightly, 5=like slightly and 6=like moderately and the Warner–Bratzler shear force for a 1.27 cm core of the muscle from each steer was measured.

All variables except ADG112 and FCR were statistically analyzed as a function of DOF and type of diet. The levels FA were also analyzed as a function of sampling site, and FA percentages in the longissimus muscle were correlated with sensory scores. ADG56 and ADG112 for steers in T3, T5 and T7 were analyzed as a function of diet and ADG period.

Compared with steers fed D2 and D3, steers fed D1 had a higher ($P<0.05$) ADG56 (1.23 and 1.22 versus 1.70 kg/day, respectively) and a greater ($P<0.05$) weight increase (26.1 and 24.1 versus 30.1%, respectively). Steers slaughtered at 56 DOF gained 21.1% weight while those slaughtered at 112

DOF gained 32.9% weight. Steers slaughtered at 112 DOF on D1, D2, and D3 had an ADG56 of 1.70, 1.24 and 1.25 kg/day, respectively, and an ADG112 of 1.45, 1.51 and 1.09 kg/day, respectively. The ADG112 for steers fed D2 was greater than the ADG56 ($P<.05$). The FCR for D1, D2 and D3 was, respectively, 6.68, 7.49 and 7.68 for 56 DOF, and 7.70, 5.66 and 9.01, for 112 DOF.

The main differences found in any of the dependent variables were due to the DOF. The following significant increases were found in the values of dependent variables with increasing DOF from 0 to 112: steer weight, from 372 to 538 kg; hot carcass weight, from 185 to 316 kg; rib eye area, from 56.1 to 79.2 cm²; adjusted fat thickness, from .22 to 1.25 cm; % KPH, from 1.0 to 2.1; yield grade, from 1.7 to 2.9; quality grade, from standard to low choice; total lipid in subcutaneous fat, from 60.4 to 83.1% and total lipid in the longissimus muscle, from 2.6 to 8.0%; MONO in subcutaneous fat, from 36.5 to 44.1%; PUFA6 in subcutaneous fat, from 1.5 to 2.6%; MONO in the longissimus muscle, from 38.4 to 47.4%; taste score, from 4.2 to 5.8 and acceptability score, from 4.4 to 5.7. For the same time period the following significant decreases in levels of dependent variables were found: SAT 16-24C in subcutaneous fat, from 48.1 to 42.8%; PUFA in subcutaneous fat, from .7 to .3%; SAT 16-24C in longissimus muscle, from 43.1 to 38.7%; PUFA3 in longissimus muscle, from 1.8 to .5%; UNKNOWNs in longissimus muscle, from 4.3 to 2.2%, and WB shear of the muscle cores from 4597 to 2960 g.

Diet had much less effect on the dependent variables than DOF. Steers fed the control corn diet had a significantly heavier hot carcass weight (301 kg) than those fed the corn + soybeans diet (279 kg) or the corn +

soybeans:peanut skins diet (272 kg) and a higher ADG through 56 DOF, (1.7 versus 1.2 kg/day). Diet had little effect on the FA composition of subcutaneous fat or longissimus muscle. Steers fed the corn + soybeans diet contained higher levels of MONO and lower levels of 14:0, 16:0 and 18:3 ω 6 in longissimus muscle than those fed the corn + soybeans:peanut skins diet, and steers fed the control corn diet had lower levels of 18:3 ω 3 in the longissimus muscle than those fed the corn + soybean diet or the corn + soybeans:peanut skins diet.

Compared with the longissimus muscle, the subcutaneous fat had higher levels of SAT 10–15C ($P<.05$) (8.1 versus 5.7%), SAT 16–24C (42.6 versus 39.4%), and lower levels of PUFA6 (2.5 versus 4.1%), PUFA3 (.4 versus .8%) and UNKNOWNNS (.8 versus 2.7%). The highest correlation coefficients between sensory scores and % FA in the longissimus muscle intramuscular lipids were taste with A15:0 FA ($-.71$, $P<.001$), and 18:3 ω 3 ($-.64$, $P<.001$).

In this study, tannins fed to cattle in a diet that also contained polyunsaturated fatty acids in the form of an oil embedded in a protein matrix (extruded full fat soybeans) did not inhibit hydrogenation of the unsaturated FA by rumen microorganisms. This conclusion is based on the fact that compared with the soybean supplemented diet, the diet containing an equivalent level of soybeans plus peanut skins failed to produce beef containing higher levels of polyunsaturated fatty acids, particularly 18:2 ω 6 and 18:3 ω 3. Instead, the diet containing peanut skins produced beef with significantly higher percentages of saturated FA and a lower percentage of MONO fatty acid types. Obviously, acceptable ways,

other than feeding natural sources of tannins, must be found to prohibit hydrogenation of unsaturated fatty acids by rumen microorganisms if the FA composition of beef is to be altered appreciably.

REFERENCES

REFERENCES

- AOCS., 1975. "Official and Tentative Methods," 4th ed. American Oil Chemists' Society, Champaign, IL.
- Bidner, T. D., Schupp, A. R., Montgomery, R. E., and Carpenter, J. C. 1981. Acceptability of beef finished on all-forage, forage-plus-grain or high energy diets. *J. Anim. Sci.* 53:1181.
- Bolton, J. C. 1987. Sensory and chemical evaluation of flavor in ground beef from grass- and grain fed steers. Master's Thesis, University of Tennessee, Knoxville.
- Bonanome, A., and Grundy, S. M. 1988. Effect of dietary stearic acid on plasma cholesterol and lipoprotein levels. *The New England Journal of Medicine.* 318:1244.
- Bowling, R. A., Riggs, J. K., Smith, G. C., Carpenter, Z. L., Reddish, R. L., and Butler, O.D. 1978. Production, carcass and palatability characteristics of steer produced by different management systems. *J. Anim. Sci.* 46:333.
- Burns, J. C., and Cope, W. A. 1974. Nutritive value of crownvetch forage as influenced by structural constituents and phenolic and tannin compounds. *Agron. J.* 66:195.
- Chalmers, M. I., Cuthbertson, D. P., and Synge, R. L. M. 1954. Ruminal ammonia formation in relation to the protein requirement of sheep. Duodenal administration and heat processing and factors influencing fate of casein supplements. *Agr. Sci.* 44:254.
- Chalupa, W., and Kutches, A. J. 1968. Biohydrogenation of linoleic-1-C¹⁴ acid by rumen protozoa. *J. Anim. Sci.* 27:1502.
- Cook, L. J., Scott, T. W., and Pan, Y. S. 1972. Formaldehyde-treated casein-safflower oil supplement for dairy cows. *J. Dairy Res.* 39:211.

- deMan, J. M. 1985. "Principles of Food Chemistry", Revised 5th Printing. The AVI Publishing Co., Inc. Westport, CT. Pages 40 and 46.
- Dinius, D. A., Oltjen, R. R., Lyon, C. K., Kohler, G. O., and Walker, H. G. 1974. Utilization of a formaldehyde treated casein-safflower oil complex by growing and finishing steers. J. Anim. Sci. 39:124.
- Donnelly, E. D., and Anthony, W.B. 1970. Effect of genotype and tannin on dry matter digestibility in *sericea lespedeza* Crop Sci. 10:200.
- Eggum, B. O., and Christensen, K. D. 1975. "Breeding for Seed Improvement Using Nuclear Techniques". International Atomic Energy Agency, Vienna. pages 135-143.
- Ferguson, K. A., Hemsley, J. A., and Reis, P. J. 1967. The effect of protecting dietary protein from microbial degradation in the rumen. Aust. J. Sci. 30:215.
- Goldstein, J. L., and Swain, T. 1965. The inhibition of enzymes by tannins. Phytochem. 4:185.
- Greathouse, G. A., Schalles, R. R., Brent, B. E., Dayton, A. D., and Smith, E. F. 1974. Effects of levels and sources of protein on performance and carcass characteristics of steer fed all-concentrate rations. J. Anim. Sci. 39:102.
- Gupta, B. S., Gupta, B. N., Saha, R. C., Bhandari, A. B., and Mathur, H. L. 1977. Studies on long term feeding of sal (*shorea robusta*) seed meal to adult cattle. Indian Vet. J. 54:463.
- Hagerman, A. E., and Bulter, L. G. 1978. Protein precipitation for the quantative determination of tannins. J. Agric. Food Chem. 26:809.
- Hagerman, A. E., and Butler, L. G. 1980. Condensed tannin purification and characterization of tannin-associated proteins. J. Agric. Food Chem. 28:947.
- Hale, O. M., and McCormick, W. C. 1981. Value of peanut skins (testa) as a feed ingredient for growing-finishing swine. J. Anim. Sci. 53:1006.

- Hancock, D. L., Williams, J. E., Hedrick, H. B., Beaver, E. E., Larrick, D. K., Eilersieck, M.R., Garner, G. B., Marrow, R. E., Paterson, J. A., and Gerresh, J. R. 1987. Performance, body composition and carcass characteristics of finishing steers as influenced by previous forage systems. *J. Anim. Sci.* 65:1381.
- Haslam, E., Ople, C. T., and Porter, L. J. 1977. Procyanidin metabolism: A hypothesis. *Phytochemistry* 16:1625.
- Hawkins, G. E. 1955. Consumption and digestibility of *Lespedeza sericea* hay and alfalfa hay plus gallotannin. *J. Dairy Sci.* 38:237.
- Hidiroglou, N., McDowell, L. R., and Johnson, D. D. 1987. Effect of diet on animal performance, lipid composition of subcutaneous adipose and liver tissue of beef cattle. *Meat Sci.* 20:195.
- Hill G.M., Utley, P.R., and Newton, G.L. 1986. Influence of dietary crude protein on peanut skin digestability and utilization by feedlot steers. *J. Anim. Sci.* 62:887.
- Hill, G.M., Utley, P.R., and Newton, G.L. 1986. Digestibility and utilization of ammonia-treated and urea-supplemented peanut skin diets fed to cattle. *J. Anim. Sci.* 63:705.
- Holden, C. 1985. Flavor, fatty acid composition and contents of tocopherols, carotenoids, and phospholipids of beef produced by different feeding regimes. University of Tennessee, Knoxville, Master's Thesis.
- Hood, R. L., and Thornton, R. F. 1976. Site variation in the deposition of linoleic acid in adipose tissue of cattle given formaldehyde-treated sunflower seed. *Aust. J. Agric. Res.* 27:895.
- Hoon, I. O., Hoff, J. E., Armstrong, G. S., and Lawrance, A. H. 1980. Hydrophobic interaction in tannin-protein complexes. *J. Agric. Food. Chem.* 28:394.
- Johnson, A. R. 1974. Biomanipulation of ruminant fats. *Food Manufacture* 49:19.

- Kuller, L. H. 1983. "Epidemiology of Coronary Heart Disease", ed. Perkins, E. G. and Vised, W. J., American Oil Chemists Society, Champaign, Illinois.
- Kumar, R., and Singh, M. 1984. Tannins: Their adverse role in ruminant nutrition. *J. Agric. Food Chem.* 32:447.
- Leander, R. C., Hedrick, H. B., Stringer, W. C., Clark, J. C., Thompson, G. B., and Matches, A. G. 1978. Characteristics of bovine longissimus and semitendinosus muscles from grass land grain-fed animals. *J. Anim. Sci.* 46:965.
- Lease, E. L., and Mitchell, J. H. 1940. A study of the tannins of *lespedeza aericoa*. South Carolina Agr. Exp. Sta. Annu. Rep. 53:71.
- Lohan, O. P., Lall, K., Pal, R. N., and Negi, S. S. 1979. Dairy Industry Conference, Hyderabad, India, Feb. 1979.
- Loomis, W. D. 1974. Overcoming problems of phenolics and quinones in the isolation of plant enzymes and organelles. *Methods Enzymol.* 31:528.
- Mann, T. F. 1983. Lipids, fatty acids and flavor of beef from steers grazed on different pastures or fed up to 112 days on a corn based finishing ration. University of Tennessee, Knoxville, Master's Thesis.
- Mattson, F. H., and Grundy, S. M. 1985. Comparison of effects of dietary saturated, monounsaturated, and polyunsaturated fatty acids on plasma lipids and lipoproteins in man. *J. Lipid Res.* 26:194.
- McBrayer A. C., Utley, P.R., Lowrey, R.S., and McCormick W.C. 1983. Evaluation of peanut skins (testa) as a feed ingredient for growing-finishing cattle. *J. Anim. Sci.* 56:1983.
- Melton, S. L., Moyers, R. E., and Playford, C. G. 1979. Lipids extracted from soy products by different procedures. *J. Amer. Oil Chem. Soc.* 56:489.
- Melton, S. L., Amiri, M., Davis, G. W., and Backus, W. R. 1982. Flavor and chemical characteristics of ground beef from grass-, forage-grain- and grain-finished steers. *J. Anim. Sci.* 55:77.

- Melton, S. L. 1983. Effect of forage feeding on beef flavor. *Food Tech.* 37:239.
- Miller, G. J., Varnel, T. R., and Rice, R. W. 1967. Fatty acid composition of certain ovine tissues as affected by maintenance level rations of roughages and concentrates. *J. Anim. Sci.* 26:41.
- Montgomery, R. E., and Bidner, T. D. 1979. Palatability and fatty acid composition of forage and grain finished beef. *J. Anim. Sci.* 49:53. (Abstract)
- Mudgal, V. D., and Sampath, S. R. 1969. Proceedings of II Workshop on Agricultural by products and ration for livestock, Bhubneshwar, India, 1969.
- Musha, T., and Eugenia, A. 1970. Carob tannins-growth depression and levels of insoluble nitrogen in the digestive tract of rats. *J. Nut.* 100:573.
- Narasinga, B. S. and Prabhavathi, T. 1982. Tannin content of foods commonly consumed in India and its influence on ionisable iron. *J. Sci. Food Agric.* 33:89.
- Newsome, R. L., Moody, W. G., Langlois, B. E., Gay, N., McMillian, M., and Fox, J. D. 1985. Effects of cattle-finishing systems on carcass traits and aging method on loin shrinkage and steak color. *J. Anim. Sci.* 60:1208.
- Oltjen, R. R., and Dinius, D. A. 1975. Production practices that alter the composition of foods of animal origin. *J. Anim. Sci.* 41:703.
- Perkins, E. G., and Visek, W. J. 1983. "Dietary Fats and Health", American Oil Chemists' Society, Champaign, IL, pages 496-511 and 679-688.
- Peter, A. P. 1971. Aldehyde treatment of soybean meal for ruminants. University of Illinois, Urbana, PhD. dissertation.
- Polan, C. E., McNeil, J. J., and Tove, S. B. 1964. Biohydrogenation of unsaturated fatty acids by rumen bacteria. *J. Bact.* 88:1056.

- Radhakrishna, M. R., and Sivaprasad, J. 1980. Tannin content of sorghum varieties and their role in iron bioavailability. *J. Agric. Food Chem.* 28:55.
- Reagan, J. O., Stribling, K. V., Carpenter, J. A. , and Campion, D. R. 1983. Microbiological, vacuum packaging and palatability attributes of beef produced at varied levels of forages and grain. *J. Anim. Sci.* 53:1482.
- Rule, D. C., and Beitz, D. C. 1986. Fatty acids of adipose tissue, plasma, muscle and duodenal ingesta of steers fed extruded soybeans. *J. Amer. Oil Chem. Soc.* 63:1429.
- Rule, D. C., Parrish, F. C., and Beitz, D. C. 1986. Effects of extruded soybeans on steer growth and sensory characteristics and lipid composition of steaks. *Nutrition Reports International* 33:285.
- Rumsey, T. S., Oltjen, R. R., Bovard, K. P., and Priode, B. M. 1972. Influence of widely diverse finishing regimens and breeding on depot fat composition in beef cattle. *J. Anim. Sci.* 35:1069.
- SAS. 1985. "Sas User's Guide", SAS Institute Inc., Cary, NC.
- Schell, A. S. 1988. Chemical components of ground beef produced on grass- or grain diets and their relation to beef flavor. University of Tennessee, Knoxville, Master's Thesis.
- Schroeder, J. W., Cramer, D. A., Bowling, R. A., and Cook, C. W. 1980. Palatability, shelflife and chemical differences between forage- and grain-finished beef. *J. Anim. Sci.* 50:852.
- Scott, T. W., Cook, L. J., and Mills, S. C. 1971. Protection of dietary polyunsaturated fatty acids against microbial hydrogenation in ruminants. *J. Amer. Oil Chem. Soc.* 48:358.
- Sibbald, I. R., Loughheed, T. C., and Linton, J. H. 1968. A methionine supplement for ruminants. *Proc. of Second World Conf. on Animal.* College Park, Maryland.

- Skelley, G. C. Stanford, W. C., and Edwards, R. L. 1973. Bovine fat composition and its relation to animal diet and carcass characteristics. *J. Anim. Sci.* 36:576.
- Sumida, D. M., Vogt, D. W., Cobb, E. H., Iwanaga, I. I., and Reimer, D. 1972. Effect of breed type and feeding regime on fatty acid composition of certain bovine tissues. *J. Anim. Sci.* 35:1058.
- Swain, T., and Kleiman, A. 1979. The resource potential in phytochemistry. *Recent Advances in Phytochem.* 12:617.
- Swenson, M. J. 1970. *Duke's Physiology of Domestic Animals*, 8th edition. Cornstock Publishing Associates, Cornell University Press, Ithaca.
- Tatum, J. D., Smith, G. C., Berry, B. W., Murphey, C. E., Williams, F.L., and Carpenter, C. E. 1980. Carcass characteristics, time on feed and cooked beef palatability attributes. *J. Anim. Sci.* 50:833.
- Topel, D. G. 1986. Future meat-animal composition: Industry adaptation of new technologies. *J. Anim. Sci.* 63:633.
- Tracey, M. V. 1975. Altering fatty acid composition of ruminant products. *Cereal Foods World* 20:77.
- Utley, P. R., Hellwig, R. E., and McCormick, W. C. 1975. Finishing beef cattle for slaughter on all-forage diets. *J. Anim. Sci.* 40:1034.
- Utley, P. R., and Hellwig, R. E. 1985. Feeding value of peanut skins added to bermudagrass pellets and fed to growing beef calves. *J. Anim. Sci.* 60:329.
- Van Buren, J. P. and Robinson, W. B. 1969. Complexes between protein and tannic acid. *J. Agr. Food Chem.* 17:772.
- Van Soest, P.J. 1984. *Nutritional Ecology of the Ruminant*. Corvallis: O & B Books Inc.
- Vohra, P., Kratzler, F. H., and Joslyn, M. A. 1965. The growth depressing and toxic effects of tannins to chicks. *Poultry Sci.* 44:135.

- Waller, J. C. 1989. Personal communication. University of Tennessee, Knoxville.
- Westerling, D. B., and Hedrick, H. B. 1979. Fatty acid composition of bovine lipids as influenced by diet, sex and anatomical location and relationship to sensory characteristics. *J. Anim. Sci.* 48:1343.
- Yeo, Y. K. 1982. Beef flavor and fatty acids in different carcass sites as affected by grass and corn diets up to 140 days. University of Tennessee, Knoxville, PhD. dissertation.
- Zelter, S. Z., Leroy, F., and Tissier, J.P. 1970. Protection of proteins in the feed against bacteria deamination in the rumen. I. Studies in vitro: Behavior in the rumen of some proteins tanned with tannin from chestnut wood of certain aldehydes (formaldehyde, glutaraldehyde, glyoxal). *Ann. Biol. Anim. Biochim. Biophys.* 10:111.
- Zelter, S. Z. and Leroy, F. 1966. Schutz der Nahrungsproteine gegen microbielle Desaminierung im Pansen. *Z. Tierphysiol., Tierernahr. u. Futtermittelkde.* 22:39.

VITA

Melanie Jane Huskey was born on February 19, 1964, to Jackson Huskey and Jane Stewart Huskey. In 1982, she graduated from Ninety Six High School, in Ninety Six, SC. Melanie entered the University of Tennessee in September, 1982, and received her BS in Animal Science in March of 1986.

In March of 1986, she was offered a co-op job with Cryovac in Duncan, SC, where she worked until September of 1986. At that time, she began work on a Master of Science degree in the Food Technology and Science Dept. at the University of Tennessee. On December 12, 1987, Melanie married George Douglas Sims. From June to August, 1987, she co-oped with the Tennessee Extension Service. On January 3, 1989, she began work with Cryovac in Duncan, SC, as a full time employee as an Associate Food Technologist. And in the summer of 1989, Melanie received her Master of Science degree in Food Technology and Science.