EFFECTS OF MANAGEMENT SYSTEMS ON THE FATTY ACID AND CHOLESTEROL CONTENT OF BEEF

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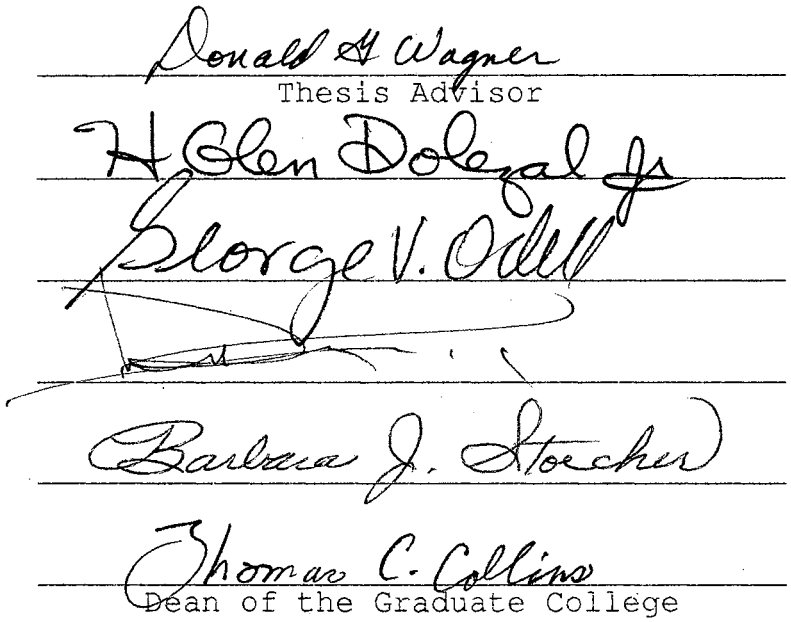

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NOMENCLATURE

AOAC	Association of Official Analytical Chemists
°C	degrees Celcius
cm	centimeters
d	days
FAME	fatty acid methyl esters
g	grams
hr	hours
i.m.	intramuscular fat
LP	Laidlomycin propionate
M	moles/liter
m	meters
mm	millimeters
MUFA	monounsaturated fatty acids
NL	neutral lipid
oz	ounces
PhL	phospholipid
PL	polar lipid
PUFA	polyunsaturated fatty acids
s.c.	subcutaneous fat
SFA	saturated fatty acids
TL	total lipid
TOF	time on feed
TRT	treatment
ul	microliters
um	micrometers
VFA	volatile fatty acid

CHAPTER I

INTRODUCTION

Often, questions are raised as to the importance of research aimed at altering the lipid and cholesterol content of beef products. The answer to these questions should become evident based on the answers of 83 freshmen agriculture students given a beef survey quiz in AnSi 1124, Introduction to Animal Science. Fifty-six percent of these 83 students believe that beef has a lot more fat and cholesterol than chicken and other meat. Eighty-one percent knew that the American Heart Association recommends that we should eat chicken and fish more often than red meat. The percent answering true to these questions indicates which organizations are getting their message to the public. Unfortunately in the beef industry, we continue to promote our product based on taste. Of course those of us who eat beef regularly know that nothing compares to a big juicy steak; however, those who do not elect to eat beef regularly because of concerns with fat and cholesterol probably will not be convinced by this approach. Instead, the fat and cholesterol in beef needs to be compared to other protein sources and daily values calculated to put it all in

perspective. When these comparisons are made, the beef industry needs the most up-to-date numbers for beef raised under today's management systems, completely trimmed of external fat, and with the most accurate measures available. For these reasons, the objective of this research was: 1) to ascertain the effects of management systems on longissimus muscle fatty acid and cholesterol content and 2) to compare traditional with newer methods of quantifying fatty acid and cholesterol content.

CHAPTER II

LITERATURE REVIEW

The Fat in Beef:

Perception versus Reality

The public perception of beef is that its saturated fat and cholesterol content entitles its removal from a healthy diet. This perception is even evident in students with Agriculture majors. Recently, a beef survey quiz was given to 83 freshmen students with Agriculture majors attending AnSi 1124, Introduction to Animal Science. Over half of these students (56%) believe that beef has a lot more fat and cholesterol than chicken and other meat. Conversely, these same students knew that the American Heart Association recommends that we eat poultry and fish more often than red meat (81%). Unfortunately, this perception of beef promoted by health officials has taken over reality.

Table 1 shows the fat, saturated fat and cholesterol content of beef, pork, and chicken taken from the USDA Agriculture Handbooks (USDA, 1979, 1990, & 1992). Beef actually has numerically less cholesterol than chicken and pork; thus, making the quiz question about beef having a lot more fat and cholesterol than chicken and other meats false. The fat and saturated fat content of beef, pork and chicken

TABLE 1. Fat, saturated fat and cholesterol content of beef, pork and chicken[a].

	Calories kcal/3 oz.	Calories from Fat %	Fat g/3 oz.	Saturated Fat g/3 oz.	Hyperchol.[b] Fat g/3 oz	Cholesterol mg/3 oz.
BEEF						
Rib, Choice, Broiled	201	52	11.74	4.77	3.23	66
Rib, Select, Broiled	175	46	8.86	3.60	2.43	66
Round, Choice, Broiled	162	34	6.22	2.18	1.53	66
Round, Select, Broiled	146	27	4.44	1.55	1.09	66
PORK						
Loin chops, Broiled	171	36	6.86	2.51	1.71	70
Ham, Roasted	183	44	8.92	3.08	2.11	78
CHICKEN						
Breast, w/o skin, Roasted	140	19	3.03	.86	.65	72
Breast, w/ skin, Fried	221	46	11.22	2.99	2.11	72
Drumstick, w/o skin, Roasted	146	30	4.81	1.26	.95	79
Drumstick, w/ skin, Fried	228	53	13.39	3.52	3.29	73

[a]Adapted from USDA Agriculture Handbooks: Chicken, 8-5, Aug. 1979; Pork, 8-10, Dec. 1992; Beef, 8-13, May 1990).
[b]Hypercholesterolemic Fat Content=Saturated fat content - C18:0.

with the skin on are relatively similar. The advantage of chicken is that removing the skin also removes most of the fat. However, this difference is only true when the skin is removed and no fat is added in sauces or oils during cooking. The answer of the freshmen students is typical of most Americans who believe beef fat is predominately saturated. Reiser et al. (1985) compared beef fat to coconut oil (all saturated fatty acids) and safflower oil (almost all polyunsaturated fatty acids) in humans diets receiving 35% of their calories from fat with 60% as the test fat. The individuals in the beef fat and safflower oil group had lower concentrations of serum total cholesterol and low-density lipoprotein (LDL) cholesterol than the individuals consuming the diet high in coconut oil. They concluded that grouping beef fat in the 'saturated' category with coconut oil is unwarranted. Weibe et al. (1984) investigated the source of protein in the diet with beef versus plant. The study revealed that those consuming the diet with the beef as a protein source had increased high density lipoprotein (HDL) cholesterol and decreased plasma triglycerides compared to those consuming the plant protein diet. Beef in the diet as a source of high quality protein was not associated with a hypercholesterolemic effect. Actually, over 50% of the fat in beef is unsaturated (USDA, 1990). The most prevalent fatty acids in beef are oleic, palmitic and stearic acids which together account for about 87% of the total fatty acids present. Oleic acid is a

monounsaturated fatty acid (MUFA) that accounts for about 44% of the total. The MUFA have been shown to be as effective as the polyunsaturated fatty acids (PUFA) at lowering serum cholesterol levels (Mattson and Grundy, 1985; Mensink and Katan, 1989; Gustafsson et al., 1994). Palmitic acid is a saturated fatty acid that is present at about 28% and is considered to be hypercholesterolemic or cholesterol elevating (Hegsted et al., 1965; Keys et al., 1965). More recently, Sundram et al. (1994) compared palmitic to a combination of lauric and myristic acids. Serum cholesterol concentrations were higher in the group consuming the diet high in lauric and myristic acids than those consuming the diet high in palmitic acid. Thus, palmitic acid may be less hypercholesterolemic than the combination of myristic and lauric acids. The third most prevalent fatty acid in beef is stearic acid at about 15%. Even though stearic acid has shown to be neutral or non-cholesterolemic (Hegsted et al., 1965; Keys et al., 1965), it is still lumped into the saturated fatty acid group and perceived as hypercholesterolemic. Denke and Grundy (1991) compared beef tallow and cocoa butter which are both high in stearic acid to butter or olive oil. LDL-cholesterol was lower in the diets with beef tallow, cocoa butter and olive oil. Bonanome and Grundy (1988) compared diets high in palmitic acid to ones high in stearic and oleic acids. The diets rich in stearic and oleic acids decreased total cholesterol by 14 and 21%, and LDL-cholesterol by 10% and 15%,

respectively. Theses researchers noted increased oleic acid concentration in plasma triglycerides and cholesterol esters after consuming the high stearic acid diets indicating that stearic acid is rapidly converted to oleic acid upon ingestion. This conversion to a MUFA after consuption explains its non-hypercholesterolemic effect.

According to the American Heart Association Diet (AHA, 1986), one should consume two servings (six oz.) per day of meat, poultry or seafood. Additionally, the AHA advocates the use of poultry (without the skin) and fish more often then red meat. O'Brien and Reiser (1980) actually tested these AHA recommendations on 29 adult men. These men consumed all four of the following diets: 1) at least 170 g/d of red meat, no fish or poultry and 3 eggs per day (HCRM); 2) at least 170 g/d of red meat, no fish, poultry or eggs and less than 300 mg cholesterol/d (LCRM); 3) at least 170 g/d of fish or poultry, no red meat or eggs and less than 300 mg of cholesterol/d (LCFP) 4) at least 170 g fish or poultry, no red meat and 3 eggs/d (HCFP). On the HCRM and HCFP diets, cholesterol intakes were greater than 1000 mg/d. In group one, no differences ($P > .05$) were noted in plasma cholesterol concentrations between any of the four treatments. In group two, HCFP and HCRM had higher ($P < .05$) plasma cholesterol concentrations than LCRM. In the LCFP, plasma cholesterol concentrations did not differ ($P > .05$) from LCRM or HCRM but were less ($P < .05$) than HCFP. Concentrations of HDL-cholesterol did not ($P > .05$) differ

between treatments or groups. These results indicate that in one group the addition of three eggs per day increased plasma cholesterol. More importantly, they show no evidence for the AHA recommendation of consuming poultry and fish more often than red meat. These authors concluded from this trial that strict adherence to the AHA recommendations would result in no substantial changes in plasma cholesterol. Ginsberg et al. (1990) also compared the Step 1 diet of the AHA (AHA; 30% of calories from fat; 10% of calories each as saturated, monounsaturated and polyunsaturated) to a diet high in MUFA (MUFA; 38% of calories from fat; 10% saturated, 18% monounsaturated and 10% polyunsaturated) or the average American diet (AAD; 38% calories from fat; 18% saturated, 10% MUFA, 10% PUFA). The MUFA diet decreased total cholesterol and LDL-cholesterol .46 and .36 mmol/L, respectively. The AHA diet also decreased total cholesterol .36 mmol/L but did not ($P>.05$) decrease LDL-cholesterol. Thus the MUFA diet was as, if not more, effective than the AHA diet. Similarly, Grundy (1986) compared a low fat diet (<20% of calories from fat) to a high MUFA diet (40% of calories from fat, 28% MUFA) in individuals with plasma cholesterol concentrations greater than 251 mg/dL as a cholesterol lowering diet. The MUFA diet decreased serum total and LDL-cholesterol by 13 and 21% and did not affect serum HDL-cholesterol or triglycerides. The low fat diet decreased total (8%) and LDL cholesterol (15%) to a lesser extent than the MUFA. However, the low fat diet decreased

HDL-cholesterol and increased serum triglycerides. Together, these studies indicate that recommendations of health officials to consume low fat diets devoid of red meat may not be the most advantageous for reducing plasma cholesterol levels in humans. Actually diets rich in MUFA appear to be the most effective at reducing LDL and total cholesterol without affecting triglycerides or HDL cholesterol. Since the fatty acid in greatest quantity in beef is oleic acid, dietary inclusion of beef as a source of high quality protein should not be perceived as an unhealthy choice.

Effects of Management Systems on Lipids

Age

Several researchers have investigated compositional changes that occur during growth and with advancing age. Hecker et al. (1975) and Link et al. (1970a) observed that as the intramuscular lipid content of the muscle increases with advancing age and growth, this increase is largely due to a proportional increase in triglycerides and decrease in phospholipid concentration. Hecker et al. (1975) suggested that the increase in triglyceride concentration is probably due to adipocyte infiltration into the muscle. The phospholipids are essential cell constituents that are associated with muscle leanness and membrane structure, and whose concentration is related to the physiological activity of that muscle's fibers (Bloor et al., 1934; Terrell et al., 1969; Turkki et al., 1967). The phospholipid fraction

remains constant during growth and its contribution to total lipid decreases as the triglycerides increase (Link et al., 1970a; O'Keefe et al., 1968; Duckett et al., 1993). Hecker et al. (1975) and Turkki et al. (1967) also suggested that fiber type (red versus white) plays an important role in determining the amount of phospholipid in the muscle. These authors have observed that red fibers contain 50% more phospholipids than white fibers .

Age may be the primary contributor to changes in the fatty acid composition of adipose tissue (Clemens et al., 1973). These workers found associations between animal age and myristic, palmitoleic, stearic and linoleic acids; however, no apparent trends could be drawn. In addition, others (Waldman et al., 1968; Clemens et al., 1973; Westerling and Hedrick, 1979) found significant correlations between animal age and oleic acid concentrations suggesting that this is due to more of the energy intake being deposited as fat as they approach physiological maturity. With respect to the polyunsaturated fatty acids, Link et al. (1970b) reported that since the polyunsaturated fatty acids are located predominantly in the phospholipid fraction, they are diluted with the fatty acids from the neutral lipid with advancing age. Concentrations of linoleic, linolenic and arachidonic acids decreased from the first biopsy period to the second, a difference of 60 days. Link et al. (1970b) found that polyunsaturated fatty acids per unit weight of muscle remain about the same during growth. Terrell et al.

(1968) found palmitic and stearic to be negatively associated with days of age in the polar lipid fraction, which lead to decreased saturated fatty acid concentrations in the polar lipid with advancing age.

Breed

Several researchers (Sumida et al., 1972; Gillis et al., 1973; Leat et al., 1977; Pyle et al., 1977; Eichhorn et al., 1986; Larick et al., 1989; Mills et al., 1992; Huerta-Leidenz et al., 1993) have noted differences in fatty acid composition between different breeds. In a comparison of Holstein versus beef breeds, Mills et al. (1992) reported increased concentrations of palmitoleic acid and decreased concentrations of stearic acid in Holstein steers. Leat (1977) also found similar differences in the unsaturated fatty acid content of Friesian versus Angus steers. Eichhorn et al. (1986) evaluated fifteen breeds of cows that were part of the Meat Animal Research Center crossbreeding program and found that breed was responsible for differences in nine out of the twelve fatty acids measured. These researchers attributed these differences in composition to be a reflection of the triglyceride to phospholipid ratio between the breeds. Similarly, Huerta-Leidenz (1993) comparing Brahman and Hereford cows, found increases in myristoleic, palmitoleic, oleic, linoleic, and linolenic acids along with decreases in palmitic and stearic acids in the s.c. fat of Brahman cows compared to Hereford. These differences resulted in Brahman cows having increased

concentrations of MUFA and PUFA at the expense of the SFA. These compositional differences remained when breeds were compared by analysis of covariance at common backfat thickness. Gillis et al. (1973) evaluated crossbreeding systems and found that myristic, palmitoleic and stearic acids were influenced by sire and dam breeds utilized in the crossbreeding system. In the sires, Limousin bulls had higher concentrations of myristic and palmitoleic acids in their i.m. fat than Simmental bulls. In the dam breeds, Angus cows had increased concentrations of palmitoleic acid in their i.m. fat. Pyle et al. (1977) also found differences in crossbred steers out of Angus dams and thirteen different sire breeds. Palmitoleic, stearic, and oleic acid concentrations were affected by sire breed in the s.c., i.m. and intermuscular fat in the brisket. Correlations between age and individual fatty acids were significant. Palmitic and oleic acids were positively associated with animal age (r=.48 and r=.31, respectively); whereas, stearic acid was negatively associated with animal age (r=-.46).

Cholesterol content did not differ between early and late maturing breed types (Wheeler et al., 1987). However, plasma cholesterol content was lower for the late maturing breed versus early maturing breed type. The relationship between plasma and tissue cholesterol content was low (r=.22). Thus, altering plasma cholesterol content in cattle may have little effect on tissue levels.

Diet

In a comparison of forage versus grain finishing diets, Williams et al. (1983) reported that consumption of the grain diet resulted in increased marbling scores, quality grades and percent fat in the soft tissue. This increase in fat content in the soft tissue resulted in decreased crude protein, moisture and ash concentrations. In comparison of mineral concentrations, cattle on the forage diets had increased concentrations of zinc, phosphorus, magnesium and potassium. Concentrations of zinc, iron, phosphorus, sodium and potassium were negatively correlated with fat content. As the total lipid content in the muscle increased, a proportional increase in triglyceride content was noted (Williams et al., 1983; Miller et al., 1981). The phospholipid content decreased and was inversely related with total fat content (Williams et al., 1983).

The difference between the forage and grain finishing diets resulted in differences in the fatty acid composition of the lipid. Grain feeding leads to increases in oleic acid and decreases in stearic, linoleic and linolenic acids (Williams et al., 1983). Other researchers (Sumida et al., 1972; Westerling and Hedrick, 1979; Williams et al., 1983; Mitchell et al., 1991) also noted increased concentrations of oleic acid in grain-fed versus forage-fed cattle. Sumida et al. (1972) found that cattle fed high concentrate feedlot diets had increased amounts of myristic, palmitic (C16:0), stearic, palmitoleic and oleic acids when compared to cattle

on pasture diets. Cattle on forage diets have increased concentrations of saturated and polyunsaturated fatty acids (Williams et al., 1983; Westerling and Hedrick, 1979; Marmer et al., 1984). Marmer et al. (1984) found increased amounts of the branched chain fatty acids in cattle fed forage diets. This increase in branched chain fatty acids is believed to be due to the digestion of microorganisms from the rumen. These fatty acids are prevalent in forage fed diets because the contribution from dietary lipids is minimal. The increase in polyunsaturated fatty acids of forage fed cattle is primarily due to an increase in linoleic acid (Miller et al.,1981; Williams et al. 1983; Marmer et al., 1984; Larick and Turner, 1989).

Ionophores

Ionophores are carboxylic polyether compounds that facilitate the transfer of ions across lipid membranes thereby disturbing the electrical charge across the surface. In doing so, they presumably work as selective antibiotics in that they force sensitive cells to expend additional energy to maintain equilibrium and thus reduce their survivability. Usually, the gram positive bacteria and protozoa are most vulnerable to the effects of ionophores. The importance of these ruminal bacterial changes are decreased lactic acid and methane production, and increased propionic acid production. The shifting of volatile fatty acid (VFA) concentration to increased propionate increases the efficiency of energy utilization. Estimates are that

20% more metabolizable energy is available to monensin supplemented lambs (Rowe et al., 1981). These fermentation changes have other effects as propionate is gluconeogenic. This results in a sparing effect on gluconeogenic amino acids (Schelling, 1984). Bergen and Bates (1984) reported increases from 22 to 55% in protein bypassing degradation in the rumen with ionophore supplementation. Overall, these changes in bacterial population upon ionophore feeding increase the efficiency of feed utilization by 6.4% (Owens et al., 1991).

Laidlomycin propionate (LP), trade name Cattlyst®, was released for use in ruminant animals this year. This ionophore differs from the more traditional ones by being acylated after its production which ultimately makes it more effective at relatively low dosages (Spires and Algeo, 1983). These newer ionophores are believed to work in the same manner as the more traditional ones; however, only limited research is available. Spires and Algeo (1983) showed that LP increased propionic acid production and decreased lactic acid production *in vitro*. However, research with LP in feedlot diets has found no differences in VFA concentrations (Galyean et al., 1992; Zinn and Spires, 1987). Laidlomycin propionate increases average daily gains, and decreases the amount of feed required to produce a pound of gain (Trenkle, 1992; Zinn and Spires, 1987). In contrast, monensin or lasalocid did not affect gains but improved feed efficiency (Trenkle, 1992).

Monensin typically reduces feed intake (Trenkle, 1992; Galyean et al., 1992); whereas LP does not have this effect. Laidlomycin propionate has gained added attention as it can influence carcass traits (Owens et al., 1991). Zinn and Spires (1987) reported increased fat thickness, marbling scores and carcass weights in steers supplemented with LP. Owens et al. (1991) in a summary of data reported that LP increased marbling scores with a quadratic maxima at 15 mg/kg. These increases in marbling scores have been attributed to the added carcass weights of the ionophore supplemented animals as a result of increased gains but appear to be dose-dependent (Owens et al., 1991; Zinn and Spires, 1987).

Ionophores do not appear to influence the amount of lipid deposited or proportion of lipid present in the storage or structural components (Gilka et al., 1989; Marmer et al., 1985). However, fatty acid composition is altered by ionophore incorporation. Gilka et al. (1989) reported decreased myristic acid content of i.m. lipid from feeding monensin and lasalocid to lambs. This finding is in agreement with Marmer et al. (1985) who also reported decreased saturated fatty acid (SFA) content of monensin supplemented steers on sorghum-sudan diet. These authors suggest that the decrease in SFA results from suppressed ruminal biohydrogenation due to alterations in ruminal bacterial and protozoa species when ionophores are fed. The populations of bacteria and protozoa responsible for

biohydrogenation of unsaturated fatty acids may be reduced when LP is added to high concentrate diets (Christie, 1981). Myristic acid increases plasma cholesterol in humans, and thus is considered hypercholesterolemic (Hegsted et al. 1965; Keys et al. 1965). Therefore, a reduction in myristic acid concentration due to LP addition would be perceived as beneficial to human health. Additionally, Marmer et al. (1985) and Gilka et al. (1989) both reported increased concentrations of the odd chain fatty acids which were attributed to the greater quantities of propionate available for de novo fatty acid synthesis.

Ionophores increased plasma cholesterol concentrations and the total fatty acids contained in the cholesteryl esters when monensin was supplemented to forage diets (O'Kelly and Spiers, 1988). Conversely, other researchers (Lalman et al., 1993; Duff et al., 1994) reported ionophore supplementation to have no effect on plasma cholesterol content. The increase in plasma cholesterol content noted by O'Kelley and Spiers (1988) was linked to the increased outflow of lipid from the rumen. Ruminants lack a homeostatic mechanism for regulating plasma cholesterol level such that the increase in lipid synthesis from the monensin supplemented steers probably contributed to the increase in plasma cholesterol. Also they found increased PUFA in the cholesteryl esters indicating that increased amounts of PUFA escaped biohydrogenation in the rumen. These authors attribute the increase in lipid content of the

ruminal bacteria to: reduced methane production allowing the carbon and hydrogen to be rechanneled into microbial synthesis or changes in the bacterial species due to ionophore addition. Ultimately, whether these changes were the result of increased bacterial lipid synthesis and/or altered bacterial populations, the result is increased efficiency of utilization of dietary metabolizable energy.

The possibility exists for ionophores to affect cholesterol metabolism when altering VFA proportions. Research has shown that supplementing propionic acid to hypercholesterolemic hogs and heifers does successfully reduce plasma cholesterol levels (Thacker and Bowland, 1981; Thacker et al., 1981; Lalman et al., 1993). Bush and Milligan (1971) found that propionic acid addition *in vitro* to bovine liver tissue reduced the activity of HMG-CoA synthase, the enzyme responsible for the condensation of acetoacetyl-CoA with acetyl-CoA to form HMG-CoA, the key precursor for cholesterol production. Therefore, the influence of ionophores on shifting ruminal VFA proportions increasing propionic acid could potentially affect tissue cholesterol levels. Additionally, monensin has been found to interrupt the recycling of low density lipoprotein cholesterol in human fibroblasts (Basu et al., 1981).

Time-On-Feed

Regardless of the age or breed of the cattle used, TOF studies (Zinn et al., 1970a; Greene et al., 1989; Wheeler et al., 1989; Williams et al., 1989; Huffhines et al., 1992;

May et al., 1992) continue to demonstrate that i.m. fat deposition proceeds in a non-linear manner. Instead, i.m. fat deposition appears to be a function of the number of days cattle are exposed to a high concentrate diet. In a previous study, Duckett et al. (1993) found that yearling, British-cross steers required approximately 112 d on a high concentrate diet to reach the U. S. Choice quality grade. Greene et al. (1989) found only approximately 65 d were needed for purebred Angus steers to reach U. S. Choice; whereas, Zinn et al. (1970a) reported 210 d for purebred Hereford steers fed an 80% concentrate ration. Huffhines et al. (1992) reported a plateau in percent grading U. S. Choice at 84 d for long-yearling, purebred Hereford steers. In trials with exotic breed-types, Miller et al. (1987) and Wheeler et al. (1989) discovered that extending the feeding period to 168 or 182 d did not result in these cattle reaching the U. S. Choice quality grade. Instead, increasing the TOF to these endpoints resulted in unnecessary s.c. fat deposition with no improvement in quality grades. Zinn et al. (1970b), Tatum et al. (1980), Dolezal et al. (1982) and May et al. (1992) all reported the greatest improvement in palatability occurred within the first 100 d on feed with little improvement in palatability thereafter. Several researchers (Waldman et al., 1968; Westerling and Hedrick, 1979; Larick and Turner, 1989; Larick and Turner, 1990; Mitchell et al., 1992) have found existing relationships between flavor ratings and certain

fatty acids present in the longissimus muscle (LM). Generally, oleic acid has been positively correlated with flavor, whereas, PUFA have been positively correlated with off-flavor and aftertaste. Additionally, some SFA (palmitic and stearic acids) have also been negatively associated with flavor. Duckett et al. (1993) reported a positive relationship between oleic acid and tenderness ($r = .33$), and flavor ($r = .39$) ratings from taste panel evaluation, and was negatively associated with Warner-Bratzler shear force values ($r = -.50$). In contrast, the PUFA exhibited a negative relationship with tenderness ($r = -.49$) and flavor ($r = -.35$) ratings from taste panel evaluation, and also a positive association with Warner-Bratzler shear force values ($r = .66$). SFA content exhibited no relationships ($P > .05$) with taste panel ratings or shear force values. These results indicate that type of fat may influence taste panel ratings and possibly shear force.

Increase in TOF resulted in increased i.m. fat content and concomitant decreases in mineral, protein and moisture contents. Bowling et al. (1978), Miller et al. (1981), Williams et al. (1983) and Duckett et al. (1993) observed similar reductions in moisture content when fat content increased. This decrease would be attributed to the differences in moisture content of fat versus lean.

Numerous researchers (Bloor and Snider, 1934; Turkki and Campbell, 1967; Link et al., 1970a & b; Hecker, et al., 1975; Hornstein, et al., 1967; Miller et al., 1981; Larick &

Turner, 1989; Duckett et al., 1993) report that the PhL remains relatively constant throughout growth probably due to their function as structural components of the cell. Conversely, Larick and Turner (1990) reported an increase in the PhL content at d 54. However, these workers were identifying the composition of PhL in LM from heifers that came off various grazing trials which may explain the observed differences. The increase in the i.m. fat content in the LM with increased TOF appears to be due to an enlargement of the adipocyte cell with storage reservoirs (triglycerides) versus an increase in adipocyte cell number since the structural components of the cell (phospholipids) remained constant. This enlargement of the adipocyte resulted in a dilution of the PhL's contribution to the TL with advancing TOF. Hecker et al. (1975), Link et al. (1970a & b) and O'Keefe et al. (1968) also reported similar dilutions of the PhL with increased growth. The consequence of this dilution is evident in the fatty acid composition of TL across TOF.

Researchers (Terrell and Bray, 1969; Link, et al., 1970b; Marmer et al., 1984; Larick and Turner, 1989 & 1990; Duckett et al., 1993) have found that the PUFA are almost exclusively located in the PhL fraction where they apparently serve as structural elements of the cells (Bloor and Snider, 1934). Since the percent contribution of PhL to TL declined greatly with advancing TOF (Duckett et al., 1993), this ultimately decreased the PUFA content in the LM

with increased TOF. However as the PUFA content declined with TOF, the MUFA content increased. This increase in MUFA resulted from increased concentrations of oleic acid in the NL as TOF increased. These reported differences in oleic acid concentrations are suggested to be the result of increased microsomal desaturase activity with increased animal age (Waldman et al., 1968) or of decreased ruminal biohydrogenation with grain feeding (Larick and Turner, 1990). If the microsomal desaturase activity is increased with animal age and physiological maturity, then one would predict mature animals to contain relatively high levels of oleic acid. However, Eichhorn et al. (1986) reported relatively low concentrations (40%) of oleic acid in the muscle of mature bovine females when fed ad libitum. Thus, the increased deposition of oleic acid with increased TOF might be better explained by a decrease in ruminal biohydrogenation of fatty acids upon grain feeding. Latham et al. (1972) reported reductions in the number of lipolytic bacteria and in the in-vitro lipolytic activity of rumen fluid, along with the extent of biohydrogenation of unsaturated fatty acids when dairy cows were fed a low roughage diet. The hydrogenation of linoleic and linolenic acids on the low roughage (10%) diet was 59 and 63%, respectively, of the high roughage (40%) diet. Several bacteria are believed to be responsible for biohydrogenation of fatty acids in the rumen but most function optimally at a near neutral pH (Christie, 1981). Therefore, high

concentrate diets that reduce ruminal pH could limit the extent of biohydrogenation in the rumen ultimately allowing the passage of more unsaturated fatty acids to the small intestine for absorption and incorporation into tissues. Moreover, the increased concentrations of oleic acid with TOF could offer partial explanation for the high concentrations of MUFA reported in Wagyu beef fed over 300 d (Smith et al., 1990). The high MUFA content of Wagyu beef is believed to be due to genetic differences in enzyme activity, however, when Wagyu-cross steers are fed the same length of time as American-bred steers, no differences in MUFA content are detected (Sturdivant et al., 1992). This would imply that TOF may be having more of an effect on the MUFA content of Wagyu beef than actual genetic differences.

Cholesterol content in the LM increased cubically as TOF advanced with the highest concentration reported at d 168 (Duckett et al., 1993). Wheeler et al. (1987) reported no differences in cholesterol content of steers fed 0, 77, 128 or 182 d.

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CHAPTER III

EFFECTS OF ESTROGENIC AND/OR ANDROGENIC IMPLANTATION ON PERFORMANCE, CARCASS COMPOSITION, MEAT QUALITY AND NUTRIENT COMPOSITION IN BEEF CATTLE: A REVIEW

ABSTRACT

Information from 60 steer and heifer trials was used to determine the effect of implanting on performance, carcass traits, meat quality and nutrient composition. The change in each trait due to implanting was computed by subtracting the implanted mean from the non-implanted mean within each study and these comparisons were then summarized by implant scheme. Due to the fact that many studies evaluated more than one implant treatment, the percentage of treatments that showed a significant response when compared to non-implanted controls was calculated as the number of implant treatments that increased(decreased) ($P < .05$) a trait divided by the total number of implant treatments that reported values for that trait. Implanting steers increased average daily gain (ADG) 17% and feed efficiency (FE) by 8%. Average daily gain and FE were increased in 84% and 69% of treatment comparisons, respectively between implanted and

non-implanted steers. This increase in growth resulted in implanted steers having heavier (34 lbs) carcass weights (CW) than non-implanted steers. The increase in CW was revealed in 63% of all treatment comparisons. In heifers, implants increased ADG 6% and FE 5%. The response to implanting on growth in heifers was dependent upon animal age upon feedlot entry. Carcass weights were increased by implanting an average of 21 lbs over non-implanted heifers. Dressing percentage, fat thickness, quality grade, yield grade and percent grading Choice in both steers and heifers were unaffected ($P > .05$) by implants in over 90% of all implant treatment comparisons. Ribeye area (REA) was increased ($P < .05$) in about one-third of all implant comparisons; however, adjusted REA (in^2/100 lbs. CW) was the same between implanted and non-implanted animals indicating that the increase in REA was associated with increased CW attained from implanting. Marbling scores (MS) were decreased ($P < .05$) in only 14 and 7% of the implant comparisons in steers and heifers, respectively. Steak tenderness assessed by subjective or objective measures was unaffected ($P > .05$) by implants in over 80% of all comparisons. This review indicates that implanting has little effect on carcass or meat quality but substantially increases performance.

INTRODUCTION

Numerous reviews are available discussing the probable modes of action (25, 26, 98, 107) of estrogenic and/or

androgenic compounds and their effects on growth (2, 6, 48, 61, 70, 99, 100, 109, 116, 118, 139), residues and safety (61), or glucocorticoid status (116). Fewer reviews address the effects of these compounds on carcass characteristics (17, 33, 37, 57, 58, 70, 113) or meat quality (95, 140). Of these reviews, Schanbacher (113), Patterson and Slater (95), Unruh (140) and Handcock et al. (58) examine the effects of both endogenous and exogenous hormones on numerous species; whereas, Eng (37) and Cross and Belk (17, 33) were limited by the audience of their review. Hutcheson (70) addresses the effects of these compounds on growth and carcass traits; however, only the effects of implants on heifers were examined. Even though a comprehensive review in this area is unavailable, specific perceptions have evolved in the industry regarding the effects of implantation on carcass and meat quality (16, 92).

For these reasons, information from 60 studies was summarized to ascertain the effects of estrogenic and/or androgenic implants on performance, carcass characteristics, meat quality and nutrient composition. The change in each trait due to implanting was computed by subtracting the implanted mean from the non-implanted mean within each study and these comparisons were then summarized by implant scheme. Due to the fact that many studies evaluated more than one implant treatment, the percentage of treatments that showed a specific response ($P < .05$) when compared to non-implanted controls was calculated as the number of

implant treatments that increased(decreased) ($P < .05$) a trait divided by the total number of implant treatments that reported values for that trait. The mean for each trait in non-implanted steers and heifers along with the change due to implanting is presented in Table 1. Also included in this table is the calculated mean for each trait based on the mean for non-implanted animals and the increased(decreased) due to implanting. In each trait, the majority response will be presented and then deviations from the majority will be discussed as to apparent effects of different implant schemes, time-on-feed, breed type, and animal age. The abbreviations used for implants and their hormone content are presented in Table 2. Implant combinations are denoted as two implant abbreviations used together and reimplants are denoted by a '/' between the first implant(s) used and second implant(s). For example, SF/S would be the abbreviation for a combination of Synovex-S and Finaplix-S on first implant with a reimplant of Synovex-S.

PERFORMANCE

Average Daily Gain (ADG): Eighty-four percent of the 122 implant treatment comparisons found implanted steers had higher ($P<.05$) ADG than non-implanted controls (5, 10, 12, 18, 20, 24, 31, 39, 47, 59, 63, 65, 67, 68, 69, 78, 80, 83, 85, 87, 88, 93, 97, 103, 105, 106, 108, 111, 112, 124, 125, 126, 130, 143, 147, 149). Overall, the average increase in ADG by implanting was 17%. This increase translates to a

half pound increase in ADG as the non-implanted steers had a mean ADG of 2.77 lb/d. Differences in the response of the various implants are presented in Table 3. The largest increases (>20%) in ADG were noted using the following implants: Synovex-S plus Finaplix-S in a single or double implant; Synovex-S with reimplants of Synovex-S plus Finaplix-S, Synovex-S, Finaplix-S, or Revalor-S; and Revalor-S with reimplant of Synovex-S or Revalor-S. Intermediate (15-18%) responses were noted with: Compudose plus Finaplix-S with or without reimplant of Finaplix-S; Revalor-S; Synovex-S; and Synovex-S plus Finaplix-S with reimplant of Synovex-S. The lowest (2-14%) improvements in gains were associated with implants of Compudose, Finaplix-S with or without reimplant of Finaplix-S, Ralgro in single or double implants, Ralgro plus Finaplix-S in single or a reimplant, and Synovex-S plus Finaplix-S reimplanted with Finaplix-S. Of the remaining 20 implant treatment comparisons which did not increase ($P > .05$) growth over non-implanted controls, eleven were with estrogenic implants, five with androgenic implants and four with combination implants. Implants and reimplants of Finaplix-S alone in steers did not ($P > .05$) increase ADG in any treatment comparisons (5, 10, 63, 124). Hunt (69) found Finaplix-S alone or implanted with Compudose was ineffective in increasing gains in steers; however, only five animals per treatment were used in the study. Busby and Loy (24) reported all implants of Ralgro and Synovex-S with or

without Finaplix-S increased ($P < .05$) gains in the growing but not in the finishing phase. Kercher (78) reported no ($P > .05$) increase in growth by implanting with Ralgro or Synovex-S and reimplanted with Compudose or Ralgro plus Finaplix; however, this lack of response was probably due to length of the feeding period being over 300 d. In yearling steers, a single implant of Synovex-S was found ineffective at increasing growth over non-implanted controls (10, 47, 68, 93). Compudose or Finaplix-S twice did not increase growth in steers of *Bos indicus* breeding except when used in combination (63). Rumsey (112) noted that Synovex-S with a reimplant of Synovex-S increased ($P < .05$) ADG when reimplanted 60 d after the first implant but not at 30 d. Double implants of Ralgro did not increase ADG in steers but varying breed responses were noted (143).

Sixty-four percent of 28 implant treatment comparisons in heifers reported implants did not ($P > .05$) increase ADG (34, 38, 53, 54, 129, 133, 141). The mean increase in ADG by implants averaged over all 29 comparisons was 7% which equates to less than 0.2 lb increase over the 2.49 lb/d average for non-implanted controls. The implants that were effective in stimulating growth ($P < .05$) depended on the age of the heifers upon arrival into the feedlot. Compudose, Synovex-H with or without a reimplant of Synovex-H and Ralgro implanted twice all increased ($P < .05$) ADG 6, 5, 14, and 7%, respectively, in heifers not specified as yearlings and with in-weights of less than 625 lbs (1, 8,

52, 91, 121). In contrast, Synovex-H with or without a reimplant of Synovex-H, and Ralgro were ineffective ($P > .05$) in increasing growth in yearling heifers (38, 53, 54, 86, 129, 133). Growth was stimulated ($P < .05$) 15% in yearling heifers with implants of Finaplix-H twice, Synovex-H reimplanted with Finaplix-S on d 62 but not d 30 or double implants of Synovex-H plus Finaplix-H (128, 129, 133). Finaplix-H double implants increased ADG 9% in heifer calves (91) and 15% in yearling heifers (128) but were ineffective in other comparisons in calves and yearlings (34, 129, 133). Garber (52) noted that Synovex-H twice in heifer calves increased ADG 5% in intact heifers; however, spaying the heifers and implanting with Synovex-H or Synovex-S resulted in ADG 4 and 8-fold higher than the implanted intact heifers.

Feed efficiency (FE): Percent improvement in FE due to implanting steers is shown in Table 4. Overall, implants improved feed efficiency 8% in 69% of the treatments comparisons between implanted and implanted steers (5, 10, 12, 18, 24, 31, 39, 47, 59, 63, 65, 67, 69, 78, 83, 85, 87, 88, 93, 97, 103, 105, 106, 108, 111, 124, 125, 126, 130, 143, 149). The greatest improvements (>10%) were observed when steers were implanted with Compudose plus Finaplix-S reimplanted with Finaplix-S, Finaplix-S, Revalor-S reimplanted with Revalor-S or Synovex-S, Synovex-S reimplanted with Finaplix-S, Finaplix-S plus Synovex-S or Revalor-S, Synovex-S plus Finaplix-S in both one or two

implants and double implant of Synovex-S plus Finaplix-S and Synovex-S plus Finaplix-S. Compudose and Ralgro with or without the Finaplix-S, Revalor-S, Synovex-S, double Synovex-S and Synovex-S plus Finaplix-S with reimplants of Synovex-S or Finaplix-S were intermediate (6-9%) in their response to increasing efficiency. The lowest increases in FE (< 4%) were noted with implants and reimplants of Finaplix-S, Ralgro or the two combined. Apple (5) did not ($P > .05$) note any improvement in feed efficiency with any of the implant treatments used in Holstein steers implanted four times and fed for 249 d. Similarly as with ADG, double implants of Finaplix-S alone did not improve feed efficiency in the finishing phase (5, 10, 63, 124). Compudose plus Finaplix-S increased FE but neither were effective when used alone in *Bos indicus* steers (63). Although Synovex-S improved FE 18% in British yearling steers, the limited number of animals per treatment did not allow this to be significant (111). The remaining 15 implant treatment comparisons that did not report increased feed efficiency all fed the steers for longer than 139 d (5, 10, 18, 24, 80, 85, 87, 106, 108, 124, 125, 143).

In heifers, 71% of the 24 treatment comparisons found no ($P > .05$) improvement in feed efficiency due to implanting (8, 38, 52, 53, 54, 86, 91, 129, 141). Trenkle (129) found that implanting with Synovex-H with reimplant of Finaplix-S at d 30 or 62 or Finaplix-S double implant all increased FE 10%. Synovex-H plus Finaplix-H implants and

reimplants in yearling heifers increased FE 14% (129, 133). Finaplix-H implanted twice increased FE 12% (128, 129). In heifer calves, Adams (1) reported Synovex-H improved FE 8%.

CARCASS QUANTITATIVE TRAITS

Dressing percent (DP): Ninety-four percent of the 136 implant treatments reported no change ($P > .05$) in DP compared to non-implanted steers and heifers (1, 5, 8, 10, 12, 18, 24, 31 , 47, 52, 53, 54, 59, 63, 65, 67, 68, 69, 78, 80, 83, 85, 88, 91, 93, 97, 103, 105, 106, 108, 111, 112, 121, 122, 124, 125, 126, 128, 129, 130, 133, 141, 143, 147, 149). Dressing percent was increased ($P < .05$) in five treatment comparisons between negative controls and implants of Synovex-H twice and Synovex-H plus Finplix-H twice in heifers (133), Synovex-S once or reimplanted (10) and Compudose (88) in steers. Huffman (68) found implants of Finaplix-S alone decreased DP but not when used in combination with estrogens. Rumsey (112) reported decreases in DP with Synovex-S reimplanted with Synovex-S at d 30 or 60 but this difference was not consistent at different locations.

Hides weights: In steers, Trenkle (125) reported hide as percent of carcass weight to be unaffected ($P > .05$) by implanting Revalor-S once or twice, or Synovex-S reimplanted with Synovex-S or Synovex-S plus Finaplix-S. Conversely, Apple et al. (5) reported increased hide pulling scores (1=easy to 5=extremely difficult) when combination implants were administered to Holstein steers repeatedly. Synovex-S

plus Finaplix-S had higher pull scores than Ralgro plus Finaplix-S both of which were greater than non-implanted, Ralgro or Synovex-S. Finaplix-S was intermediate to Ralgro plus Finaplix-S, Ralgro, Synovex-S and non-implanted controls. Thus with the lack of data in this area, it is difficult to document whether implanting increases hide weights or pulls, or if this may be interactive with breed.

Carcass Weight (CW): Implanting steers resulted in an additional 34 lbs of CW in 63% of the 122 treatments compared (5, 10, 12, 20, 24, 39, 47, 59, 67, 68, 80, 87, 88, 97, 102, 103, 105, 106, 112, 117, 122, 124, 125, 126, 128, 130, 147). Revalor reimplanted with Revalor-S or Synovex-S, Synovex-S reimplanted with Finaplix-S, Revalor-S, Synovex-S plus Finaplix-S or Synovex-S and double implants of Synovex-S plus Finaplix-S all increased CW 40 additional pounds over non-implanted controls (Table 4). Revalor-S, Synovex-S, and Synovex-S plus Finaplix-S increased CW about 36 lbs over non-implanted steers. Of the remaining 45 implant treatments that did not ($P > .05$) increase CW, 30 were estrogenic implants of Compudose (63, 78, 108), Ralgro (18, 31, 65, 78, 83, 85, 108, 143) or Synovex-S (20, 47, 68, 78, 83, 93, 108, 111, 112). Reimplanting, with the exception of Finaplix-S/Finaplix-S, resulted in twice the added CW (44 vs. 22 lbs) of a single implant. Finaplix-S implanted once or twice without the presence of an estrogen did not ($P > .05$) increase CW presumably due to the lack of response in growth (5, 10, 63, 68, 69, 78, 122, 124). In steers of *Bos*

indicus breeding, Compudose and Finaplix-S implants did not increase CW (63). Hunt (69) and Kercher (78) reported all implant treatments did not ($P > .05$) increase CW over non-implanted controls; however, this lack of a significant response was probably due to the limited number of animals per treatment in each study. Perry (97) noted that Revalor-S increased CW in Holstein and Angus steers but not in Angus x Simmental steers.

In heifers, 83% (6/29) reported no ($P > .05$) increase in CW due to implantation (8, 38, 52, 53, 54, 86, 91, 129, 133, 141). Adams (1) and Marchello (86) reported increases of 29 and 39 lbs with Synovex-H implants. However, Marchello (140) found this response to be seasonal. Double implants of Finaplix-S increased CW 26 (91) and 30 (128) lbs. Compudose in heifer calves increased CW an additional 22 lbs over non-implanted controls (121). The largest increase in CW was with a double implant of Synovex-H plus Finaplix-H which added 50 lbs (133).

Ribeye Area (REA): REA was unaffected ($P > .05$) by implant in 66% of 115 treatments conducted on steers (5, 10, 18, 24, 31, 47, 59, 63, 65, 68, 69, 78, 80, 83, 85, 88, 93, 97, 103, 105, 106, 108, 111, 112, 122, 125, 130, 143, 149). The implant combinations that increased REA an inch larger than non-implanted steers were: double Ralgro plus Finaplix-S, double implants of Revalor-S, and Synovex-S plus Finaplix-S reimplanted with Synovex-S or Synovex-S plus Finaplix-S (Table 5). This increase in REA was attributed to increased

CW of the implanted steers as adjusted REA were both 1.76 in^2/100lbs CW for non-implanted and implanted steers. Thus, the 39 treatments comparing implants to non-implanted steers found increased REA when CW was also increased (5, 12, 47, 67, 69, 80, 88, 93, 97, 103, 105, 106, 112, 124, 125, 126, 130, 147).

Sixty percent of the treatments in heifers found no ($P > .05$) difference in REA (1, 8, 34, 38, 53, 54, 86, 93, 129, 133). As in steers, implanted and non-implanted heifers had similar adjusted REA of 2.0 in^2/100lbs CW. Trenkle (129, 133) found implanting heifers with Synovex-H plus Finaplix-H twice increased REA 1.8 in^2. Synovex-H reimplanted with Finaplix-H at d 30 or 62 increased REA 1.4 in^2 (129). Synovex-H single or reimplanted and Compudose increased REA 1.1 (86), .7 (52) and 1.0 in^2 (121), respectively.

Fat Thickness (FT): Implanting steers or heifers did not alter ($P > .05$) FT in over 90% of the treatments (1, 5, 10, 12, 18, 24, 31, 34, 38, 47, 52, 53, 54, 59, 63, 65, 68, 69, 78, 80, 83, 85, 86, 87, 88, 93, 97, 103, 105, 108, 111, 112, 122, 124, 125, 126, 128, 129, 130, 133, 141, 143, 149). In heifers, Synovex-H increased (8) and Compudose decreased (121) FT. In steers, 11 treatment comparisons showed increased FT by implanting with Finaplix-S (69), Synovex-S plus Finaplix-S in single or double (106, 147), Synovex-S (112, 147) Synovex-S double implant (112, 147), Synovex-S reimplanted with Synovex-S plus Finaplix-S (126, 147), Synovex-S plus Finaplix-S reimplanted with Synovex-S (147).

All of the treatments that increased FT were used in steers and heifers of British breeding.

Kidney, Pelvic and Heart Fat (KPH): Eighty percent of the 81 implant treatments in steers found no difference in the percentage of KPH in the carcass (5, 10, 47, 59, 63, 68, 78, 85, 103, 106, 111, 124, 125, 126, 130, 143, 147). Sixteen treatments reported decreased ($P < .05$) KPH percentages. Of these, eleven were using estrogenic implants of Synovex-S or Ralgro in steers of British breeding (12, 65, 68, 83, 105, 112). In heifers, 95% reported no ($P > .05$) change in the percentage of KPH in heifer carcasses due to implants (8, 34, 38, 52, 86, 129, 133). Finaplix-H double implant decreased KPH in one study (128).

Yield Grade (YG): Yield grade was not affected ($P > .05$) in 90% of all implant treatments (1, 5, 10, 12, 24, 38, 39, 47, 52, 53, 59, 63, 65, 67, 68, 69, 78, 80, 83, 85, 87, 103, 105, 112, 122, 124, 125, 126, 128, 129, 130, 133, 141, 143, 149). YG was decreased in 5 implant treatments all of which also reported increased REA (87, 112, 130, 133). Conversely, YG was increased in 8 implant treatments due to increases in FT (8, 106, 147).

CARCASS QUALITATIVE TRAITS

Marbling Score (MS): Eighty-six percent of the 83 treatments comparing implanted steers to non-implanted controls found no ($P > .05$) effect of implants on MS (5,12, 18, 24, 31, 39, 47, 59, 63, 65, 68, 69, 78, 80, 83, 87, 93, 97, 105, 106, 111, 112, 122, 124, 143, 147, 149). Since

large variations exist in MS between animals in the same trial making differences ($P < .05$) in MS hard to detect, Table 6 is a summary of the change in MS by the 83 implant comparisons. Overall, implants decreased MS 21 points from the 438 (Small 38) average for non-implanted steers 417 (Small 17) both of which would qualify for the U.S. Choice quality grade. Twelve implant treatments decreased ($P < .05$) MS compared to non-implanted controls. Single and double implants of Ralgro decreased ($P < .05$) MS (85). Huffman (68) reported Finaplix-S alone and Synovex-S plus Finaplix-S decreased ($P < .05$) MS 53 and 45 points, respectively. Bartle (12) found that all implants (Revalor-S, Synovex-S or combinations of the two) evaluated decreased ($P<.05$) MS compared to non-implanted controls. Busby and Loy (24) found that implants of Ralgro plus Finaplix-S and Synovex-S decreased ($P < .05$) MS; whereas, implants of Ralgro and Synovex-S plus Finaplix-S did not ($P > .05$)) differ from non-implanted steers. Preston (103) reported decreases ($P < .05$) of 20 points in MS when implanting crossbred steers with Synovex-S plus Finaplix-S.

In heifers, the percentage of treatments reporting no difference ($P > .05$) in MS increased to 93% (1, 8, 34, 38, 53, 54, 86, 93, 141). Garber (52) reported Synovex-H implants decreased MS by 90 points in intact heifers and 110 points in spayed heifers. In contrast, implanting spayed heifers with Synovex-S lowered MS only 50 points below non-implanted.

Quality Grade (QG): Quality grades were unaffected ($P > .05$) in 94% of the 88 implant treatments reporting it in steers and heifers (1, 5, 8, 18, 24, 31, 34, 38, 39, 47, 53, 54, 59, 63, 65, 67, 69, 78, 80, 83, 86, 87, 103, 105, 106, 108, 111, 112, 122, 124, 141, 143, 149). QG was reduced ($P < .05$) in 5 treatments that also showed a decreased MS. Garber (52) found implanting with Synovex-H decreased QG 1/3 of a grade, from average to low Choice. In steers, QG was decreased from Choice- to Select+ with estrogenic implants of STEER-oid, Compudose, and Ralgro (85, 87).

Percent Choice: Of the 69 treatment comparisons between implants and non-implanted heifers and steers that calculated percent grading U. S. Choice, 93% found no difference ($P > .05$; 5, 8, 10, 12, 20, 24, 47, 125, 126, 128, 129, 130, 133, 147). Only one implant treatment using double implants of Synovex-H plus Finaplix-H in heifers decreased ($P < .05$) percent grading Choice (129). Preston (103) noted decreased ($P < .05$) percent U. S. Choice with implants of Synovex-S plus Finaplix-S. Botts(20) reported distinct breed differences in the effect of implants on percent U. S. choice. Implanting Limousin steers with Synovex-S with a reimplant of Synovex-S with or without Finaplix-S and Synovex-S plus Finaplix-S all decreased the percent grading U. S. choice in Limousin steers but had no effect in British and Brahman steers.

Maturity: Information on the effect of implants on maturity is limited with only 5 studies reporting skeletal, lean or

overall maturity scores. Lean maturity was unaffected ($P > .05$) by implanting (5, 47). However, implants advanced skeletal maturity compared to non-implanted steers (5, 47, 143). Skeletal and overall maturity were hastened by implanting with multiple Synovex-S, Synovex-S plus Finaplix-S and Ralgro plus Finaplix-S but not ($P > .05$) with Finaplix-S or Ralgro alone; however, steers from these implant treatments still qualified for A maturity. Similarly, Foutz (47) reported advanced skeletal maturity with Synovex-S, Revalor-S, and Synovex-S plus Finaplix-S with or without a reimplant of Finaplix-S. The implant treatments containing trenbolone acetate increased maturity to a greater extent than Synovex-S alone; however, all qualified for A maturity. Conversely, others reported no effect of implants on maturity in heifers or steers (34, 68, 124).

Dark Cutters: Dark cutting beef is the result of antemortem depletion of glycogen stores due to stresses such as: mixing unfamiliar animals (15, 104), estrus (77), or feed withdrawal (15). However, implants have been implicated in increasing the incidence of dark cutters (55). In steers, no dark cutters were observed when implanted with Revalor-S, Synovex-S, and Finaplix-S or in combinations (12, 47, 68, 128, 133, 144). Lean color was unaffected by implanting with Ralgro, Synovex-S, Finaplix-H or combinations of these implants (5, 34, 68). Apple (5) reported that Finaplix-S alone advanced ($P < .05$) lean color compared to Ralgro,

Synovex-S plus Finaplix-S, Ralgro plus Finaplix-S or non-implanted steers. Trenkle (129) noted that Synovex-H plus Finaplix-H implanted and reimplanted at d 62 resulted in a higher number of dark cutters than non-implanted heifers (25 vs. 5%).

MEAT QUALITY

Tenderness: Eighty-three percent of the 30 treatment comparisons between implanted and non-implanted steers and heifers found implants to have no ($P > .05$) effect on longissimus tenderness as measured by Warner-Bratzler shear (WBS; 5, 27, 34, 67, 68, 69, 94, 122, 125, 142). Summarization of shear force data between studies is difficult due to the lack of a standard protocol for shear force determination. For this reason, the percent change in WBS was calculated for each implant treatment comparison (Table 8). Overall, WBS was increased 6.5% by implanting which equates to 0.6 lb increase in shear force over the average of 7.9 lbs for non-implanted steers. In heifers, only one study was available comparing Finaplix-H implants to non-implanted controls (34). Although the difference was non-significant ($P > .05$), there was a numerical decrease of 1.7% in WBS by implanting heifers. Five treatment comparisons found implants of Ralgro (59) or Synovex-S, Revalor-S, and Synovex-S plus Finaplix-S with or without a reimplant of Finaplix-S (47) increased ($P < .05$) WBS. Hawkins (59) evaluated tenderness using the Armour Tenderometer, Krammer shear, and Instron press methods in

addition to the WBS. The Armour Tenderometer and WBS were in agreement that implanted steers were less ($P < .05$) tender than non-implanted controls. No ($P > .05$) differences in tenderness were detected with the Krammer shear or Instron press. Actual taste panel evaluation of tenderness and overall palatability revealed that trained panelists could not ($P > .05$) detect any differences between implanted and non-implanted steers. Thus, the different methods for measuring tenderness objectively may need to be reevaluated as to which shows the closest agreement with actual taste panel ratings. Differences that may actually be measured using the WBS method may not be of practical significance and thus drawing lines for tough versus tender may be misleading.

Vanderwert (142) measured tenderness in not only the longissimus but also the adductor, semimembranous, semitendinosus and biceps femoris. Ralgro implantation had no effect ($P > .05$) on tenderness in any of these muscles. However, correlations between the shear force values of the various muscles were all very low and non-significant indicating that palatability of one muscle may not be indicative of other muscles. Differences did exist between breed types with Angus cattle being more tender than Limousin in the longissimus and semitendinosus. In this study, associations between MS and WBS were extremely low and non-significant ($r = -.08$; 142) providing evidence that MS may not be a reliable predictor of tenderness. Actually,

breed and temperature of the longissimus muscle at 18 and 24 h post-mortem had the highest associations with Warner-Bratzler shear force (r = - .51, - .62 and - .6, respectively; 144).

Sensory panel ratings: In 28 treatment comparisons between implanted and non-implanted steers and heifers, 24 (86%) found implants to have no effect ($P > .05$) on any taste panel traits measured (5, 18, 34, 59, 68, 94, 97, 123, 125, 142). Calkins (27) reported decreased muscle fiber tenderness for steaks from Ralgro implanted steers compared to non-implanted but not with Synovex-S implants which were intermediate in their ratings. Hunt (69) found steaks from Finaplix-S implant treatments had increased ($P < .05$) aroma intensity and that steaks from Compudose plus Finaplix-S treatment were intermediate in intensity. Tatum (122) using Brangus clones found Finaplix-S implants increased and Synovex-S implants decreased tenderness and overall palatability ratings. In this trial, the combination of Synovex-S and Finaplix-S had no ($P > .05$) effect on any taste panel measures.

Fiber type: Fiber type will be abbreviated and characterized as: SO=slow, oxidative, and red (βRed; Type I); FOG=fast, oxidative and glycolytic, and intermediate (α Red; Type IIA); FG=fast, glycolytic and white (αWhite; Type IIB). Percentages of the three fiber types were not different in Finaplix-H implanted heifers; however, numerical increases in percent FOG existed between implanted

and non-implanted (34). In steers, implanting with Finaplix-S plus Ralgro and then Synovex-S plus Finaplix-S during the finishing phase altered the fiber type present by increasing FOG and decreasing FG (30). Additionally, implanting increased the cross sectional area of SO resulting in the FOG and SO occupying more area of the myofiber. These changes in fiber type by implanting would indicate increased oxidative capacity of the longissimus. Conversely, Vanderwert (144) reported decreased ($P < .05$) percentages of FOG fibers in the longissimus of Ralgro implanted steers and bulls with no ($P > .05$) differences in percentages of SO and FG.

NUTRIENT COMPOSITION

Proximate composition: Ninety percent of the 20 implant comparisons that measured proximate composition in the longissimus muscle or rib section found implanting to have no effect ($P > .05$) on percentages of fat, moisture or protein (27, 47, 67, 69, 86, 94, 105, 143, 144). Borger (19) found that Ralgro decreased the percent fat and increased the percent moisture in the longissimus muscle of steers; however, these differences were not observed in the adductor and intercostal muscles. In heifers, Finaplix-H increased the percentage of water and decreased the percentage of fat in the longissimus muscle (34).

Fatty acid composition: Kennett and Siebert (76) found that estradiol and progesterone implantation increased the ratio of saturated fatty acids (SFA) to polyunsaturated fatty

acids (PUFA) in intramuscular fat of steers finished on Australian pastures. This was due to numerical increases in SFA and decreases in PUFA. The monounsaturated (MUFA) fatty acid concentration showed numerical increases with implantation; however, this was not statistically significant due to limited number of animals. The ratio of SFA to PUFA was directly proportional to steer weight ($P < .01$), and thus covariate analysis with live weight removed this effect. Thus, it appears that anabolic implants may alter the composition of intramuscular fat on a forage diet. Since differences in fatty acid composition exist based on type of diet (36), research is needed on grain-fed cattle with anabolic implantation.

TABLE 1. Average of each trait for non-implanted steers and heifers, and the change by implanting.

	Steers			Heifers		
	Non - implanted, Mean	Change by Implanting	Implanted, Calculated Mean	Non- implanted, Mean	Change by Implanting	Implanted, Calculated Mean
ADG, lbs/d	2.77	17%	3.24	2.45	6%	2.60
DMI, lbs/d	19.2	5%	20.2	17.6	1%	17.8
F/G	6.96	- 8%	6.40	6.82	- 5%	6.50
DP, %	62	0	62	60	0	60
HCW, lbs	678	34	712	575	21	596
REA, in^2	11.8	.5	12.3	11.4	.7	12.1
FT, in.	.46	.02	.48	.47	0	.47
KPH, %	2.2	0	2.2	2.8	-.3	2.5
MS[a]	438	-21	417	455	-27	428
QG[b]	10	-1	9	10	0	10
Choice, %	74	-15	59	71	-9	62
YG	2.8	0	2.8	2.7	-.2	2.5
WBS, lbs	7.9	6.5%	8.5	12	-1.7%	11.8

[a] MS: 300=Slight, 400=Small, 500=Moderate.
[b] QG: 8=Select, 9=Select+, 10=Choice-, 11=Choice.

TABLE 2. The trade name of the various implants, their hormone content and the abbreviations used for them.

Abbr.	Implant	Hormone content
C	Compudose	24 mg Estradiol-17β
F-H	Finaplix-H	200 mg Trenbolone Acetate
F	Finaplix-S	140 mg Trenbolone Acetate
Ra	Ralgro	36 mg Zeranol
Re	Revalor	28 mg Estradiol-17β + 140 mg Trenbolone Acetate
S-H	Synovex-H	20 mg Estradiol Benzoate + 200 mg Testosterone Propionate
S	Synovex-S	20 mg Estradiol Benzoate + 200 mg Progesterone

TABLE 3. Percent increase in average daily gain (ADG) due to implanting steers.

Implant[a]	Increase in ADG,%	Min, %	Max, %	Reference Number
C	14	4	22	63, 78, 80, 87, 88, 108, 124
CF	18	12	27	63, 69, 78, 124
CF/F	15	14	17	63, 124
F	10	-6	26	68, 69, 78
F/F	2	-1	6	5, 10, 63, 124
Ra	12	6	27	24, 31, 78, 80, 83, 85, 108
Ra/Ra	12	4	17	5, 18, 59, 65, 80, 83, 85, 143, 149
RaF	10	6	14	24, 78
RaF/RaF	9	9	9	5
Re	16	4	27	12, 47, 97, 125
Re/Re	26	21	31	12, 125
Re/S	20	20	20	12
S	17	-5	36	10, 24, 39, 47, 68, 78, 83, 93, 105, 108, 111, 112, 126, 130, 147
S/F	20	13	28	126, 130
S/Re	20	20	20	12
S/S	20	10	43	5, 10, 12, 20, 67, 80, 83, 93, 108, 112, 125, 126, 130, 147
S/SF	21	14	30	20, 67, 125, 126, 130, 147
SF	23	6	44	20, 24, 47, 68, 78, 103, 130, 147
SF/F	10	8	12	10, 47
SF/S	18	16	20	67, 147
SF/SF	22	15	30	5, 10, 67, 106, 126, 130, 147

[a]Implant abbreviations: C=Compudose; CF=Compudose + Finaplix-S; CF/F=Compudose + Finaplix-S reimplant Finaplix-S; F=Finaplix-S; F/F=Finaplix-S implant and reimplant; Ra=Ralgro; Ra/Ra=Ralgro implant and reimplant; RaF=Ralgro + Finaplix-S; RaF/RaF=Ralgro + Finaplix-S implant and reimplant; Re=Revalor; Re/Re=Revalor implant and reimplant; Re/S=Revalor reimplant Synovex-S; S=Synovex-S; S/F=Synovex-S reimplant Finaplix-S; S/Re=Synovex-S reimplant Revalor; S/S=Synovex-S implant and reimplant; S/SF=Synovex-S reimplant Synovex-S + Finaplix-S; SF=Synovex-S + Finaplix-S; SF/F=Synovex-S + Finaplix-S reimplant Finaplix-S; SF/S=Synovex-S + Finaplix-S reimplant Synovex-S; SF/SF=Synovex-S + Finaplix-S implant and reimplant.

TABLE 4. Percent improvement in feed efficiency (FE) due to implanting steers.

Implant[a]	Increase in FE, %	Min, %	Max, %	Reference Number
C	7	1	9	63, 80, 87, 88, 108, 124
CF	7	1	13	63, 69, 124
CF/F	12	9	14	63, 124
F	17	17	17	69
F/F	4	2	6	5, 10, 63, 124
Ra	6	1	10	24, 31, 80, 83, 108, 85
Ra/Ra	4	1	10	5, 18, 59, 65, 80, 83, 85, 143, 149
RaF	7	7	7	24
RaF/RaF	0	0	0	5
Re	9	2	13	12, 47, 97, 125
Re/Re	13	12	14	12, 125
Re/S	10	10	10	12
S	6	0	10	10, 24, 39, 47, 83, 93, 108, 111, 126, 130
S/F	12	9	15	126, 130
S/Re	10	10	10	12
S/S	8	4	12	5, 10, 12, 67, 80, 83, 93, 108, 112, 125, 126, 130
S/SF	10	5	14	67, 125, 126, 130
SF	12	8	17	24, 47, 103, 130
SF/F	8	8	8	10, 47
SF/S	9	9	9	67
SF/SF	11	5	17	5, 10, 67, 106, 126, 130

[a]Implant abbreviations: C=Compudose; CF=Compudose + Finaplix-S; CF/F=Compudose + Finaplix-S reimplant Finaplix-S; F=Finaplix-S; F/F=Finaplix-S implant and reimplant; Ra=Ralgro; Ra/Ra=Ralgro implant and reimplant; RaF=Ralgro + Finaplix-S; RaF/RaF=Ralgro + Finaplix-S implant and reimplant; Re=Revalor; Re/Re=Revalor implant and reimplant; Re/S=Revalor reimplant Synovex-S; S=Synovex-S; S/F=Synovex-S reimplant Finaplix-S; S/Re=Synovex-S reimplant Revalor; S/S=Synovex-S implant and reimplant; S/SF=Synovex-S reimplant Synovex-S + Finaplix-S; SF=Synovex-S + Finaplix-S; SF/F=Synovex-S + Finaplix-S reimplant Finaplix-S; SF/S=Synovex-S + Finaplix-S reimplant Synovex-S; SF/SF=Synovex-S + Finaplix-S implant and reimplant.

TABLE 5. Implant effects on carcass weight (CW) in steers.

Implant[a]	Increase in CW, lbs	Reference Number
C	10	63, 78, 80, 88, 108, 124
CF	29	63, 69, 78, 124
CF/F	24	63, 124
F	11	68, 69, 78, 122
F/F	-1	5, 10, 63, 124
Ra	18	24, 31, 78, 80, 83, 85, 108
Ra/Ra	28	5, 18, 59, 65, 80, 83, 85, 143, 149
RaF	13	24, 78
RaF/RaF	37	5
Re	36	12, 47, 85, 97, 125
Re/Re	82	12, 125
Re/S	46	12
S	34	10, 24, 39, 47, 78, 83, 93, 105, 108, 111, 112, 122, 126, 130, 147
S/F	49	126, 130
S/Re	50	12
S/S	38	5, 10, 12, 20, 67, 80, 83, 93, 108, 112, 125, 126, 147
S/SF	58	20, 67, 125, 126, 130, 147
SF	39	20, 47, 68, 78, 103, 130, 147
SF/F	21	10, 47
SF/S	45	67, 147
SF/SF	54	5, 10, 67, 106, 126, 130, 147

[a]Implant abbreviations: C=Compudose; CF=Compudose + Finaplix-S; CF/F=Compudose + Finaplix-S reimplant Finaplix-S; F=Finaplix-S; F/F=Finaplix-S implant and reimplant; Ra=Ralgro; Ra/Ra=Ralgro implant and reimplant; RaF=Ralgro + Finaplix-S; RaF/RaF=Ralgro + Finaplix-S implant and reimplant; Re=Revalor; Re/Re=Revalor implant and reimplant; Re/S=Revalor reimplant Synovex-S; S=Synovex-S; S/F=Synovex-S reimplant Finaplix-S; S/Re=Synovex-S reimplant Revalor; S/S=Synovex-S implant and reimplant; S/SF=Synovex-S reimplant Synovex-S + Finaplix-S; SF=Synovex-S + Finaplix-S; SF/F=Synovex-S + Finaplix-S reimplant Finaplix-S; SF/S=Synovex-S + Finaplix-S reimplant Synovex-S; SF/SF=Synovex-S + Finaplix-S implant and reimplant.

TABLE 6. Implant effects on ribeye area (REA) in steers.

Implant[a]	Increase in REA, in^2	Reference Number
C	.1	63, 78, 80, 87, 88, 108, 124
CF	.4	63, 69, 78, 124
CF/F	.6	63, 124
F	.6	68, 69, 78, 122
F/F	.3	5, 10, 63, 124
Ra	0	24, 31, 78, 80, 83, 85, 108
Ra/Ra	.2	5, 18, 59, 65, 80, 83, 85, 143, 149
Ra/S	.5	108
RaF	.6	24, 78
RaF/RaF	1.1	5
Re	.6	12, 47, 97, 122, 125
Re/Re	1.2	12, 125
Re/S	.8	12
S	.3	10, 24, 47, 68, 78, 83, 93, 105, 108, 111, 126, 130
S/F	.8	126, 130
S/Re	.7	12
S/S	.5	5, 10, 12, 67, 80, 83, 93, 108, 112, 124, 125, 130, 147
S/SF	.8	67, 125, 126, 130, 147
SF	.6	24, 47, 68, 78, 103, 147, 130
SF/F	.9	10, 47
SF/S	1.0	67, 147
SF/SF	1.0	5, 10, 67, 106, 126, 130, 147

[a]Implant abbreviations: C=Compudose; CF=Compudose + Finaplix-S; CF/F=Compudose + Finaplix-S reimplant Finaplix-S; F=Finaplix-S; F/F=Finaplix-S implant and reimplant; Ra=Ralgro; Ra/Ra=Ralgro implant and reimplant; RaF=Ralgro + Finaplix-S; RaF/RaF=Ralgro + Finaplix-S implant and reimplant; Re=Revalor; Re/Re=Revalor implant and reimplant; Re/S=Revalor reimplant Synovex-S; S=Synovex-S; S/F=Synovex-S reimplant Finaplix-S; S/Re=Synovex-S reimplant Revalor; S/S=Synovex-S implant and reimplant; S/SF=Synovex-S reimplant Synovex-S + Finaplix-S; SF=Synovex-S + Finaplix-S; SF/F=Synovex-S + Finaplix-S reimplant Finaplix-S; SF/S=Synovex-S + Finaplix-S reimplant Synovex-S; SF/SF=Synovex-S + Finaplix-S implant and reimplant.

TABLE 7. Change in marbling score (MS) due to implanting steers.

Implant[a]	Change in MS[b]	Min[b]	Max[b]	Reference Number
C	-20	-52	6	63, 78, 80, 87, 124
CF	-12	-60	60	63, 69, 78, 124
CF/F	-25	-27	-23	63, 124
F	-8	-53	50	68, 69, 78, 122
F/F	-2	-29	13	5, 10, 63, 124
Ra	-15	-60	30	24, 31, 78, 80, 83, 85
Ra/Ra	-35	-80	-9	5, 18, 59, 65, 80, 83, 85, 143, 149
RaF	-69	-105	-33	24, 78
RaF/RaF	-27	-27	-27	5
Re	-10	-45	31	12, 47, 97, 122
Re/Re	-20	-20	-20	12
S	-15	-95	12	24, 39, 47, 68, 78, 83, 93, 105, 111, 112, 122, 147
S/S	20	10	43	5, 10, 12, 20, 67, 80, 83, 93, 108, 112, 125, 126, 130, 147
S/SF	-3	-3	-3	147
SF	-25	-45	-13	24, 47, 68, 78, 103, 147
SF/F	-25	-25	-25	47
SF/S	-8	-8	-8	147
SF/SF	-34	-47	-33	5, 106, 147

[a]Implant abbreviations: C=Compudose; CF=Compudose + Finaplix-S; CF/F=Compudose + Finaplix-S reimplant Finaplix-S; F=Finaplix-S; F/F=Finaplix-S implant and reimplant; Ra=Ralgro; Ra/Ra=Ralgro implant and reimplant; RaF=Ralgro + Finaplix-S; RaF/RaF=Ralgro + Finaplix-S implant and reimplant; Re=Revalor; Re/Re=Revalor implant and reimplant; Re/S=Revalor reimplant Synovex-S; S=Synovex-S; S/F=Synovex-S reimplant Finaplix-S; S/Re=Synovex-S reimplant Revalor; S/S=Synovex-S implant and reimplant; S/SF=Synovex-S reimplant Synovex-S + Finaplix-S; SF=Synovex-S + Finaplix-S; SF/F=Synovex-S + Finaplix-S reimplant Finaplix-S; SF/S=Synovex-S + Finaplix-S reimplant Synovex-S; SF/SF=Synovex-S + Finaplix-S implant and reimplant.

[b]Marbling score: 1000 point system with every marbling score equal to 100 points (300-399=Slight, 400-499=Small, 500-599=Modest, 600-699=Moderate).

TABLE 8. Effects of implants on Warner-Bratzler shear (WBS) force percentages.

Implant[a]	Change in WBS, %	Min	Max	Reference number
C	6	6	6	27
CF	-7	-7	-7	69
F	7	-3	26	68, 69, 122
F/F	1	1	1	5
Ra/Ra	1	-10	6	5,27, 59, 142
RaF/RaF	9	9	9	5
Re	8	8	9	47, 122, 125
Re/Re	12	12	12	125
S	11	10	11	47, 68, 122
S/S	4	-1	6	5, 67, 125
S/SF	14	6	21	67, 125
SF	12	3	21	47, 68
SF/F	10	10	10	47
SF/S	12	12	12	47
SF/SF	5	1	7	5, 67

[a]Implant abbreviations: C=Compudose; CF=Compudose + Finaplix-S; CF/F=Compudose + Finaplix-S reimplant Finaplix-S; F=Finaplix-S; F/F=Finaplix-S implant and reimplant; Ra=Ralgro; Ra/Ra=Ralgro implant and reimplant; RaF=Ralgro + Finaplix-S; RaF/RaF=Ralgro + Finaplix-S implant and reimplant; Re=Revalor; Re/Re=Revalor implant and reimplant; Re/S=Revalor reimplant Synovex-S; S=Synovex-S; S/F=Synovex-S reimplant Finaplix-S; S/Re=Synovex-S reimplant Revalor; S/S=Synovex-S implant and reimplant; S/SF=Synovex-S reimplant Synovex-S + Finaplix-S; SF=Synovex-S + Finaplix-S; SF/F=Synovex-S + Finaplix-S reimplant Finaplix-S; SF/S=Synovex-S + Finaplix-S reimplant Synovex-S; SF/SF=Synovex-S + Finaplix-S implant and reimplant.

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CHAPTER IV

EFFECT OF LAIDLOMYCIN PROPIONATE ON LONGISSIMUS MUSCLE FATTY ACID AND CHOLESTEROL CONTENT

ABSTRACT

Differences in fatty acid composition and cholesterol content of longissimus muscle (LM) were assessed as a function of ionophore incorporation into a high concentrate diet. Ribeye steaks (n=70) were obtained from crossbred steers that had been fed a high concentrate diet for 111 d with or without the addition of the ionophore, laidlomycin propionate (LP; 11 mg/kg). Fatty acid composition and cholesterol content of the LM were determined by GLC. Marbling scores (MS) and total lipid (TL) content in the LM were unaffected (P = .81 and .18, respectively) by LP incorporation. Additionally, LP did not alter (P = .18 & .44, respectively) the proportion of lipid present in the storage (neutral lipid, NL) versus the structural (polar lipid, PL) component. Numerical differences in cholesterol content (mg/100g) were noted between treatments (mg/100g) in the LM; however, the magnitude of this difference may not be of practical significance (40.53 vs. 38.67; P = .29). The

incorporation LP into a high concentrate diet decreased ($P <$ .10) saturated fatty acid (SFA) concentrations and increased ($P \leq .10$) polyunsaturated fatty acid (PUFA) concentrations. These results suggest that the addition of LP to a high concentrate diet may reduce ruminal biohydrogenation allowing for passage of more unsaturated fatty acids to the small intestine. Ultimately, LP may offer a means by which beef producers could provide a product lower in saturated fat and cholesterol.

Key Words: Laidlomycin propionate, Fatty acids, Cholesterol

INTRODUCTION

Ionophores are routinely incorporated into high concentrate diets to enhance feed utilization; however, no information is available as to how lipid composition or cholesterol content in the muscle may be affected by the addition of ionophores to these high concentrate diets. Previous research (Marmer et al., 1985 and Gilka et al., 1989b) indicates that ionophores reduce the saturated fatty acid (SFA) and increase the odd chain fatty acid content of both steer and lamb i.m. fat when supplemented to forage-type diets. O'Kelly and Spiers (1988) reported monensin supplementation to forage diets increased the output of lipid from the rumen resulting in increased plasma cholesterol and lipid concentrations in the supplemented steers. Together these results suggest that ionophore

incorporation, at least on high roughage diets, may suppress ruminal biohydrogenation and alter de novo fatty acid synthesis with an end result of changing the composition of depot fat. Since ruminal bacteria populations are dependent on diet type, this study was designed to evaluate the effects of the ionophore, laidlomycin propionate, on the longissimus muscle (LM) lipid and cholesterol content from steers fed a high concentrate diet.

MATERIALS AND METHODS

Angus x Hereford steers (n=140) were equally allotted to four treatments: control (C), laidlomycin propionate (LP; 11 mg/kg), tylosin (10 mg/kg) or a combination of laidlomycin propionate (11 mg/kg) plus tylosin (10 mg/kg). Laidlomycin propionate, trade name Cattlyst®, was released in 1994 for commercial usage by SYNTEX Animal Health (Des Moines, IA). At the time of this study, laidlomycin propionate was still under investigation by FDA and thus was withdrawn from the diet ten days prior to slaughter. All steers were fed the same basal diet (87.8% DM, 1.78 Mcal/kg of NEm, 1.18 Mcal/kg of NEg) for 111 d and then commercially slaughtered. Carcass weights and marbling scores were obtained 24 h postmortem. Longissimus muscle (LM) sections, corresponding to the 9-12th rib, were removed from the C and LP treatments. Steaks were trimmed of all exterior fat and epimysial connective tissue, and then pulverized in liquid

nitrogen for storage at -20°C. Moisture and crude fat content were determined by drying at 100°C for 24 h and then extracting with petroleum ether for 8 h (AOAC, 1984). The neutral (NL) and polar (PL) lipid fractions were sequentially separated according to the dry column method of Marmer and Maxwell (1981). Aliquots of NL and PL were freed of solvent and dried at 95°C for 24 h to determine dry-lipid weight (AOAC, 1984). The lipid weight of the NL and PL were summed for each sample to obtain a total (TL) lipid weight. Phospholipid (PhL) content was calculated by determining P content of PL (Vaskovsky et al., 1975) and multiplying by 25. Both the NL (Slover and Lanza, 1979) and PL (Maxwell and Marmer, 1983) fractions were esterified to yield fatty acid methyl esters (FAME). The FAME along with an aliquot from the NL were analyzed by GLC for fatty acid composition and cholesterol content under the conditions previously described by Duckett et al. (1993).

Statistical analysis of experimental data was performed using the GLM procedure of SAS (1985). The main effect was treatment (C vs. LP); the error term was steer within treatment. Differences between treatment means were compared using least squares means and correlation coefficients were determined by the correlation procedure of SAS (1985).

RESULTS and DISCUSSION

Muscle Lipids. The incorporation of LP into a high concentrate diet did not alter marbling score (MS; $P = .81$) or carcass weight ($P = .73$; Table 1). Average MS for both treatments qualified for the U.S. Choice quality grade. In contrast, Zinn and Spires (1987) and Spires et al. (1990) reported increased fat thickness, marbling scores and quality grades with LP addition. In a review of ionophores, Owens et al. (1991) reported increases in marbling scores with a quadratic maximum at 15 ppm LP. Spires et al. (1990), however, attributes these advantages to the heavier carcass weights of the LP supplemented animals. Additional carcass data has been previously reported (VanKoevering et al., 1991).

Moisture, crude fat and TL values of the LM were unaffected ($P = .79$, .41, & .27, respectively) by LP addition. Laidlomycin propionate did not alter ($P = .28$, .59, and .45, respectively) the proportion of lipid present in the storage (NL) versus the structural component (PL and PhL). Similarily, Marmer et al. (1985) reported no differences in NL, PL or PhL content in the LM when monensin was added to cattle diets. Gilka et al. (1989a) also found no differences in fat or moisture content with the addition of monensin or lasalocid to lamb diets. Therefore, ionophores appear to exert indirect influences on lipid amounts and proportions by increasing carcass weights. Marbling score showed a moderate association with TL and NL ($r = .60$), and a low association with PL ($r = .34$).

Cholesterol. Cholesterol content, reported on a wet, dry matter or fat-free dry matter basis, revealed numerical decreases with LP addition; however, these differences were not consistent enough to reach statistical significance (P = .29, .32 and .14, respectively). Preliminary investigation indicated a reducing effect of LP on tissue cholesterol content (41.67 vs. 45.21 mg/100g, P = .08; Duckett et al., 1992b). The lack of inconsistency in the response to LP was not a limitiation in the method (Duckett et al., 1992a), rather it was attributed to the inherent variability that exists between animals in tissue cholesterol content. Associations between cholesterol and MS (r = .25) or TL (r = .29) were low indicating its importance as an essential cell component.

The possibility exists for ionophores to affect cholesterol metabolism when altering VFA proportions. Research has shown that supplementing propionic acid to hypercholesterolemic hogs and heifers does successfully reduce plasma cholesterol levels (Thacker and Bowland, 1981; Thacker et al., 1981; Lalman et al., 1993). Bush and Milligan (1971) found that propionic acid addition *in vitro* to bovine liver tissue reduced the activity of HMG-CoA synthase, the enzyme responsible for the condensation of acetoacetyl-CoA with acetyl-CoA to form HMG-CoA, the key precursor for cholesterol production. Therefore, the influence of ionophores on shifting ruminal VFA proportions by increasing propionic acid could potentially affect tissue

cholesterol levels. Additionally, monensin has been found to interrupt the recycling of low density lipoprotein cholesterol in human fibroblasts (Basu et al., 1981). However, it is unknown if LP were fed at a higher dosage whether more consistent results might be found.

Fatty Acids. In the NL (Table 2), oleic (C18:1) acid content was increased 2% ($P = .05$) due to LP. In the PL (Table 3), palmitoleic (C16:1) acid decreased ($P = .06$) in concentration. However, linoleic (C18:2) and linolenic (C18:3) acids along with the polyunsaturated fatty acid (PUFA) content revealed higher ($P < .05$) concentrations in the PL due to LP addition. In the TL (Table 4), palmitoleic (C16:1) acid decreased ($P = .10$) due to LP addition. Myrsitic (C14:0) acid content was lower ($P = .10$) in the LP muscle compared to CONT. The reduction in myristic acid content resulted in decreased ($P = .07$) concentrations of saturated fatty acids (SFA) in the LM of LP steers. On a gravimetric basis (data not presented in tabular form), LP addition resulted in a .3 g reduction (2.1 vs. 2.4 g/100g; $P = .12$) in the saturated fat content of the LM. Ultimately, these ionophore induced changes in the LM resulted in a 3% decrease ($P = .03$) in the hypercholesterolemic (C14:0 + C16:0) to hypocholesterolemic (MUFA + PUFA) fatty acid ratio. Gilka et al (1989b) also reported decreased myristic acid content of i.m. lipid from feeding monensin and lasalocid to lambs. Myrsitic acid increases plasma cholesterol in humans, and thus is considered

hypercholesterolemic (Hegsted et al. 1965; Keys et al. 1965). Therefore, a reduction in myristic acid concentration due to LP addition would be perceived as beneficial to human health. Together the increases in PUFA in the PL and the decrease in SFA in the TL indicate that ionophore incorporation into a high concentrate diet suppresses ruminal biohydrogenation allowing the passage of more unsaturated fatty acids to the small intestine. This finding is in agreement with Marmer et al. (1985) who also reported decreased SFA content of monensin supplemented steers on sorghum-sudan diet. The decrease in biohydrogenation could be due to alterations in ruminal bacterial and protozoal species when ionophores are fed. The populations of bacteria and protozoa responsible for biohydrogenation of unsaturated fatty acids may be reduced when LP is added to high concentrate diets. The increased proportions of PUFA in the PL may be due to the actions of ionophores in the rumen since they complex with lipids to facilitate the transfer of ions across cell membranes.

Marmer et al. (1985) and Gilka et al. (1989b) both reported increased concentrations of the odd chain fatty acids which were atributed to the greater quantities of propionate available for de novo fatty acid synthesis. In this study the odd chain fatty acids (OCFA) were unaffected by LP addition suggesting that the amount of propionate available for de novo fatty acid synthesis was limited.

IMPLICATIONS

Laidlomycin propionate incorporation into a high concentrate diet increased the polyunsaturated fatty acid content of the polar lipid and decreased the saturated fatty acid content of the total lipid. Ultimately, these changes translated to .3 g reduction in the saturated fat content of the longissimus muscle. With the current emphasis on saturated fat and cholesterol content, further research into this ionophore is warranted.

TABLE 1. Effect of laidlomycin propionate on longissimus muscle lipid and cholesterol content.

	Control	Laidlomycin Propionate	SEM	OSL[a]
Carcass weight, kg	324.8	326.8	4.0	.73
Marbling score[b]	461	456	15.0	.81
Moisture, %	73.11	73.20	.23	.76
Crude fat, %	4.49	4.09	.31	.25
Total lipid, %	5.25	4.74	.27	.18
Neutral lipid, %	4.56	4.06	.26	.18
Polar lipid, %	.69	.68	.01	.44
Phospholipid, %	.49	.56	.03	.45
Cholesterol, mg/100g muscle	40.53	38.67	1.23	.29
Cholesterol, mg/100g (dm)	150.93	144.40	4.56	.32
Cholesterol mg/100g (fat-free dm)	188.07	175.58	6.00	.14

[a]OSL=Observed Significance Level.
[b]Marbling score: small = 400 - 499.

TABLE 2. Effect of laidlomycin propionate on fatty acid composition of the neutral lipid.

Fatty Acid, %	Control	Laidlomycin propionate	SEM	OSL[a]
14:0	3.53	3.39	.06	.15
14:1	.76	.75	.03	.82
15:0	.63	.60	.02	.31
16:0	27.31	26.99	.18	.22
16:1	4.08	3.91	.09	.19
17:0	1.78	1.73	.05	.51
18:0	13.55	13.50	.25	.90
18:1	45.13	45.93	.28	.05
18:2	1.60	1.63	.09	.69
18:3	.07	.07	.01	.90
U	1.54	1.42	.06	.15
SFA	44.38	43.88	.28	.22
OCFA	2.40	2.33	.06	.42
MUFA	49.97	50.59	.30	.15
PUFA	1.67	1.70	.09	.78
Ratio[b]	.598	.582	.006	.11

[a]OSL=Observed Signficance Level.
[b]Ratio of hypercholesterolemic to hypocholesterolemic fatty acids=(C14:0+C16:0)/(MUFA+PUFA).

TABLE 3. Effect of laidlomycin propionate on fatty acid composition of the polar lipid.

Fatty Acid, %	Control	Laidlomycin propionate	SEM	OSL[a]
14:0	.84	.70	.07	.17
14:1	.06	.02	.02	.25
15:0	.08	.04	.02	.16
16:0	19.68	19.36	.22	.28
16:1	1.80	1.53	.10	.08
17:0	.74	.68	.04	.29
18:0	12.04	11.95	.11	.56
18:1	27.84	26.84	.55	.18
18:2	21.16	22.69	.64	.09
18:3	.46	.33	.06	.10
20:4	8.90	9.40	.26	.17
22:5	.92	1.01	.04	.22
22:6	1.29	1.31	.04	.80
U	4.14	4.10	.10	.74
SFA	32.56	32.02	.30	.19
OCFA	.82	.72	.05	.17
MUFA	29.74	28.40	.62	.13
PUFA	32.73	34.74	.82	.09
Ratio[b]	.329	.319	.006	.23

[a]OSL=Observed Significance Level.
[b]Ratio of hypercholesterolemic to hypocholesterolemic fatty acids=(C14:0+C16:0)/(MUFA+PUFA).

TABLE 4. Effect of laidlomycin propionate on fatty acid composition of the total lipid.

Fatty Acid,%	Control	Laidlomycin propionate	SEM	OSL[a]
14:0	3.14	2.98	.06	.08
14:1	.65	.64	.03	.70
15:0	.55	.52	.02	.17
16:0	26.19	25.81	.17	.12
16:1	3.75	3.54	.09	.10
17:0	1.63	1.56	.04	.25
18:0	13.34	13.26	.21	.81
18:1	42.59	42.98	.30	.37
18:2	4.47	4.89	.23	.21
18:3	.13	.11	.01	.46
20:4	1.29	1.46	.08	.16
22:5	.13	.16	.01	.18
22:6	.18	.20	.01	.30
U	1.90	1.81	.05	.30
SFA	42.66	42.04	.26	.09
OCFA	2.17	2.08	.06	.25
MUFA	47.00	47.15	.35	.74
PUFA	6.21	6.82	.31	.17
Ratio[b]	.552	.533	.006	.03

[a]OSL=Observed Significance Level.
[b]Ratio of hypercholesterolemic to hypocholesterolemic fatty acids=(C14:0+C16:0)/(MUFA+PUFA).

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CHAPTER V

EFFECT OF MANAGEMENT SYSTEMS ON LONGISSIMUS MUSCLE FATTY ACID AND CHOLESTEROL CONTENT

ABSTRACT

Differences in fatty acid and cholesterol content were assessed based on the management system utilized prior to feedlot entry. Ribeye steaks (n=70) were obtained from crossbred Angus steers that originated from two ranches in Oklahoma and were assigned the following treatments: early weaned (EW; direct entry into feedlot after weaning at 3.5 mo of age); normal weaned (NW: direct entry into feedlot after weaning at 7.9 mo of age); wheat pasture (WP; grazed on wheat pasture for 112 d after weaning at 7.9 mo of age and then entered feedlot at 11.6 mo of age); short grazed (SG; wintered on dry native range after weaning at 7.9 mo of age, grazed on early intensive managed native range for 68 d, and then entered feedlot at 15.4 mo of age); and long grazed (LG; wintered on dry native range after weaning at 7.9 mo of age, grazed native range for 122 d, and then entered the feedlot at 17.4 mo of age). Responses to management system for marbling score, crude protein, moisture, crude fat, total fatty acid and monounsaturated fatty acid (MUFA) content were dependent on ranch origin of

the steers. Cholesterol content (mg/100g) was higher for the EW and NW treatments compared to WP, SG, and LG. Also, tissue cholesterol content was different ($P < .05$) between the two ranch origins. The concentration of odd chain fatty acids (OCFA) was highest ($P < .05$) in the WP treatment; whereas, the polyunsaturated fatty acids (PUFA) content was highest ($P < .05$) in the EW treatment. Saturated fatty acid content (SFA) did not ($P < .05$) differ between treatments. These results indicate that the management system utilized prior to feedlot entry can influence muscle lipid composition.

(Key Words: Beef, Fatty acid, Cholesterol.)

INTRODUCTION

Many Oklahoma beef producers utilize available wheat pasture and native range to background cattle prior to feedlot entry. These various management systems used prior to feedlot entry influence the age at which the animals are slaughtered. Animal age is suggested to be the primary contributor toward changes in the fatty acid composition of adipose tissue (Clemens et al., 1973). Differences also exist in fatty acid composition between forage-fed and grain-fed beef (Sumida et al., 1972; Westerling et al., 1979; Williams et al., 1983; Mitchell et al., 1991; Duckett et al., 1993); however, the compositional changes that occur with grain feeding after grazing different forage sources is unknown. Previous research indicates that increasing time

on feed on a high concentrate diet results in increased monounsaturated fatty acid (MUFA) and decreased polyunsaturated fatty acid (PUFA) content. Thus, management systems that utilize forage, shorten length of grain feeding and increase age at slaughter have the potential to change fat composition. For these reasons, longissimus muscle fatty acid and cholesterol contents were evaluated for differences based on the management systems prior to feedlot entry.

MATERIALS AND METHODS

Ribeye steaks (n=70) were obtained from steers that originated from two Oklahoma ranches ith the following treatments: early weaned (EW; direct entry into feedlot after weaning at 3.5 mo of age); normal weaned (NW: direct entry into feedlot after weaning at 7.9 mo of age); wheat pasture (WP; grazed on wheat pasture for 112 d after weaning at 7.9 mo of age and then entered feedlot at 11.6 mo of age); short grazed (SG; wintered on dry native range after weaning at 7.9 mo of age, grazed on early intensive managed native range for 68d, and then entered feedlot at 15.4 mo of age); and long grazed (LG; wintered on dry native range after weaning at 7.9 mo of age, grazed native range for 122 d, and then entered the feedlot at 17.4 mo of age). The steers from the two ranches were the result of matings between Angus cross cows and Angus bulls. However, cow mature size and other breed influences differed between the

two ranches. In ranch 1, the steers contained percentages of exotic breed types; whereas, steers from ranch 2 were all of British breed influence. Steers were slaughtered at a similar fat thickness endpoint (1.27 cm) which required 287, 198, 134, 123 and 101 d in the feedlot for EW, NW, WP, SG and LG, respectively. Ribeye steaks were removed from each carcass, trimmed of all exterior fat and pulverized in liquid nitrogen for storage at -20°C. One g samples were extracted according to the following adaptation of Burton et el. (1985): to 1 g muscle, add 1 ml sodium dodecyl sulfate (.08M), vortex, add 2 ml ethanol, vortex, add 2 ml heptane containing 1 mg/ml of the internal standards heneiocasonic acid (C21:0) and stigmasterol, vortex 2 min, and centrifuge for 5 min. A 0.25 ml aliquot of the lipid-heptane layer was esterified to yield fatty acid methyl esters (FAME; Morrison and Smith, 1964). The FAME were analyzed using a HP5890A gas chromatograph equipped with a HP7673A automatic sampler (Hewlett Packard, San Fernando, CA). The injector and flame-ionization detector were maintained at 300°C and 320°C, respectively. Column oven temperature was maintained at: 160 to 214°C at 2°C/min, 214 to 310°C at 20°C/min and held at 310°C for 8.2 min. Fatty acids and cholesterol were separated utilizing a 25 m Ultra 1 capillary column (.20 mm i.d.; Hewlett Packard, San Fernando, CA). Fatty acid and cholesterol content were quantified based on the response of each internal standard and the retention times of known standards (Alltech Associates, Deerfield, IL).

Statistical analysis of experimental data was performed using the GLM procedure of SAS (1985). The main effects were ranch, treatment and the two-way interaction; the error term was animal within ranch by treatment. Differences in the main effects were separated using least squares means (SAS, 1985). Interactions were declared significant at α =.15. Correlation coefficients were determined by the correlation procedure of SAS (1985).

RESULTS AND DISCUSSION

The effect of animal age at slaughter on performance (Gill et al., 1993b), economics and carcass characteristics (Gill et al., 1993a), tenderness (Burton et al., 1994), and cutability (Deering et al., 1993) has been previously reported. Responses to management systems for marbling score, crude fat, moisture and crude protein content were dependent upon ranch origin (Table 1). In ranch 1, treatment had no effect ($P > .05$) on the marbling score or crude fat values; however in ranch 2, EW had higher ($P < .05$) marbling scores and crude fat contents than NW, WP and LG with values for SG being intermediate. Thus, these differences in internal fat deposition from the various management systems appear to be dependent on genetic potential of the animal. Moisture content also did not differ ($P > .05$) due to treatment in ranch 1. However in ranch 2, LG had higher ($P < .05$) moisture contents than EW and NW. Also, WP and SG had higher moisture percentages in

the LM than EW. The differences in moisture content reflect the differences in fat content between the ranches and management systems. Crude protein concentration was lower ($P < .05$) for SG and LG treatments for both ranches than EW, NW and WP (ranch 1) or NW (ranch 2). The lower crude protein content of the SG and LG treatments appears to be due to the lower crude protein content of the native range these steers grazed prior to feedlot entry.

Tissue fatty acid composition between the various management systems is presented in Table 2. Lauric (C12:0), myristoleic (C14:1), palmitoleic (C16:1), oleic (C18:1), linolenic (C18:3), and arachidonic (C20:4) acids along with the saturated fatty acid (SFA) content did not ($P > .05$) differ due to management system or ranch origin. Myristic (C14:0) acid was in higher concentrations in the LM of EW and SG compared to LG with NW and WP being intermediate. The WP treatment produced higher ($P < .05$) concentrations of pentadecylic (C15:0) acid and odd chain fatty acids (OCFA) than the other treatments. The WP treatment also recorded the highest ($P < .05$) gains in the feedlot period suggesting increased propionic acid production which led to increased growth and de novo fatty acid synthesis.

Stearic (C18:0) acid was higher ($P < .05$) in LG than NW with the EW, WP and SG treatments being intermediate in their concentrations. The LG treatment also contained the highest ($P < .05$) concentration of docosahexaenoic (C22:6; DHA) acid. Typically, forage-fed steers will have increased

concentrations of SFA and PUFA (Duckett et al., 1993). The increased concentrations of stearic and DHA acids in the i.m. fat of the LG treatment suggests that triglyceride accumulation that is typically noticed between 84 and 112 d (Duckett et al., 1993) on a high concentrate diet had not yet occurred. Both stearic and DHA acids showed negative and positive associations with time on feed ($r = -.23$, $P = .05$; $r = -.30$, $P = .01$) and animal age ($r = .26$, $P = .03$; $r = .35$, $P < .01$) at slaughter, respectively. Additionally, DHA and total fatty acid content were negatively associated ($r = -.34$, $P < .01$). The PUFA content in the LM was greater ($P < .05$) in the EW treatment than NW which was also higher ($P < .05$) than SG. The WP and LG had concentrations of PUFA intermediate to NW and SG. In contrast, Duckett et al. (1993) reported increased MUFA and decreased PUFA with increased grain feeding (0-196 d). Possibly, the increased length of grain feeding in this study (282 d) compared to the previous study (196 d) greater suppressed ruminal biohyrogenation such that more linoleic acid escaped and became deposited in the i.m. fat. The PUFA and time on feed showed a moderate, positive relationship ($r = .41$, $P < .01$). Further research in the area of changing time on feed and altering ruminal biohydrogenation is warranted.

Interactions between ranch and treatment were evident ($P < .15$) for total fatty acid content, palmitic (C16:0), margaric (C17:0) and linoleic (C18:2) acids, MUFA content and ratio of hypercholesterolemic to hypocholesterolemic

fatty acids (Table 3). Within each ranch, treatment had no ($P > .05$) effect on the total amount of fatty acid detected by GLC. Between the ranches, however, the LG treatment from ranch 1 had a higher ($P < .05$) total fatty acid content than WP (ranch 1) or LG (ranch 2). The SG treatment had higher ($P < .05$) concentrations of palmitic (C16:0) acid than LG in ranch 1 but EW reported highest ($P < .05$) concentrations in ranch 2. Margaric (C17:0) acid was in greater ($P < .05$) concentrations in the EW and SG of ranch 1 and WP of ranch 2 compared to EW from ranch 1. The EW treatment of ranch 1 had increased ($P<.05$) concentrations of linoleic (C18:2) acid compared to NW, WP, SG, and LG from ranch 1 and WP, SG and LG from ranch 2. The LG treatment from ranch 1 had higher concentrations of MUFA than SG from ranch 2. The ratio of hypercholesterolemic (C12 + C14 + C16) to hypocholesterolemic (MUFA + PUFA) fatty acids was higher ($P < .05$) for the EW treatment from ranch 2 than EW (ranch 1), WP (both ranches), SG (ranch 2), and LG (both ranches) with NW (both ranches) and SG (ranch 1) reporting values intermediate. Also, LG from ranch 1 had a lower ($P <.05$) ratio than SG (ranch 1) and EW (ranch 2). These interactions between treatment and ranch show the genetic variation in fat composition. Several researchers (Sumida et al., 1972; Gillis et al., 1973; Leat et al., 1977; Pyle et al., 1977; Eichhorn et al., 1986; Larick et al., 1989; Mills et al., 1992; Huerta-Leidenz et al., 1993) have noted differences in the fatty acid composition between different

breeds. Gillis et al. (1973) and Pyle et al. (1977) found that even crossbred steers with predominately the same breed percentages had different fat composition. These differences in composition indicate that genetics of the animal are important in determining the effect of management systems.

Figure 3 shows the differences in tissue cholesterol content across treatments. Steaks from the NW treatment contained increased ($P < .05$) amounts of cholesterol compared to WP and LG with EW and SG being intermediate to the others. However, differences ($P < .10$) also existed in cholesterol content between the two ranches (48.73 vs. 52.55 mg/100g). Wheeler et al. (1987) found no differences between breeds in tissue cholesterol content even though differences were noted in plasma cholesterol concentrations. Hecker et al. (1975) reported a 70% decrease in cholesterol concentration of i.m. fat with advancing age (28 d old calf to slaughter animal at 560 d of age). In this study, cholesterol and animal age showed a negative relationship ($r = -.27$; $P = .02$).

IMPLICATIONS

Management systems utilized prior to feedlot entry can influence i.m. fat composition. Cholesterol content appears to be influenced by animal age at slaughter. However, the extent of influence by the management systems is dependent on the genetic make-up of the animal.

TABLE 1. Interactions between ranch and treatment on marbling score and proximate composition of the longissimus muscle.

Treatment[a]	EW	NW	WP	SG	LG	SEM
Marbling score[b]						
Ranch 1	410^{d}	433^{cd}	456^{cd}	460^{cd}	447^{cd}	
Ranch 2	493^{c}	414^{d}	412^{d}	476^{cd}	423^{d}	24
Crude fat, %						
Ranch 1	3.99^{e}	4.82^{de}	4.58^{de}	5.58^{cd}	5.14^{de}	
Ranch 2	6.76^{c}	4.57^{de}	4.66^{de}	5.49^{cde}	4.32^{de}	.54
Moisture, %						
Ranch 1	73.66^{cd}	72.97^{cd}	72.33^{de}	72.80^{cd}	73.68^{cd}	
Ranch 2	71.06^{e}	72.24^{de}	72.70^{cd}	72.97^{cd}	73.86^{c}	.54
Crude protein, %						
Ranch 1	22.13^{cde}	22.22^{cde}	22.73^{c}	21.24^{g}	21.15^{g}	
Ranch 2	21.82^{efg}	22.61^{cd}	22.00^{def}	21.42^{fg}	21.61^{efg}	.25

[a]EW=Early Weaned (direct entry in feedlot after weaning at 3.5 mo); NW=Normal Weaned (direct entry in feedlot after weaning at 7.9 mo); WP=Wheat Pasture (grazed on wheat pasture for 112 d after weaning (7.9 mo) and then entered feedlot at 11.6 mo); SG=Short Grazed (wintered on dry native range after weaning (7.9 mo), grazed on early intensive managed native range for 68 d and then entered feedlot at 15.4 mo); LG=Long Grazed (wintered on dry native range after weaning (7.9 mo), grazed on native range for 122d and then entered feedlot at 17.4 mo).

[b]Marbling Score: 400-499=Small.

[cdefg]Means with uncommon superscripts in the same row differ ($P<.05$).

TABLE 2. Effect of management systems on longissimus muscle fatty acid composition.

Fatty Acid, %	EW[a]	NW	WP	SG	LG	SEM
C12:0[b]	.04	.04	.04	.04	.04	.01
C14:0	3.45[d]	3.31[de]	3.34[de]	3.41[d]	3.08[e]	.11
C14:1	.64	.66	.59	.64	.59	.04
C15:0	.33[d]	.28[d]	.58[c]	.31[d]	.39[d]	.02
C16:1	3.13	2.76	3.05	3.08	3.02	.11
C18:0	14.56[de]	14.41[e]	14.90[de]	14.95[de]	15.36[d]	.14
C18:1	42.54	43.03	43.43	42.86	43.31	.53
C18:3	.12	.08	.08	.12	.08	.03
C20:4	.25	.26	.25	.25	.30	.02
C22:6	.04[e]	.05[e]	.05[e]	.06[e]	.10[d]	.01
SFA[c]	45.40	44.52	44.50	45.15	44.51	.51
OCFA[c]	1.96[e]	1.91[e]	2.26[d]	2.01[e]	2.01[e]	.09
PUFA[c]	3.23[d]	2.87[e]	2.69[ef]	2.46[f]	2.80[ef]	.15

[a]EW=Early Weaned (direct entry in feedlot after weaning at 3.5 mo); NW=Normal Weaned (direct entry in feedlot after weaning at 7.9 mo); WP=Wheat Pasture (grazed on wheat pasture for 112 d after weaning (7.9 mo) and then entered feedlot at 11.6 mo); SG=Short Grazed (wintered on dry native range after weaning (7.9 mo), grazed on early intensive managed native range for 68 d and then entered feedlot at 15.4 mo); LG=Long Grazed (wintered on dry native range after weaning (7.9 mo), grazed on native range for 122d and then entered feedlot at 17.4 mo).

[b]C12:0: Number of carbons:number of double bonds in each fatty acid.

[c]SFA=Saturated fatty acids (C12:0 + C14:0 + C16:0 + C18:0); OCFA=Odd chain fatty acids (C15:0 + C17:0); MUFA=Monounsaturated fatty acids (C14:1 + C16:1 + C18:1); PUFA=Polyunsaturated fatty acids (C18:2 + C18:3 + C20:4 + C22:6); RATIO=Ratio of hypercholesterolemic fatty acids (C12:0 + C14:0 + C16:0)/hypocholesterolemic fatty acids (MUFA+PUFA).

[def]Means with uncommon superscripts in the same row differ (P<.05).

TABLE 3. Interactions between ranch and treatment on fatty acid composition of the longissimus muscle.

Treatment[a]	EW	NW	WP	SG	LG	SEM
Total Fatty Acids, %						
Ranch 1	4.32^{cd}	5.46^{cd}	4.25^{d}	4.93^{cd}	6.33^{d}	
Ranch 2	5.88^{cd}	5.49^{cd}	4.96^{cd}	5.80^{cd}	3.88^{d}	.74
C16:1, %						
Ranch 1	26.40^{de}	26.88^{de}	26.21^{de}	27.07^{cd}	25.64^{e}	
Ranch 2	28.28^{c}	26.64^{de}	26.21^{de}	26.41^{de}	26.40^{de}	.47
C17:0, %						
Ranch 1	1.78^{c}	1.60^{cd}	1.60^{cd}	1.80^{c}	1.67^{cd}	
Ranch 2	1.48^{d}	1.65^{cd}	1.76^{c}	1.59^{cd}	1.58^{cd}	.10
C18:2, %						
Ranch 1	3.00^{c}	2.30^{def}	2.25^{def}	2.16^{ef}	2.27^{def}	
Ranch 2	2.65^{cd}	2.66^{cdc}	2.38^{de}	1.90^{f}	2.37^{de}	.15
MUFA[b], %						
Ranch 1	46.76^{cd}	46.88^{cd}	47.17^{cd}	45.69^{c}	47.55^{b}	
Ranch 2	45.85^{cd}	46.02^{cd}	46.98^{cd}	47.48^{cd}	46.28^{cd}	.63
RATIO[b]						
Ranch 1	.598de	.610^{cde}	.597de	.640^{cd}	.574^{e}	
Ranch 2	.650^{c}	.614^{cde}	.594de	.593de	.600de	.02

[a]EW=Early Weaned (direct entry in feedlot after weaning at 3.5 mo); NW=Normal Weaned (direct entry in feedlot after weaning at 7.9 mo); WP=Wheat Pasture (grazed on wheat pasture for 112 d after weaning (7.9 mo) and then entered feedlot at 11.6 mo); SG=Short Grazed (wintered on dry native range after weaning (7.9 mo), grazed on early intensive managed native range for 68 d and then entered feedlot at 15.4 mo); LG=Long Grazed (wintered on dry native range after weaning (7.9 mo), grazed on native range for 122d and then entered feedlot at 17.4 mo).

[b]MUFA=Monounsaturated fatty acids (C14:1 + C16:1 + C18:1); RATIO=Ratio of hypercholesterolemic fatty acids (C12:0 + C14:0 + C16:0) / hypocholesterolemic fatty acids (MUFA+PUFA).

[cdef]Means with uncommon superscripts in the same row differ (P<.05).

FIGURE 1. Effect of management system on cholesterol content.

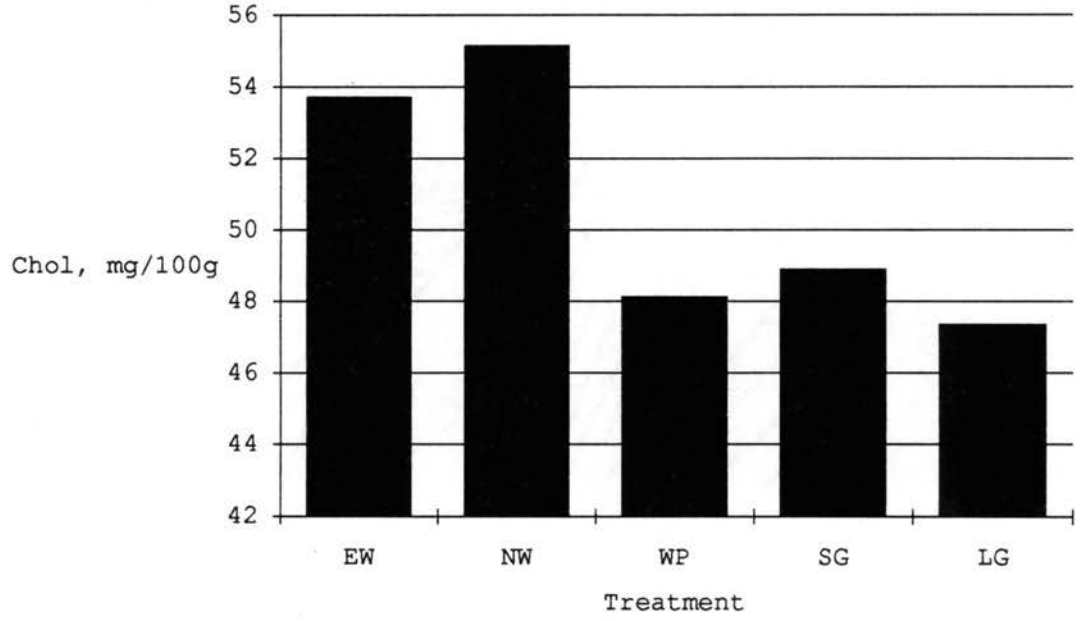
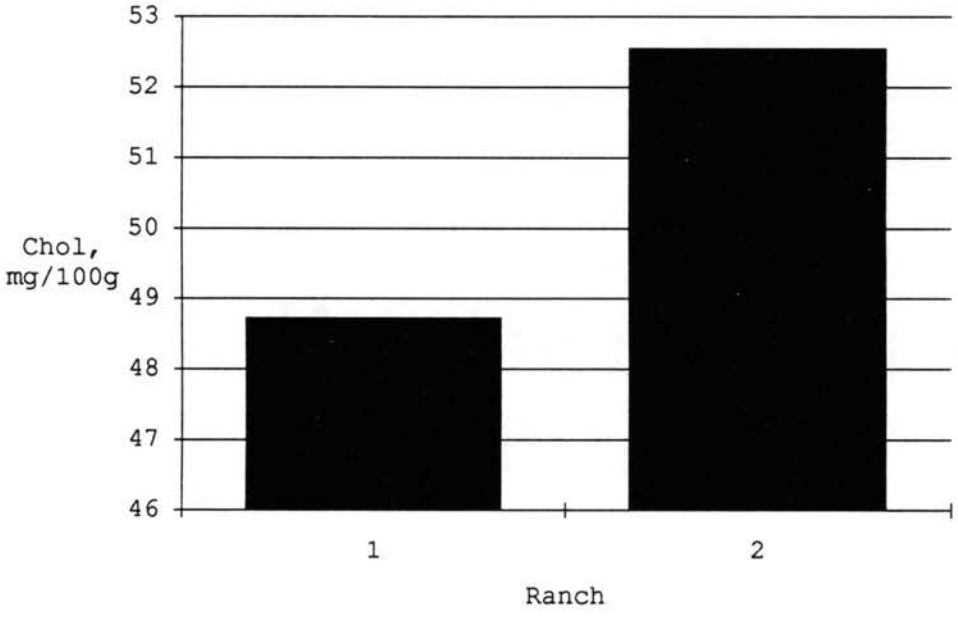


FIGURE 2. Effect of ranch on cholesterol content.



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CHAPTER VI

COMPARISON OF LIPID EXTRACTION METHODS FOR QUANTIFICATION OF FATTY ACID AND CHOLESTEROL CONTENT IN BEEF

ABSTRACT

Fatty acid and cholesterol concentration were quantified by GLC and differences between two solvent extraction methods evaluated. No differences ($P > .05$) were noted in the fatty acid composition or cholesterol content between the two extraction methods evaluated. However, the newer method of lipid extraction required less labor, solvent and created less waste. Thus the newer lipid extraction method evaluated allowed the quanitification of tissue fatty acid and cholesterol content in about two hour.

INTRODUCTION

The traditional methods of tissue lipid extraction involve large volumes of carcinogenic solvents, takes long time periods and creates large volumes of waste. With current empahsis on saftey in laboratories and on waste disposal, newer methods that eliminate the hazards and time associated with the traditional methods of lipid extraction are needed. For these reseaons, an alternative lipid

extraction method of Burton et al. (1985) was evaluated. Fatty acid and cholesterol concentration were measured by GLC from both extraction methods.

MATERIALS and METHODS

Sample Preparation

Twenty one ribeye steaks were obtained from steer carcasses. The longissimus muscle was trimmed of all exterior fat and epimysial tissue, and then pulverized in liquid nitrogen for storage at -20°C.

Lipid extraction procedures

Each sample of longissimus muscle was subjected to both of the following extraction methods: Folch et al. (1957) and Burton et al. (1985). The Folch et al. (1967) method was conducted as follows: to 10 g sample, add 180 mls of chloroform:methanol (2:1), homogenize for 3 min., filter into flask containing 50 mls of .5% NaCl, rinse, then add 60 mls of chloroform:methanol (2:1) and filter paper plus residue and rehomogenize for 3 min., refilter into previous residue, place filtrate into Buchner funnel and allow to separate. The chloroform layer was freed of solvent on a rotary evaporator, and then made to 10 mls with hexane. The method of Burton et al. (1985) consists of the following: weigh a 1 g sample into a test tube, add 1ml 0.08 M SDS, vortex, add 2 ml ethanol and vortex, then add 2 ml heptane containing 1 mg/ml of the internal standards heneicosanoic acid (C21:0) and stigmasterol, vortex 2 min and centrifuge for 5 min to separate layers. An aliquot of each extract

(0.25ml from Burton et al. (1985) and 1 ml of Folch et al. (1957) extract plus 1 mg of each internal standard) was freed of solvent, and then 1 ml of benezene and 2 ml of 14% boron-trifluoride in methanol were added under nitrogen. These extracts were then heated at 100°C for 45 min to yield fatty acid methyl esters (FAME; Morrison and Smith, 1967).

Fatty acid and cholesterol analyses

The FAME were analyzed using a HP5890A gas chromatograph equipped with a HP7673A automatic sampler (Hewlett Packard, San Fernando, CA). The injector and flame-ionization detector were maintained at 300 and 310°C, respectively. The column oven temperature was programmed at: 160 to 214°C at .2°C/min, 214 to 310°C at 2°C/min and held at 310°C for 8.2 min. Separations of fatty acids and cholesterol were accomplished on a HP Ultra 1 (Hewlett Packard, San Fernado, CA). Fatty acids and cholesterol were identified based on retention times of known compounds (Alltech Assoc., Deerfield, IL). The fatty acid and cholesterol concentration were quantified based on the response of each internal standard.

Statistical analyses

Differences in each fatty acid and cholesterol concentration between methods were tested using Proc Univariate procedure (SAS, 1985). Means reported in text are least squares means and standard errors of those means for each extraction method.

RESULTS AND DISCUSSION

Table 1 shows the composition of the lipid extract from the two methods. No differences (P>.05) were noted for any fatty acid percentage, total fatty acid or cholesterol content quantified between the two extraction methods. The differences were in time involved to perform the extraction, the solvent volume and type used and the equipment needed to perform the extraction. The method of Burton et al. (1985) takes only 15 min per sample; whereas, each extraction with the Folch et al. (1957) method takes from 2-10 hr for complete separation of the solvent layers. The Folch et al. (1957) utilizes large volumes of cholorform:methanol (2:1) and creates volumes of waste. Thus based on this comparison of these two methods, the method of Burton et al. (1985) should be a preferred method of lipid extraction. The use of the internal standards in this extraction method allows for the quantification of fatty acid and cholesterol content, thereby reducing the time involved for fat and cholesterol analysis to about 1 hour.

TABLE 1. Fatty acid and cholesterol content from the two extraction methods.

	Extraction Method		
	Folch[a]	Burton[b]	SEM
Total Fatty acids, g/100g	4.98	5.32	.19
Cholesterol, mg/100g	49.22	53.24	2.65
C14:0[c], %	3.37	3.40	.02
C14:1, %	.59	.61	.01
C15:0, %	.52	.44	.06
C16:0, %	27.52	27.75	.20
C16:1, %	3.11	2.94	.06
C17:0, %	1.66	1.67	.02
C18:0, %	15.59	15.62	.08
C18:1, %	44.08	44.20	.13
C18:2, %	2.84	2.68	.10
C18:3, %	.11	.13	.03
C20:4, %	.54	.48	.04

[a]Extraction method of Folch et al. (1957).
[b]Extraction method of Burton et al. (1985).
[c]14:0=number of carbons:number of double bonds in each fatty acid.

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