THE EFFECTS OF DIETARY FAT AND A SURFACTANT ON THE DIGESTIBILITY AND PERFORMANCE OF STEERS

by

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CHAPTER I

INTRODUCTION

The use of animal and hydrolyzed vegetable fats in commercial feedlots is surrounded by concern and controversy.

The literature would suggest that the reluctance of the livestock and feed industries to use fat as a feed ingredient in ruminant rations is justified. One of the many factors influencing the use of fats in livestock feeds is production economics. The formulation of rations using animal or hydrolyzed vegetable fats entails more than the simple addition of energy to the ration. Many biological barriers and interactions affect the utilization of fat-containing rations. While a wide variation exists among results of feeding fats to all livestock species, the ruminant animal may have the greatest variation because of its large complex system of metabolism. The ruminant animal also has a tremendous variety of feed ingredients available for utilization.

Although fat is considered as a concentrated source of energy in most livestock rations, it possesses many other beneficial characteristics. Increased growth, improved feed efficiency, palatability and absorption of fat-soluble vitamins are attributed to dietary fat. Dust control, improvement of pellet quality and reduction in machinery wear are important to feed manufacturers.

Fat for ruminants varies from 1 to 10% of the total ration depending on the type and quality of ration being fed, the quality of fat, and the economic value of fat as compared to other high energy ingredients. Fat contains 9.4 kilocalories of gross energy per gram or about 2.25 times that of carbohydrates and proteins.

The addition of surface-active agents or "surfactants" to ruminant rations has not been studied to any great extent. Surfactants have been widely used in the poultry industry for many years. Ely and Schott (1952) were among the first to show beneficial response on poultry growth rates.

The "key" point to the addition of fat or any other ingredient or additive is whether one is realizing a beneficial return, either physical or biological, from the animal, based on the cost of the added ingredient.

This experiment was designed to study the effects of dietary fat and a surface-active agent (polydimethylsiloxane) on the digestibility and performance of two-hundred steers (Hereford, Angus and Hereford X Angus) fed under typical Kansas feedlot conditions. Incorporated within the original design was an organoleptic evaluation of resulting steaks. Thus, the experiment included objective measurements on the animals from their arrival in the feedlot to the final consumer product.

CHAPTER II

REVIEW OF LITERATURE

The Effects of Added Dietary Fat In Ruminant Rations

The last decade has witnessed a tremendous increase in the use of added animal fat in the rations designed for various classes of poultry. No such widespread use has been made of this feed, however, in the diets of adult ruminants.

The early studies of Willey et al. (1952) demonstrated that 5% added cottonseed oil to a basal ration of cottonseed meal, ground sorghum grain, cottonseed hulls, wheat bran, and alfalfa hay decreased consumption by 2 to 3 pounds per day per steer, but gave rise to a considerably higher feed efficiency, (824 vs. 710), requiring about 100 pounds less feed per 100 pounds gain. There were no differences in average daily gain. The differences in carcass weight, dressing percent, and hide weight were not great enough to be significant. There were no differences in the average weight of the 9, 10, and 11th rib cuts of the steers fed different levels of fat. The steers fed high levels of fat appeared to have less fat and more lean in the rib cuts. From the experiment it was observed that saturation of body fat was greater in steers fed high fat levels than those on the control rations.

Schweigert and Wilder (1955) set a general recommendation for beef cattle that approximately 3% of the total feed could be made up of added fat. They indicated that 3% fat could replace 2.5 pounds of corn meal, but noted that the higher fat ration would be less readily consumed in the early weeks than the control diet.

Beef fat was found to be satisfactory in steer fattening rations up to 5% of the concentrate mixture (Henteges *et al.*, 1954). Steers receiving 5% added fat gained 2.3 pounds daily compared to 1.8 pounds for the basal, and required less feed per unit of gain. However, there was little difference in carcass grade or dressing percentage.

A similar study was conducted by Wise *et al.* (1959) who added 5% yellow grease, a blend of vegetable and animal fats, or cottonseed foots to a complete mixed ration based on ground ear corn. All steers were fed *ad libitum* and received 24 mg. stilbestrol implants. Average daily gain in lb., total digestible nutrient (TDN) intake in lb. per day and pounds TDN per lb. of gain for the treatments, respectively: Basal, 2.7, 16.9, 4.0; Yellow grease, 2.4, 15.7, 4.1; Blend, 2.4, 14.9, 3.8; and Cottonseed foots, 2.6, 16.2, 3.9. In the carcass evaluation the percent separable fat, percent separable lean, mm^2 of marbling per in^2 of ribeye muscle, and ribeye area in in^2 for the treatments were: Basal, 32.8, 55.4, 45.7, 11.7; Yellow grease, 34.4, 54.7, 46.9, 11.1; Blend, 32.2, 55.9, 34.6, 10.9; and Cottonseed foots, 33.5, 54.5, 38.3, 11.3.

Morrison (1949) reported that digestive disturbances result in cattle feeding experiments when the level of fat exceeds more than one pound per 1,000 pounds body weight.

Hubbert et al. (1961), fed yearling steers 4% tallow which resulted in a slight depression in feed intake but had no significant influence on average daily gain. However, the addition of tallow produced more efficient conversion of feed to gain (935 vs. 1034 lb. of feed per 100 lb. gain). In a replication study, average daily gains and feed required per 100 lb. of gain respectively were: no tallow 2.63, 971; 4% tallow 2.88, 898.

Matsushima and Dowe (1954) conducted an experiment in which beef tallow was fed at 3% in the form of pellets to a ground ear corn basal ration. The steers receiving beef tallow gained 2.00 pounds per day verus 2.11 pounds for the control diet. There were no digestive disturbances and no significant differences in carcass characteristics. Cost per pound of gain was in favor of the group of steers fed the beef tallow pellets.

The addition of 7% fat (bleachable fancy tallow) to roughage-containing diets (alfalfa and straw) significantly increased ($P < .01$) average daily gains of steers fed alfalfa pellets (Erwin et al., 1956). The same level of fat significantly reduced ($P < .01$) the average daily gain of steers consuming wheat straw rations during the 183-day feeding period.

Wise et al. (1963) demonstrated that by adding 2% animal fat to a basal all-concentrate ration, average daily gain was reduced from 2.60 to 2.45, and feed per unit gain decreased from 6.55 to 6.18.

In an extensive study, adding mixed animal fat (predominately inedible beef tallow) at 0, 5, and 10% of the basal ration (Bohman _et al._, 1957), 5% animal fat increased the rate of gain 28% (2.01 vs. 2.57, $P<.01$). The addition of 10% fat was not as effective as the lower level but increased gain 12% (2.01 vs. 2.27, n.s.). Both levels of added fat decreased the amount of feed required per pound of gain by 23 and 16% for the rations containing 5% and 10% fat, respectively ($P<.01$). Carcass data, with the exception of dressing percent, appeared to favor the rations containing fat but the differences were small and not statistically significant.

The effect of various fat sources (yellow grease, hydrogenated cottonseed oil, or crude cottonseed oil) added at the rate of 5% of a ground ear corn ration for steers varying in initial weight (702 lb. vs. 623 lb.) was studied by Ellis _et al._ (1962). The heavy steers consumed less and gained less on fat-containing ration. Light steers consumed approximately the same amount of both rations, but gained more on the fat-containing diet. The addition of 5% fat improved feed efficiency by approximately 8.5%.

Figroid _et al._ (1971) studied the effects of beef tallow added at three levels to rations of various concentrate:roughage ratios. Twelve steers were fed four fat levels (0, 5, 10, and 15%) at three different concentrate levels (60%, 75% and 90%).

The first 56 days (60% concentrate) there was no improvement due to fat. During the second 56 days (75% concentrate), 5% added fat decreased the feed required per 100 lb. gain but did not increase the average daily gain. The last 28 days on trial (90% concentrate) daily gains (lbs.) were .9, 2.43, and 2.36 for 0, 5, and 20% fat respectively. Similarly, pounds feed per 100 lbs. gain were 1654, 687, and 610. The over-all results of the 113 day trial showed that when compared to controls, steers receiving 5% added fat had improved average daily gains (2.71 lb. vs. 2.55 lb.) and feed efficiencies (597 vs. 662 lbs. feed per 100 lbs. gain). The 10% fat level did not increase the average daily gains but did improve feed efficiency.

Edwards et al. (1961) fed yearling steers a basal ration of ground ear corn and two levels of added fat (2.5% and 5.0%). The fat was a stabilized animal fat (yellow grease). Average daily gains were: 2.27 lb., for basal ration; 2.52 lb., for 2.5% added fat; and 2.40 for 5% added fat. These differences were not significant. Added fat levels resulted in a significant increase in the percentage of separable rib fat ($P < .05$) and a highly significant increase in stearic acid content of rib fat.

The Effects of Fat on Digestibility

Two experiments (Dyer et al., 1957), were conducted to study the effect of added fat on performance of yearling steers. Experiment I, demonstrated that 7% fat added to the basal ration increased gain (1.35 vs. 1.63). The digestibilities of dry matter and crude fiber were significantly reduced ($P < .05$) when fat was added to the ration. In these experiments, fat fed at high levels (7% of the ration) did not significantly increase average daily gain, probably because of the accompanying reduction in digestibility of dry matter and crude fiber.

Roberts and McKirdy (1964) studied the effects of two oils and animal tallow, which replaced 5% of the basal ration by weight, on feedlot performance, characteristics of carcass fat and ration digestibility for fattening steers. After 133 days on test, average daily gain and feed per 100 lb. gain were respectively: Control, 2.22 lb., 915 lb.; Rapeseed oil, 2.45 lb., 831 lb.; Sunflowerseed oil, 2.65 lb., 818 lb.; Animal tallow, 2.35 lb., and 848 lb. There were no significant differences among treatments in average daily gain. All treatments receiving either an oil or animal tallow were more efficient in feed conversion. There were no significant differences among treatments in dressing percentage, USDA carcass grade or percent separable fat of the 9-11th rib cut. Dry matter and energy digestibility was not significantly affected by treatments. However, in all cases these digestion coefficients were lower for rations containing the added fats. The digestibility of ether extract was significantly higher ($P < .01$) when fat was added to the rations.

In a continuing study from a previous experiment, (Erwin *et al.*, 1956), Erwin *et al.* (1956b) demonstrated that 7% fat added to steer rations containing alfalfa or straw significantly ($P < .01$) reduced the digestibility of dry matter and crude fiber.

The added fat increased the digestibility of ether extract significantly. Crude protein digestibility seemed to decrease as fat was added to the ration. The decreased digestibility of certain nutrients when fat is added to the ration has not been explained definitely, but a possibility exists that the depressing effect is a physical action by coating the fiber so that the cellulolytic microorganisms cannot freely degrade the fiber.

Albin and Durham (1967) reported that the crude protein digestibility of a sorghum grain diet was reduced ($P < .05$) by the addition of 2% beef tallow. Dry matter and gross energy digestibility coefficients were also reduced by added fat.

Lucas and Loosli (1944) demonstrated that feeding high-fat rations to Holstein cows did not improve the apparent digestibility of any nutrients except that of ether extract.

Epslin et al. (1963) measured the effect of 4% added fat (animal tallow, or hydrolyzed vegetable and animal fat) to a high concentrate diet. Average daily gains for the first 57 days for twelve 830 lb. steers was 2.35 lb. They required 816 lbs. of feed per 100 lbs. gain, with no significant differences between treatments. Dressing percent was higher for steers fed added fat. There was an insufficient number of animals to permit conclusions regarding performance. Ether extract digestibility favored both fat containing rations ($P < .01$). Digestible energy and TDN were significantly increased ($P < .05$) by the added fat. Molar percent of the rumen volatile fatty acids or total volatile fatty acids were not significantly affected by the three treatments although total volatile fatty acids appeared to increase with the addition of fat to the ration. In summary, this trial indicated that 4% fat can be added to typical high grain fattening rations of beef cattle without depressing the utilization of the various ration components and that the animal made good utilization of the added fat. Fat did increase crude protein digestibility.

Putnam et al. (1969) reported the effects of adding soybean oil to corn-based finishing ration for beef cattle. Average daily gains were: 1.06 kg and 0.75 kg, feed intake, 8.95 kg and 8.09 kg, and feed per unit gain, 8.44 and 10.75 for treatments and control respectively. Ruminal pH was lower ($P < .01$) and ribeye area greater ($P < .05$) when the oil was added to the all-concentrate ration. No significant differences occurred among the other carcass traits measured. Soybean oil did not affect dry matter, crude protein, or energy digestibility. The ruminal ammonia concentrations were decreased by the addition of soybean oil while the ruminal volatile fatty acid concentrations were increased.

In a study with lambs, Swift et al. (1947) added two levels of corn oil (3.5% and 7.0%) to a corn meal-linseed meal ration to determine the affects on nutrient digestibility. The low level (3.5%) significantly increased the digestibility of dry matter, crude protein, ether extract, crude fiber, nitrogen-free-extract (NFE) and energy. When oil was increased to 7% of the diet daily, all of the digestibility coefficients, except ether extract, were reduced to values below those obtained in the basal ration.

Brooks _et al._ (1954) reported experiments to determine the effect of corn oil and lard on the digestion of cellulose by ovine rumen microorganisms _in vitro_ and the digestion of cellulose and crude protein _in vivo_. The additions of corn oil produced a significant decrease ($P < .01$) in _in vitro_ cellulose digestion. During _in vivo_ studies all sheep lost weight but greater weight loss was in sheep receiving corn oil. Thirty two grams (3%) corn oil per day added to the ration significantly decreased the digestion coefficients ($P < .05$) for cellulose and crude protein. Corn oil additions of 64 gm (6%) per day decreased these coefficients still further ($P < .01$). When lard was added to the basal ration at 3%, 33% less cellulose was digested than in the basal ration. There were no differences in crude protein digestibility for either level of lard (3% or 6%) but the lard fed at 6% (64 gm per day) decreased cellulose digestion by 53 percent and the feed intake was reduced by 6 percent. The volatile fatty acids (VFA) of rumen content were decreased from 4.1 mg. per 100 ml in the basal ration to 2.4 mg. per 100 ml in the 64 gm of added lard. The number of bacteria per gram of rumen content was not affected by the addition of lard but there appeared to be a qualitative shift in bacteria as indicated by an increase in the number of medium-sized cocci and a decrease in the numbers of small rods in the fat fed animals.

The addition of 15% added fat to sheep rations containing mainly cottonseed hulls and ground sorghum reduced ($P < .01$) the average daily gains (Brethour et al., 1958). Lambs receiving fat-containing rations were difficult to start on feed and after about 20 days on feed the wool of some animals was easily detached from the skin. In the 28-day trial seven individual lambs were lost, all on the high-fat diet. Fat significantly decreased ($P < .05$) the digestibility of dry matter and organic matter.

The Effects of Fat with Mineral and Urea Additions

Bradley et al. (1966) used fat (5%) and urea in finishing rations for steers to determine their effects on feedlot performance. The rations were equal in digestible energy and digestible protein. Average daily gain and feed efficiency were not affected by the addition of fat. When fat was added to the urea ration the rate of gain was significantly reduced ($P < .01$), and 1.0 to 1.89 kg. more feed was required for each kilogram of gain. Digestible ether extract increased ($P < .01$), but fat decreased ($P < .01$) apparent digestion of dry matter, energy and NFE. These effects combined to reduce ($P < .01$) TDN in the fat-containing diets. When fat was added to the ration containing urea the digestibility of crude protein was reduced ($P < .01$), suggesting reduced utilization of nitrogen and yielding a palusible explanation for the depressed gains when animal fat was added to urea rations.

Sixty Hereford steers were fed three rations in a feedlot trial to study the utilization of finishing rations containing urea (1.5%), 5% added fat or a combination of both (Thompson *et al.*, 1967). The rations were equal in nitrogen, calcium, phosphorus and digestible energy. Average daily gains in kilograms and feed per unit gain were: .87, 11.91 for urea diets, .76, 13.36 for fat, and .67, 14.52 for diets containing both fat and urea ($P < .05$). There were no differences in the amount of feed consumed. The rumen fluid of steers fed urea rations contained a lower percent acetate and a higher percent propionate than did that of steers receiving fat and fat plus urea. These differences are explained because of the differences in the roughage content in the three rations. Carcass data indicated that dressing percent, kidney fat and fat over rib-eye increased with the 5% added fat.

Jones *et al.* (1961) fed steers pelleted rations containing fat, urea, or fat plus urea added to a basal ration of ground shelled corn, ground corn cobs, molasses and soybean oil meal. The average daily gain in lbs and feed per lb of gain were: basal ration, 2.14 and 8.46; urea, 2.04 and 8.95; fat, 2.10 and 9.05; and fat plus urea, 1.64 and 10.29. There was a significant decrease in the average daily gain on the ration containing fat plus urea, which is in agreement with Thompson *et al.*, 1967. Ether extract digestibility of rations containing urea, fat and fat plus urea increased significantly, but the digestibility of dry matter, energy and NFE decreased significantly in rations containing fat and fat plus urea. TDN and crude protein digestibility decreased significantly in rations containing both fat and urea.

Lambs were used to study the effect of lard and urea on the digestibility and nitrogen balance with a basal ration of 11.5% protein (dry basis) containing linseed meal or soybean meal (Embry et al., 1957). Lard added at the 5% level significantly increased the digestibility of crude protein, ether extract and NFE, and increased TDN. Lard increased the digestibility of crude protein when added with urea. Nitrogen balance data did not show any significant differences between treatments.

Cameron and Hogue (1968) reported studies to determine the effect of varying dietary corn oil and hay-grain ratio with lambs. When 15% corn oil was included in the diet the iodine number of lamb depot (kidney) fat was significantly increased. Average daily gain was decreased in all cases when 15% corn oil was used in the ration, except in the medium fiber level ration. Feed efficiency seemed to increase with the 15% corn oil, with the exception of the low fiber treatment.

In an attempt to alleviate the depressing effect of corn oil upon digestibility of a lamb ration containing 46% corncobs, Davison et al. (1960b) added $CaCO_3$, $CaCl_2$ and $MgCO_3$ to a basal diet containing 0.3% calcium. Calcium (0.4%) as either chloride or carbonate alleviated the depressing effects of 5% corn oil on the digestibility or organic matter, protein and cellulose. Magnesium at the 0.25% had no effect. The 5% added corn oil saved about 1 lb. of feed per lb. gain in a fattening trial. Average daily gains, carcass grade and dressing percentage were not affected by the corn oil addition.

White et al. (1958) used crossbred wether lambs to evaluate the addition of 5% corn oil which replaced 5% corn syrup in a basal ration containing mainly corncobs. The addition of 5% corn oil to the basal ration in three consecutive periods decreased cellulose digestion. However, cellulose digestion for the 5% corn oil diet in the first period was significantly higher than for the two succeeding periods. It was suggested that the added fat decreased certain microbial metabolic activities and/or modified the rumen microbial population concerned with cellulose digestion. The crude protein digestibility was decreased with 5% added corn oil; however, when 4.4 gm calcium ($CaCO_3$) and 0.86 gm phosphorus were added to both corn oil and basal rations, the depression of digestion of cellulose and crude protein was eliminated. These data indicate that for optimum cellulose utilization the ruminal requirement for calcium was increased in the presence of supplemental fat.

The effect of added fats with and without alfalfa ash on the digestibility and utilization by cattle and sheep of rations containing ground corn cobs or cottonseed hulls was reported by Ward et al. (1957). In trial I, with sheep, 2.6% corn oil (by weight) reduced the average daily gain from 0.24 lb. (basal ration), to 0.20 lb. (added fat), with a significant ($P <.05$) reduction in feed efficiency. However, when alfalfa ash was added, the depressing effect of corn oil was completely reversed, and an increase in average daily gain and feed efficiency resulted. Trial II, 10% corn oil was used, and even a greater depression in performance occurred. In trial III, the digestibility of dry matter, crude protein, and crude fiber were all improved with the addition of 2.4% corn oil to the basal ration. Ether extract digestibility was significantly improved ($P < .01$) with the added fat. The basal ration in trial III contained 55% cottonseed hulls while the basal ration in trial IV contained 87% cottonseed hulls. The addition of 32 gm per day of corn oil to the basal ration significantly ($P < .01$) reduced the digestibility of all ration components, except crude protein and ether extract. When alfalfa ash (28 gm per day) was added to the corn oil-containing diet, depression was reversed and digestibility improved in all the ration components. Trial VI was conducted with steers to study the digestion coefficients using a basal ration of cottonseed hulls, Drackett C-1 protein, urea, corn sugar, cottonseed meal, dicalcium phosphate, sodium sulfate, vitamins A and D and sodium chloride. The addition of 10% corn oil to the basal ration resulted in a depression in the digestibility of all ration components except ether extract, and also caused a reduction in nitrogen retention. In a similar study, Tillman et al. (1954a) found that the addition of alfalfa ash to a basal ration of prairie hay containing 5% corn oil did not improve the digestibility of ration components. This effect may have been due to the high mineral content of prairie hay.

Grainger and Stroud (1959) used crossbred wether lambs in a study to determine the effect of 7% corn oil, 119 gm corn Distillers Dried Solubles and 4.4 gm calcium on cellulose digestion, fecal soap excretion, and apparent calcium digestibility. The corn oil added to the basal ration decreased cellulose digestion and apparent calcium digestion. The addition of 4.4 gm of calcium in the 7% corn oil diet was effective in preventing a reduction of cellulose digestibility, indicating that a possible quantitative relationship exists between calcium and supplemental corn oil.

An experiment to study the effect of 2% corn oil in a basal ration of 65% corn cobs for crossbred wether lambs was conducted by Summers et al. (1957). The added corn oil decreased ($P<.01$) the digestion coefficient for crude cellulose and organic matter. Crude protein digestibility also decreased ($P<.05$) with the presence of added corn oil. When alfalfa ash was added to the 2% corn oil ration the digestion coefficients were increased. This study suggests that the fat addition will increase the mineral requirements of rumen microorganisms for cellulolytic activity.

In another study, Grainger et al. (1961) reported that the addition of 7% corn oil to a basal ration resulted in a decreased calcium digestion ($P<.05$), and cellulose digestion ($P<.01$). When 4.4 gm of calcium was added to this ration the digestibility of cellulose was significantly increased ($P<.01$). These results are in close correlation with results obtained by White et al. (1958) and Davison and Woods (1960).

Bohman and Wade (1958) added beef tallow (5 and 10%) to steer rations. Fat additions significantly increased plasma fat, and significantly decreased carotene and vitamin A in both plasma and liver. In general, the addition of beef tallow increased the amount of fat in the carcasses. In a very similar study, Bohman et al. (1959) determined the effect of animal fat (0 and .5 lb. per head per day) with protein supplement (three levels) on the growth and blood constituents of wintering beef calves fed native grass hay. The animal fat had no effect on the gains, but during the summer the cattle fed fat the proceeding winter gained more than those wintered on the control ration. The addition of animal fat decreased plasma phosphorus, but increased plasma fat and plasma carotene, which were parallel to the levels of plasma fat fed during the winter months. Hemoglobin and calcium were not influenced.

The data presented indicate that the effects of added fat rations may be influenced by dietary mineral intake (particularly calcium), protein and vitamin levels, roughage to concentrate ratios, and physical form of the ration.

The Role of Fat in Rumen Metabolism

Rumen microorganisms may influence dietary fat in three ways: (1) hydrogenation of unsaturated fatty acids, (2) hydrolysis of glycerides and phospholipids and (3) fermentation of glycerol derived from glycerides and phospholipids.

Tove and Mochrie (1963) concluded from their studies that soybean oil fed to cows increased stearic acid of both milk fat and adipose tissue. These findings support the view that dietary unsaturated fatty acids are hydrogenated by rumen microflora before deposit in depot fat. If the unsaturated fatty acids were to bypass the rumen, the unsaturated acids would be deposited. Willey *et al.* (1952) showed that steers fed high levels of cottonseed oil tended to produce a body fat which was more saturated than that found in steers fed low fat rations. The percentage of oleic acid (unsaturated) was lowered in the body fat of steers fed high levels of cottonseed oil. It was suggested that this was due to formation and subsequent absorption and deposition of stearic acid produced by the complete hydrogenation in the rumen of some of the unsaturated C_{18} fatty acids of cottonseed oil.

Feeding unsaturated fat to a young animal without active rumen flora will result in the storage of unsaturated fat in the depots (Hoflund *et al.*, 1956). This work was done by the addition of a polyunsaturated fatty acid to milk of young calves. In a second study, a sheep with a permanent rumen fistula was given 300 ml of a 33% linseed oil emulsion. Rumen samples were withdrawn after 6, 12, 24, 36, 48, and 60 hours. It was suggested that the conversion by hydrogenation of linolenic acid in the dietary fat into linoleic acid occurred in the rumen.

Garton *et al.* (1958) incubated linseed oil and tung oil with rumen contents (1.0 gm per 100 ml rumen contents). Not only did hydrogenation occur, as indicated by a considerable fall in the iodine value of the lipid, but more than 75% of the total lipid recovered at the end of the incubation was in the form of free higher fatty acids. In blanks to which no oil was added, free higher fatty acids represented 50-60% of the total lipid present. The authors presumed that rumen microorganisms were responsible for the production of a lipase.

The percent of neutral fat hydrolyzed in vitro by bovine rumen liquor was studied by Hill et al. (1960). Soybean oil (0.5 gm per 10 ml of rumen liquor) was 96% hydrolyzed in 24 hours. Maximum hydrolysis occurred when the environment contained CO_2 or air; N_2 depressed lipolysis. Enzyme activity seemed to be associated primarily with the protozoa. Lipase activity was greater in rumen liquor taken from animals grazing alfalfa pasture than from animals on dry-lot feeds. Ingesta from animals more susceptible to bloat tended to have the highest levels of lipolytic activity.

Shorland et al. (1955) studied the fatty acid composition of clover-rich pasture and of the rumen contents of sheep grazed on the pasture. The results illustrated how the action of the rumen may modify the nature of the dietary fat before absorption and deposition. The extensive hydrogenation of the dietary fat in rumen not only gave rise to trans acids, but it also explained the relative stability of ruminant depot fat composition, independent of the nature of the dietary fat.

The Use and Effects of Surfactants In Animal Feeds

"Surface-active agent", or "surfactant", is a general term applied to organic compounds which, in dilute aqueous solution, considerably lower the surface tension of water, and the interfacial tension of the aqueous solution against a refined mineral oil, (Stirton, 1955). Surface-active agents may have emulsification, wetting, spreading, anti-foaming and detergent properties which make them useful in animal feeds.

Scott et al. (1952) tested six surfactants on chick growth. The surfactants were selected for their wide range of emulsifying, dispersing and wetting action. The basal diet was one which responded to the addition of 50 mg aureomycin per kg. The addition of the surface-active agents (SAA) to the basal ration did not increase the growth. In one instance, where two agents were used together the growth rate was depressed.

In a study with baby pigs, Schendel and Johnson (1952) fed a synthetic milk diet to study the effect of surfactants on stimulating growth. Ethomeen C/15 was used alone and a mixture of ethofat C/15, ethomid C/15, arquad S, aerosol SE, aerosol OS, and ultrawet K were used as the SAA. No response was obtained. Dyer et al. (1952) conducted a trial with forty weanling pigs in drylot with a 20% crude protein ration (corn, degossypolized cottonseed meal, minerals and vitamins) to study the effect of surfactants on growth. The basal diet was supplemented with three SAA; Ethomid C/15-16 (1% of the diet), E-800 (.2%) and E-800 (.2%) plus sodium tripolyphosphate (.2%). The average daily gain up to 100 lb. liveweight for the basal ration was 0.90 lb. and gain for the supplemented rations were 0.99 lb., 1.12 lb., and 0.94 lb., respectively. Feed efficiency was increased in all rations containing the surface-active agents.

Beeson et al. (1953) demonstrated that the addition 0.10% Ethomid C-15 (a polyoxyethylene-N-substituted fatty acid amide) to a basal ration containing ground yellow corn had no effect on growth rate, feed efficiency or feed consumption over a 115 day drylot feeding period with Duroc pigs. When alkyl benzene sulfonate was fed to pigs at the 0.20% level in the basal ration, average daily gain was ($P < .01$) increased. Ethomid C-15 added at 0.1% to basal ration increased the growth rate of swine significantly (Luecke et al., 1952).

Surface-active agents, Tween-80 (polyoxyethylene sorbitan monooleate) and Santomerse-80 (alkyl aryl sulfonate), were used by March et al. (1954) in a chick growth study. In the first experiment, Tween-80 was added at levels of 0.25, 0.5, 1.0, and 2.0% to a starting ration. At the end of four weeks growth data favored the surface-active agents. These effects were noted to be similar to that of adding penicillin. The chicks receiving 0.5% or more of Tween-80 were heavier at the end of eight weeks (basal, 750 gm; .5% Tween-80, 806 gm; 1.0% Tween-80, 824 gm; 2.0% Tween-80, 824 gm; and penicillin, 835 gm). The third experiment, in which Santomerse-80 and an antibiotic (penicillin) were added to basal rations was similar to previous experiment except that herring oil replaced cornstarch at 2.5, 5.0 and 7.5% in basal ration. The addition of Santomerse-80 (.2%) to the control ration (no herring oil) stimulated growth, as did the penicillin.

But when the SAA was added to rations containing 5.0 and 7.5% oil the growth rate was depressed. In experiment four, 7.5% herring oil and 7.5% tallow were used. Santomerse-80 (.2%) and/or aureomycin had no significant effect on the rate of growth or on the efficiency of feed utilization in either the basal rations or rations containing added oil.

The use of a 0.1% surface-active agent did not improve growth rate of chicks significantly (Snyder et al., 1953), but there were some indications that adding 0.4% of detergent to the basal ration would stimulate growth. It was concluded that SAA did improve growth rate over the basal diet fed to chicks during the later stages of growth.

In a trial with Leghorn chicks (Bolton, 1961), non-ionic detergents aided digestion, anionic detergents slightly depressed digestion, and catonic detergents seriously depressed digestion.

A variety of surfactants failed to show a beneficial response to pigs fed a well-balanced animal and plant protein diet (Sheffy et al., 1953).

Perry et al. (1953) fed twenty-four forty-pound crossbred weanling pigs 0.26% alkyl benzene sulfonate (SAA) in an 18% crude protein diet, and measured growth and carcass composition. Animals which received the surfactant gained 11 pounds more in 112 day trial than those in the control group. Feed efficiency was not affected. Carcasses from the surfactant-fed group had more backfat and total fat, and less protein and moisture ($P < .05$).

The nutritional significance of a surfactant added to the diet or drinking water was studied by Lillie *et al.* (1958) in two broiler experiments. The addition of the surfactant by either route was without effect on growth or feed efficiency. In the second experiment, five blends of surfactants were tested to determine if a combination of several would elicit a growth response. All blends increased the growth response, and feed efficiency was improved by four of the five surfactants used.

Voelker *et al.* (1954), in one of the few experiments with dairy calves, found no significant effects due to SAA on growth rate, plasma fat levels, or on hemoglobin. It was noted that concentrate mixtures containing detergents were comparatively unpalatable. A surface-active agent (Dural H) *in vitro* reduced surface tension of both distilled water and rumen liquid. Lassiter *et al.* (1955) evaluated various surfactants and other growth stimulants in young dairy calves. Surfactants used were Ethomid C-15 (0.1%) and Arquad HT (0.025%) in starter rations. Both surfactants stimulated the growth, but there was some variation between surfactants. Feed efficiency and feed consumption was increased with the two surfactants alone or in combination. In trial two, the addition of the surfactants did not improve the growth rate or the feed efficiency or the animals. There were no significant differences in the carcass data.

Surface-active additives have been used in chicks, pigs and young ruminant animals, with variable results. Apparently, similar studies have not been carried out with adult ruminants. This would present a fertile field for future research.

Estimating Digestibility by the Use of Chromic Oxide

The use of any digestion marker depends on the following assumptions: (1) the material should not be digested or absorbed from the digestive tract, (2) it should have no pharmacological action, (3) it should mix uniformly with the ingesta and pass through the tract at a uniform rate, (4) and it should be readily determined by chemical procedure.

Kane et al. (1949) compared the chromic oxide and lignin indicator methods with the conventional, total collection method in testing the digestibility of field cured, barned cured and ensiled alfalfa by dairy cows. With this early study it was concluded that both lignin and chromic oxide offered promise in saving time, labor, and expense in conducting a digestion trial.

Chromic oxide was administered in a capsule and by mixing with the feed in studies with calves, lambs and wethers (Barnicoat, 1945). The digestibility coefficients were uniformly low due to incomplete recovery of the ingested chromic oxide.

Putnam et al. (1964) fed a complete, pelleted ration containing chromic oxide to steers on various planes of nutrition. Digestion coefficients obtained by the 5-day "grab" sample method, 10-day total collection method using the ratio technique, and the 10-day conventional, total collection method, were significantly correlated.

Eight steers were fed a complete pelleted ration with chromic oxide at 8 a.m. daily (Bradley et al., 1958). A 7-day total collection was compared with the 8 and 10 a.m. composited grab sample method. Digestion coefficients for energy (chromic oxide, 71.96; conventional, 72.60) and protein (chromic oxide 71.60; conventional, 71.88) were very similar. The authors concluded that combining the chromic oxide in a complete pelleted ration reduced variability, and that the 8 and 10 a.m. composited grab sample method suggested a simple method for determining digestibility under practical feedlot conditions.

Lassiter et al. (1966) studied sheep on an all-concentrate diet containing 0.5% chromic oxide. Organic matter digestibility was higher ($P<.01$) and less variable ($P<.05$) for total collection. In the second experiment, no significant differences were found. It was concluded that the chromic oxide would be appropriate for comparisons between rations. McGuire et al. (1966) carried out a similar study feeding a complete pelleted ration containing 0.5% chromic oxide to six steers. Again, digestion coefficients were lower for chromic oxide method, since only 94% of the chromic oxide was recovered. There were significant differences ($P<.01$) between steers in rates of excretion of both chromic oxide and nutrients.

Diurnal variation in chromic oxide excretion was reduced by feeding twice daily verus once in a study by Hardison et al. (1956).

Schurch et al. (1950) used rats to study the digestibility coefficients of dry matter by the conventional collection method and by use of 1% chromic oxide, and found no differences between methods.

Dry matter digestibility in sheep was determined with the total collection method and the chromic oxide indicator method (Crampton and Lloyd, 1951). Chromic oxide gave variable and low coefficients as compared to the conventional method when the sheep received an all-roughage diet. When ground milo (containing chromic oxide) comprised 35% of the diet, digestion coefficients were in agreement with the conventional method. The percent recovery of chromic oxide was decreased in an all-roughage diet plus chromic oxide pellets, as compared to 98% recovery when grain was added, with the chromic oxide included in the grain portion.

Kane et al. (1953) compared the chromium ratio technique (grab samples) and several other ratio techniques to the conventional total collection method. Digestibility coefficients for dry matter, crude protein, crude fiber, NFE, and ether extract were determined. No significant differences appeared.

In an earlier study, Kane et al. (1950) compared the indicator method to the conventional method and found no differences between digestion coefficients from lignin and chromic oxide ratios and those from the standard total collection method. This trial indicated the complete recovery of lignin and chromic oxide, and suggested that these materials are suitable for digestibility indicators.

Davis <u>et al</u>. (1958) conducted a ten day digestion trial using eight lactating dairy cows to compare the conventional total collection method with the chromic oxide indicator technique. The digestibility coefficients obtained were not significantly different. There was considerable variation among the chromic oxide samples taken at various hours of the day; however, these variations could be overcome by sampling for a 10-day period.

The chromic oxide indicator method offers two distinct advantages over the total collection method: (1) A large number of animals can be studied at one time; (2) Digestion can be determined in animals on full fed. This allows valuable feed efficiency data to be collected at the same time with digestibility data. Low fed intake is usually associated with animals confined to metabolism stalls.

CHAPTER III

THE EFFECT OF DIETARY FAT AND A SURFACE-ACTIVE AGENT ON RATION DIGESTIBILITY AND PERFORMANCE OF STEERS

Objectives of the Experiment

The first objective of this experiment was to study the effect of five levels of dietary fat (0, 2, 3, 4, and 6%), with and without a surface-active agent on animal performance and ration digestibility. The second was to study the effect of the same five levels of fat and the surface-active agent on tenderness and palatability of steaks from animals fed the various diets.

Experimental Animals

One-hundred ninety-nine head of high quality, ranch type Hereford, Angus and Hereford X Angus crossbred steers with an average weight of 314.4 kg were used to study the designed objectives of the experiment. The steers were weighed two days in secession before being randomly divided into forty pens with five steers per pen. The steers were started on experiment in July 1970.

Facilities and Equipment

The experiment was conducted at the Beef Research Center at Kansas State University. The newly constructed facilities provided feedlot pens with a capacity of five steers per pen in a two-alley arrangement. Two barns of twenty individual stalls per barn were used during the three digestion trials. The barns are open toward the south but the individual waters and bunks are completely roofed. Each stall is equipped with a four-foot gate at the south end. The floor is concrete with a slope toward the outside (south) to provide adequate drainage. The individual stalls are designed so a small loader-tractor can clean the stalls daily or when needed.

The cattle working and weighing area is constructed of steel pipe with several lotting pens available. The entire area has concrete flooring.

Experimental Design

One-hundred ninety-nine steers were randomly assigned to forty feedlot pens with five steers per pen, except for one pen with four steers. The trial consisted of five 21-day and one 20-day feeding periods (125 days). Each feeding period ended with weighing of all steers. All steers were fed *ad libitum* both in outside feedlot pens and the individual feeding stalls. Steers were fed twice daily and feed samples were collected weekly.

Digestion Trials

One Hereford steer from each lot (total of 40 animals) was assigned to an individual stall for the digestion study. Each individual steer remained assigned to the same stall number throughout the three digestion trials. The digestion trials were conducted using chromic oxide as a digestibility indicator. Each digestion trial was preceded by a 14-day preliminary feeding period during which 100 gm of a pelleted preparation (88 gm of ground sorghum, 7 gm of dried molasses, and 5 gm of chromium oxide) containing 5% chromic oxide were added to the diet. Feed samples were taken from the ration of each steer during the 14-day preliminary period and the actual collection period.

During the six-day collection periods, a random sample of feed was collected from each steer at each feeding (A.M. and P.M.). The chromic oxide mixture was fed at the A.M. feeding. The three digestion trials were conducted in periods 2, 3, and 5 of the experiment. The collection schedules for each of the digestion trials is shown in Table 1. Randomization of sampling times was to remove the effects of diurnal variation in chromic oxide excretion (Phar et al., 1971). During collection, rectal grab samples were taken unless the steers defecated at the time of sampling. Fecal samples representing 12 gm fecal dry matter were collected at each sampling time. An ice cream dipper was used to collect the feces if the steer defecated at the time of sampling. Feed and feces samples were stored in polyethylene bags and frozen immediately after collection. At the end of

THIS BOOK CONTAINS NUMEROUS PAGES WITH DIAGRAMS THAT ARE CROOKED COMPARED TO THE REST OF THE INFORMATION ON THE PAGE.

THIS IS AS RECEIVED FROM CUSTOMER.

Table 1. Collection Schedules for Digestion Trials.

Date	A.M.	P.M.
Period 2[a]		
12 Aug 70	10	10
13 Aug 70	6	6
14 Aug 70	12	12
15 Aug 70	8	8
16 Aug 70	2	2
17 Aug 70	4	4
Period 3[b]		
2 Sept 70	12	12
3 Sept 70	8	8
4 Sept 70	4	4
5 Sept 70	6	6
6 Sept 70	8	8
7 Sept 70	2	2
Period 5[c]		
14 Oct 70	12	12
15 Oct 70	8	8
16 Oct 70	10	10
17 Oct 70	6	6
18 Oct 70	2	2
19 Oct 70	4	4

[a] Using rations 2 and 2A.

[b] Using rations 3, 3A, 3B, and 3C.

[c] Using ration 4, 4A, 4B, 4C, and 4D.

each digestion trial the feces and feed samples were composited for each steer (twelve feces samples and twelve feed samples per steer). Samples were dried (60°C) to a constant weight, ground in a Wiley mill to pass a 2 millimeter screen, and stored in air-tight containers for analysis.

The surface-active agent, silicone oil, (polydimethy-siloxane) was added to the rations of one-half the lots. Where the experimental design called for the surface-active agent in fat containing diets, 20 ppm of the agent was contained in the fat. In the 0% fat diets, 4 ppm of surface-active agent were added, to correspond to the surface-active agent level in the 2% fat diets.

Rumen samples were taken from the digestion steers at the end of the last digestion trial (period 5) by a stomach tube and vacuum pump. The rumen samples were strained through four layers of cheesecloth, centrifuged at 42,000 G for 5 minutes, acidified with 50% sulfuric acid, and the supernatant stored at 40°F until volatile fatty acid determinations were made.

Rations

A total of twelve different rations were used. The four basic rations were formulated by a least-cost computer program. Cost of ration ingredients are shown in Table 2. The silage consisted of two-thirds corn silage and one-third sorghum silage. All sorghum grain was steam flaked (60 minutes in the

Table 2. Cost of Ration Ingredients.

Ingredient	Cost/lb.	Cost/kg.
Silage (2/3 corn, 1/3 sorghum grain)	\$.0060	\$.0132
Steam Flaked sorghum grain	\$.0215	\$.0474
Alfalfa Dehydrated Pellets	\$.0195	\$.0499
Protein Supplement	\$.0500	\$.1102
Fat[a]	\$.0850	\$.1874

[a] Procter & Gamble Company's commercial feed fat, HEF[R].

chamber at 98° C. Final bulk density, 297 gm per liter). A protein supplement was added at a constant level throughout the trial (Table 3[a]). Dehydrated alfalfa pellets were also used. Feed ingredients were sampled periodically for proximate analysis. The feed ingredients and proximate compositions are shown on Table 3. Each of the four basic rations in which no fat was added were labled numerically 1 thru 4. The letters A, B, C, and D are to signify 2, 3, 4, and 6% added fat respectively. The calculated compositions of all twelve rations (as fed) are given in Table 4. The proximate laboratory analysis of each of the rations is in Table 5. The schedule of rations fed to steers in the outside lots in period 1 thru 6 are shown in Table 6. The ration digestion trial schedules (periods 2, 3, and 5) are shown in Table 7.

Methods of Analysis

Proximate analyses were conducted according to A.O.A.C. (1960) methods. Chromic oxide was determined by atomic absorption following nitric-perchloric acid digestion. Volatile fatty acids were determined by gas chromatography (Parks, 1970). The data collected were subject to analysis of variance. Least-square means are used throughout the entire study.

Table 3. Proximate Analysis of All Feed Ingredients.

Ingredient	% Dry Matter	% Crude Protein	% Crude Fiber	% Ether Extract	% Ca	% P
		Dry Matter Basis				
Silage	47.51	7.85	20.52	2.65	.21	.26
Steam Flaked Sorghum Grain	83.44	10.40	1.88	2.74	.05	.32
Protein Supplement[a]	90.00	67.24	5.19	1.60	5.48	1.16
Dehy. Alfalfa Pellets	90.76	15.23	35.59	1.60	1.39	.24

[a] 72% soybean meal, 10% urea, 5.74% dicalcium phosphate, 10.4% ground limestone, 1% trace mineral mix, 30,000m I.U./lb vitamin A, 70 mg/lb aureomycin, 10 mg/lb diethylstilbestrol.

Table 4. Composition of Rations.

	% of Ration											
Ration Designation[b]	1	2	2A	3	3A	3B	3C	4	4A	4B	4C	4D
Silage (2/3 corn, 1/3 sorghum grain)	60	51	51	36	36	36	36	18	18	18	18	18
Steam Flaked Sorghum Grain	20	32	30	48	46	45	44	68	66	65	64	62
Alfalfa Dehy. Pellets	16	13	13	12	12	12	12	10	10	10	10	10
Protein Supplement	4	4	4	4	4	4	4	4	4	4	4	4
Fat[a]	0	0	2	0	2	3	4	0	2	3	4	6

[a] Procter & Gamble Company's commercial feed fat, HEF[R].

[b] Each ration was further divided so that half the lots on each ration received the surface-active agent.

Table 5. Proximate Analysis and Gross Energy of All Experimental Rations.

Ration	% Dry Matter	% Crude Protein	% Crude Fiber	% Ether Extract	% Ash	Energy Cal/gm	% Ca	% P
		Dry Matter Basis						
1	61.00	13.34	15.20	2.25	5.27	4542	.72	.28
2	65.43	12.43	14.45	2.62	4.59	4432	.68	.27
2A	64.62	12.73	14.25	4.98	4.56	4598	.60	.27
3	74.52	13.28	10.27	3.34	4.10	4466	.45	.23
3A	73.82	12.71	9.90	4.84	3.83	4575	.55	.23
3B	73.05	12.52	10.17	5.82	3.79	4622	.45	.24
3C	72.16	12.54	10.07	6.57	3.76	4697	.52	.24
4	76.38	13.61	7.33	3.04	3.58	4508	.47	.26
4A	77.27	13.79	7.24	3.98	3.49	4580	.53	.28
4B	78.25	13.39	7.23	4.56	3.55	4661	.43	.29
4C	77.11	13.44	7.62	6.17	3.55	4717	.40	.31
4D	77.91	13.38	6.89	8.04	3.39	4819	.45	.33

Table 6. Schedule of Rations.

Lot #	Period 1[a] July 7 thru July 27	Period 2[a] July 28 thru Aug. 17	Period 3[a] Aug. 18 thru Sept. 7	Periods 4[a],5[a],6[b] Sept. 8 thru Nov. 8
1 : 21[c]	1	2	3	4
2 : 22	1	2	3	4
3 : 23	1	2	3	4
4 : 24	1	2	3	4
5 : 25	1	2	3	4A
6 : 26	1	2	3A	4A
7 : 27	1	2	3A	4A
8 : 28	1	2	3A	4A
9 : 29	1	2	3A	4B
10 : 30	1	2	3A	4B
11 : 31	1	2A	3B	4B
12 : 32	1	2A	3B	4B
13 : 33	1	2A	3B	4C
14 : 34	1	2A	3B	4C
15 : 35	1	2A	3B	4C
16 : 36	1	2A	3C	4C
17 : 37	1	2A	3C	4D
18 : 38	1	2A	3C	4D
19 : 39	1	2A	3C	4D
20 : 40	1	2A	3C	4D

[a] 21-day periods.

[b] 20-day period.

[c] Pens 1-20, no additive, Pens 21-40, additive.

Table 7. Ration Schedule for Digestion Trials.

Stall # Barn 1	Stall # Barn 2[b]	Period 2[a] July 28 thru Aug. 17	Period 3[a] Aug. 18 thru Sept. 7	Period 5[a] Sept. 29 thru Oct. 19
1	1	2	3	4
2	2	2	3	4
3	3	2	3	4
4	4	2	3	4
5	5	2	3	4A
6	6	2	3A	4A
7	7	2	3A	4A
8	8	2	3A	4A
9	9	2	3A	4B
10	10	2	3A	4B
11	11	2A	3B	4B
12	12	2A	3B	4B
13	13	2A	3B	4C
14	14	2A	3B	4C
15	15	2A	3B	4C
16	16	2A	3C	4C
17	17	2A	3C	4D
18	18	2A	3C	4D
19	19	2A	3C	4D
20	20	2A	3C	4D

[a] 21-day periods.

[b] Barn received additive.

CHAPTER IV

RESULTS AND DISCUSSION

Period 1

No fat was used in period 1. One-half of the animals (pens 21 thru 40) received the surface-active additive at 4 ppm. Results are shown in Table 8. Average daily gain was higher ($P < .001$) for steers on the non-additive treatment. Average daily consumption was somewhat greater ($P < .10$) for the non-additive fed steers. Since this weigh period was in July, the results might be explained by differences in wind movement.

Period 2

Steer Performance

Period 2 of the experiment consisted of one-hundred ninety-seven steers (one steer was lost in pen 23 from heat exhaustion; one steer removed in pen 11 because of necrotic pododermatitis). Results of period 2 are divided into four parts; individually fed steers, group fed steers, combined steer performance and digestion trial results. Performance for individually fed steers is given in Tables 9 and 10. There were no other significant differences, except cost/kg gain (feed cost only) approached significance ($P < .10$). Results

Table 8. Steer Performance During Period 1.

Ration[a]	Additive	Non-Additive
Number of Steers	99	100
Animal Response, kg.		
Initial Weight	306	308
Average Daily Gain	1.29	1.61[b]
Feed/kg. Gain	10.13	8.69
Cost/kg. Gain	.29	.25
Daily Consumption	12.03	12.25[c]

[a] No fat used in period 1.

[b] $P < .001$

[c] $P < .10$

Table 9. Steer Performance of Individually Fed Steers During Period 2.[a]

	Additive		Non-Additive	
Fat Level	0%	2%	0%	2%
Ration Designation	2	2A	2	2A
Number of Steers	10	10	10	10
Animal Response, kg.				
Initial Weight	320	336	338	331
Average Daily Gain	1.20	1.45	1.02	1.37
Feed/kg. Gain	11.05	10.36	19.19	10.42
Cost/kg. Gain	.87	.36	.62	.36
Daily Consumption	12.45	12.17	12.66	12.44

[a] 21-day feeding period 2.

Table 10. Summary of Individually Fed Steer Performance During Period 2.[a]

Ration 2	0% Fat	2% Fat	Additive	Non-Additive
Number of Steers	20	20	20	20
Animal Response, kg.				
Initial Weight	329	334	328	335
Average Daily Gain	1.11	1.41	1.32	1.20
Feed/kg. Gain	15.12	10.39	10.71	14.81
Cost/kg. Gain	.75	.36[b]	.61	.49
Daily Consumption	12.55	12.30	12.31	12.55

[a] 21-day feeding period 2.

[b] $P < .10$

of group fed steer performance are shown in Tables 11 and 12. Gain was improved ($P < .001$) for both fat and additive diets. There was also a significant ($P < .05$) interaction between fat and additive for gains. This would indicate that the surface-active additive must have had a direct influence with addition of fat to the diets. Feed efficiency was improved ($P < .05$) by both the fat and additive. Cost/kg gain decreased ($P < .05$) due to the additive, and daily intake was decreased ($P < .05$) by 2% fat. Combined steer performance results (all steers) are given in Tables 13 and 14. Two percent added fat, and the surface-active additive both increased average daily gains ($P < .001$) over respective controls. Feed efficiency was improved by the addition of both fat and additive ($P < .05$). Daily consumption was greater ($P < .05$) for the non-fat diets. There was an interaction ($P < .05$) between fat and additive for average daily gain. The same explanation holds true in this case as with the individually fed steer gains.

Digestion Trial

Tables 15 and 16 give the results for the digestion trial in period 2. Average daily intake (as fed) for the six-day collection was 13.0 kg per steer per day. Intake was quite good as compared to most digestion trials. Crude protein digestibility was increased ($P < .001$) with fat (2%) and additive ($P < .01$). Crude fiber digestibility was improved ($P < .01$) with addition of fat. Ether extract, dry matter, and gross energy digestion coefficients were higher ($P < .001$) for fat containing

Table 11. Group Fed Steer Performance for Period 2.[a,b]

	Additive		Non-Additive	
Fat Level	0%	2%	0%	2%
Ration Designation	2	2A	2	2A
Number of Steers	39	39	40	39
Animal Response, kg.				
Initial Weight	336	332	349	342
Average Daily Gain	1.67	2.08	1.55	1.61
Feed/kg. Gain	8.47	6.37	10.07	8.68
Cost/kg. Gain	.27	.22	.32	.30
Daily Consumption	13.52	13.02	13.64	13.28

[a] 21-day feeding period.

[b] Outside steers.

Table 12. Summary of Group Fed Steer Performance During Period 2.[a]

Ration 2	0% Fat	2% Fat	Additive	Non-Additive
Number of Steers	79	78	78	79
Animal Response, kg.				
Initial Weight	342	337	334	345
Average Daily Gain	1.61	1.84[b]	1.87[b]	1.58
Feed/kg. Gain	9.27	7.52[c]	7.42[c]	9.38
Cost/kg. Gain	.29	.26	.24[c]	.31
Daily Consumption	13.58[c]	13.15	13 27	13.46

[a] 21-day feeding period.

[b] $P < .001$

[c] $P < .05$

Table 13. Combined Steer Performance During Period 2.[a,b]

	Additive		Non-Additive	
Fat Level	0%	2%	0%	2%
Ration Designation	2	2A	2	2A
Number of Steers	49	49	50	49
Animal Response, kg.				
Initial Weight	330	330	344	337
Average Daily Gain	1.43	1.81	1.30	1.42
Feed/kg. Gain	10.28	8.48	13.21	10.30
Cost/kg. Gain	.47	.33	.46	.39
Daily Consumption	13.02	12.57	13.16	12.82

[a] 21-day feeding period.

[b] All steers used in period 2.

Table 14. Summary of Combined Steer Performance During Period 2.[a,b]

Ration 2	0% Fat	2% Fat	Additive	Non-Additive
Number of Steers	99	98	98	99
Animal Response, kg.				
Initial Weight	337	334	330	340
Average Daily Gain	1.37	1.62[c]	1.62[c]	1.36
Feed/kg. Gain	11.74	9.41[d]	9.38[d]	11.77
Cost/kg. Gain	.47	.36	.40	.43
Daily Consumption	13.09[d]	12.70	12.79	12.99

a 21-day feeding period.

b All steers used in period 2.

c $P < .001$

d $P < .05$

Table 15. Period 2 Digestion Coefficients.

	Additive		Non-Additive	
Fat Level	0%	2%	0%	2%
Ration Designation	2	2A	2	2A
Number of Steers	10	10	10	10
Crude Protein	55.28	61.44	49.77	58.72
Crude Fiber	29.60	35.49	29.64	36.76
Ether Extract	84.38	87.92	78.31	87.86
Nitrogen Free Extract	78.35	79.97	78.63	78.33
Dry Matter	65.98	69.36	64.82	67.87
Energy	64.17	68.13	64.17	67.53

Table 16. Summary of Period 2 Digestion Coefficients.

	0% Fat	2% Fat	Additive	Non-Additive
Number of Steers	20	20	20	20
Crude Protein	52.53	60.08[a]	58.36[b]	54.25
Crude Fiber	29.45	36.13[b]	32.38	33.20
Ether Extract	81.34	87.89[a]	86.15[a]	83.09
NFE	78.49	79.15	79.16	78.48
Dry Matter	65.40	68.62[a]	67.67	66.34
Energy	64.17	67.84[a]	66.15	65.85

[a] $P < .001$

[b] $P < .01$

diets. Additive increased ether extract digestion coefficient ($P < .001$). A interaction resulted between fat and additive ($P < .05$) in ether extract digestion coefficient. The surface-active seemed to remove most of the increase in digestion coefficients due to fat.

In summary, 2% added fat improved steer performance. The surface-active additive increased average daily gain, reduced feed/kg gain, cost/kg gain, and improved protein and ether extract digestibility.

Period 3

Steer Performance

Four levels of added dietary fat (0, 2, 3, and 4%) were used during period 3. Results of period 3 are presented as were in period 2. Performance results of individually fed steers are shown in Tables 17 and 18. Average daily gain was depressed ($P < .05$) and cost/kg gain was increased ($P < .05$) with 4% added fat. Performance was slightly depressed (n.s.) by additive. Group fed steers in outside lots showed no differences, with the exception of lower ($P < .05$) feed consumption for 4% added fat as seen in Tables 19 and 20. Combined performance results are shown in Tables 21 and 22. During period 3, 4% added fat depressed both daily gain and feed intake ($P < .05$).

Digestion Trial

Forty steers weighing 358 kg were used in the digestion trial in period 3. Average feed intake during the 6-day

Table 17. Individually Fed Steer Performance During Period 3.[a]

	Additive				Non-Additive			
Fat Level	0%	2%	3%	4%	0%	2%	3%	4%
Ration Designation	3	3A	3B	3C	3	3A	3B	3C
Number of Steers	5	5	5	5	5	5	5	5
Ani. Response, kg.								
Initial Weight	356	333	354	379	349	371	349	372
Ave. Daily Gain	1.59	1.44	1.30	1.06	1.33	1.64	1.63	1.08
Feed/kg. Gain	7.72	9.88	9.60	10.50	9.17	7.71	7.45	11.45
Cost/kg. Gain	.28	.39	.39	.45	.34	.30	.30	.49
Daily Consumption	12.17	12.16	11.48	11.13	11.57	12.24	11.91	12.08

[a] 21-day feeding period.

Table 18. Summary of Individually Fed Steer Performance During Period 3.[a]

	Fat Level					
Ration 3	0%	2%	3%	4%	Additive	Non-Additive
Number of Steers	10	10	10	10	20	20
Animal Response, kg.						
Initial Weight	352	352	351	376	356	359
Average Daily Gain	1.46	1.54	1.46	1.07[b]	1.34	1.42
Feed/kg. Gain	8.45	8.79	8.53	10.98	9.43	8.95
Cost/kg. Gain	.31	.35	.35	.47[b]	.39	.36
Daily Consumption	11.87	12.20	11.70	11.60	11.73	11.95

[a] 21-day feeding period.

[b] $P < .05$

Table 19. Group Fed Steer Performance During Period 3.[a]

	Additive				Non-Additive			
Fat Level	0%	2%	3%	4%	0%	2%	3%	4%
Ration Designation	3	3A	3B	3C	3	3A	3B	3C
Number of Steers	19	20	20	19	20	20	19	20
Ani. Response, kg.								
Initial Weight	363	378	380	372	382	379	374	377
Ave. Daily Gain	1.18	1.13	1.19	1.12	1.18	1.27	1.15	1.03
Feed/kg. Gain	12.44	11.70	11.12	12.55	12.41	12.20	12.09	13.46
Cost/kg. Gain	.46	.47	.46	.53	.46	.49	.50	.57
Daily Consumption	12.78	12.62	12.73	12.32	13.28	13.28	12.80	12.11

[a] 21-day feeding period.

Table 20. Summary of Group Fed Steer Performance During Period 3.[a]

	Fat Level					
Ration 3	0%	2%	3%	4%	Additive	Non-Additive
Number of Steers	39	40	39	39	78	79
Animal Response, kg.						
Initial Weight	373	379	377	374	373	379
Average Daily Gain	1.18	1.20	1.17	1.08	1.16	1.16
Feed/kg. Gain	12.42	11.95	11.61	13.00	11.95	12.54
Cost/kg. Gain	.46	.48	.48	.55	.48	.50
Daily Consumption	13.03	12.95	12.77	12.22[b]	12.61	12.87

[a] 21-day feeding period.

[b] $P < .05$

Table 21. Combined Steer Performance During Period 3.[a]

	Additive				Non-Additive			
Fat Level	0%	2%	3%	4%	0%	2%	3%	4%
Ration Designation	3	3A	3B	3C	3	3A	3B	3C
Number of Steers	24	25	25	24	25	25	24	25
Ani. Response, kg.								
Initial Weight	356	364	369	368	370	373	364	371
Ave. Daily Gain	1.33	1.26	1.28	1.18	1.28	1.41	1.31	1.11
Feed/kg. Gain	10.56	10.42	9.90	11.23	10.85	10.39	10.23	12.14
Cost/kg. Gain	.39	.41	.41	.48	.40	.41	.42	.52
Daily Consumption	12.39	12.26	12.21	11.81	12.67	12.80	12.35	11.84

[a] 21-day feeding period.

[b] All steers used in period 3.

Table 22. Summary of Combined Steer Performance During Period 3.[a]

	Fat Level					
Ration 3	0%	2%	3%	4%	Additive	Non-Additive
Number of Steers	49	50	49	49	98	99
Animal Response, kg.						
Initial Weight	363	368	367	369	364	369
Average Daily Gain	1.31	1.34	1.30	1.14[c]	1.26	1.28
Feed/kg. Gain	10.70	10.40	10.07	11.69	10.53	10.90
Cost/kg. Gain	.39	.41	.41	.50	.42	.44
Daily Consumption	12.53	12.53	12.28	11.82[c]	12.17	12.41

[a] 21-day feeding period.

[b] All steers used in period 3.

[c] $P < .05$

collection was 11.5 kg (as fed) per steer per day. Results are shown in Tables 23 and 24. There were no significant differences in fat diets, with the exception of ether extract digestibility was increased ($P < .001$) with all fat additions. During this period, the additive depressed digestibility of crude protein ($P < .001$), crude fiber ($P < .01$), dry matter ($P < .01$), and energy ($P < .01$). The contradictory nature of these results were surprising based on the results of period 2.

In summary, the surface-active additive showed no beneficial response in period 3. In fact the non-additive treatments were superior for several digestion coefficients. Gain and consumption was depressed with 4% added fat.

Period 4

Steers average 398 kg at the start of period 4, and for 21 days all steers were located in outside lots. Five levels of fat (0, 2, 3, 4, and 6%) were fed (Table 25). Results for the 5 X 2 factorial are shown in Table 26. The surface-active additive depressed rate of gain ($P < .05$) and feed intake ($P < .001$). There were no other significant differences. It should be noted that the higher levels of fat (3, 4, and 6%) were utilized very well in this period. Results of periods 3 and 4 are in agreement regarding detrimental effects of the surface-active additive.

Table 23. Period 3 Digestion Coefficients.

	Additive				Non-Additive			
Fat Level	0%	2%	3%	4%	0%	2%	3%	4%
Ration Designation	3	3A	3B	3C	3	3A	3B	3C
Number of Steers	5	5	5	5	5	5	5	5
Crude Protein	54.55	52.87	48.92	51.31	58.03	56.56	62.88	61.64
Crude Fiber	10.66	4.37	-4.58	0.17	7.16	10.42	22.57	17.51
Ether Extract	79.33	83.78	85.22	86.12	81.79	84.21	84.72	84.32
Nitrogen Free Extract	82.31	80.97	78.12	78.98	80.35	80.90	82.64	80.81
Dry Matter	68.71	67.06	63.75	65.99	67.03	68.56	71.95	69.45
Energy	67.53	65.63	62.39	64.85	65.97	68.05	70.50	69.24

Table 24. Summary of Period 3 Digestion Coefficients.

	Fat Level					
Ration 3	0%	2%	3%	4%	Additive	Non-Additive
Number of Steers	10	10	10	10	20	20
Crude Protein	56.29	54.72	55.90	56.47	51.91	59.77[a]
Crude Fiber	8.91	7.39	8.99	8.84	2.66	14.41[b]
Ether Extract	80.56	83.99[a]	84.97[a]	85.22[a]	83.61	83.76
NFE	81.33	80.94	80.38	79.89	80.09	81.18
Dry Matter	67.87	67.81	67.85	67.72	66.38	69.25[b]
Energy	66.75	66.84	66.45	67.04	65.10	68.44[b]

[a] $P < .001$

[b] $P < .01$

Table 25. Steer Performance During Period 4.[a,b]

	Additive					Non-Additive				
Fat Level	0%	2%	3%	4%	6%	0%	2%	3%	4%	6%
Ration Designation	4	4A	4B	4C	4D	4	4A	4B	4C	4D
Number of Steers	19	20	20	20	19	20	20	19	20	20
Ani. Response, kg.										
Initial Weight	388	395	397	391	399	404	401	399	399	399
Ave. Daily Gain	1.15	1.19	1.22	1.27	1.22	1.38	1.21	1.32	1.39	1.31
Feed/kg. Gain	10.03	11.95	10.05	10.12	10.78	9.00	10.65	9.18	8.63	9.59
Cost/kg. Gain	.43	.54	.48	.49	.56	.39	.49	.44	.42	.49
Daily Consump.	10.44	11.28	10.88	11.29	11.50	11.41	11.52	11.70	11.53	11.49

[a] 21-day feeding period.

[b] All steers used in period 4.

Table 26. Summary of Steer Performance During Period 4.[a,b]

	Fat Level						
Ration 4	0%	2%	3%	4%	6%	Additive	Non-Additive
Number of Steers	39	40	39	40	39	98	99
Animal Response, kg.							
Initial Weight	396	398	399	395	399	394	400
Average Daily Gain	1.26	1.20	1.27	1.33	1.27	1.21	1.32[d]
Feed/kg. Gain	9.52	11.30	9.61	9.37	10.18	10.58	9.41
Cost/kg. Gain	.41	.52	.46	.46	.53	.50	.45
Daily Consumption	10.93	11.40	11.29	11.41	11.50	11.08	11.53[c]

[a] 21-day feeding period.

[b] All steers used in period 4.

[c] $P < .001$

[d] $P < .05$

Period 5

Steer Performance

Period 5 of the experiment consisted of one-hundred ninety-seven steers on five levels of fat (0, 2, 3, 4, and 6%), with and without the surfactant. Forty steers were used in the digestion trial and the remaining steers were located in outside lots. The average initial weight was 425 kg. Steers were grouped in the same manner as in periods 2 and 3 for results. There were no significant differences among the individually fed steers for performance (Tables 27 and 28). The surface-active additive showed a slight but non-significant response in gain, feed/kg gain and cost/kg gain. It should also be noted that all steers receiving high levels of fat gained satisfactorily. Results of group fed steer performance are shown in Tables 29 and 30. Rate of gain, feed/kg, and cost/kg gain were all improved ($P < .10$) for the surface-active additive treatments. Steers with no added fat gained less and had poorer feed conversion ($P < .05$). These results are similar to those previously mentioned in period 5. Combined steer performance results (Tables 31 and 32) improved average daily gain, feed/kg gain, and cost/kg gain ($P < .10$) due to the additive effect. Steers receiving no added fat had the poorest rate of gain ($P < .01$) and feed efficiency ($P < .05$). These results are in agreement with period 2.

Table 27. Individually Fed Steer Performance During Period 5.[a]

	Additive					Non-Additive				
Fat Level	0%	2%	3%	4%	6%	0%	2%	3%	4%	6%
Ration Designation	4	4A	4B	4C	4D	4	4A	4B	4C	4D
Number of Steers	4	4	4	4	4	4	4	4	4	4
Ani. Response, kg.										
Initial Weight	427	400	429	399	432	428	421	425	428	425
Ave. Daily Gain	1.10	1.47	1.82	1.47	1.47	1.27	1.56	1.40	1.30	1.37
Feed/kg. Gain	10.50	8.49	6.63	7.37	7.39	10.12	7.65	8.13	10.75	8.00
Cost/kg. Gain	.45	.39	.31	.36	.38	.44	.35	.39	.52	.41
Daily Consump.	10.83	11.55	11.75	10.14	10.71	11.39	11.33	10.77	11.60	10.98

[a] 21-day feeding period.

Table 28. Summary of Individually Fed Steer Performance During Period 5.[a]

Ration 4	Fat Level 0%	2%	3%	4%	6%	Additive	Non-Additive
Number of Steers	8	8	8	8	8	20	20
Animal Response, kg.							
Initial Weight	428	410	427	414	429	417	425
Average Daily Gain	1.19	1.52	1.61	1.39	1.42	1.47	1.38
Feed/kg. Gain	10.31	8.07	7.38	9.06	7.69	8.08	8.93
Cost/kg. Gain	.44	.37	.35	.44	.40	.38	.42
Daily Consumption	11.11	11.44	11.26	10.87	10.84	11.00	11.21

[a] 21-day feeding period.

Table 29. Group Fed Steer Performance During Period 5.[a]

	Additive					Non-Additive				
Fat Level	0%	2%	3%	4%	6%	0%	2%	3%	4%	6%
Ration Designation	4	4A	4B	4C	4D	4	4A	4B	4C	4D
Number of Steers	15	16	16	16	15	16	15	15	16	16
Ani. Response, kg.										
Initial Weight	409	426	422	426	424	434	431	428	427	427
Ave. Daily Gain	1.52	1.83	1.57	1.64	1.58	1.33	1.49	1.50	1.74	1.60
Feed/kg. Gain	8.24	7.48	7.94	7.62	7.57	10.53	8.55	8.75	6.99	7.46
Cost/kg. Gain	.36	.34	.38	.38	.39	.45	.39	.41	.34	.39
Daily Consump.	11.57	13.06	12.12	12.17	11.66	12.42	12.37	12.41	11.82	11.80

[a] 21-day feeding period.

Table 30. Summary of Group Fed Steer Performance During Period 5.[a]

Ration 4	Fat Level 0%	2%	3%	4%	6%	Additive	Non-Additive
Number of Steers	31	31	31	32	31	78	78
Animal Response, kg.							
Initial Weight	421	429	425	427	425	421	429
Average Daily Gain	1.42[b]	1.66	1.53	1.69	1.59	1.63[c]	1.53
Feed/kg. Gain	9.39[b]	8.01	8.35	7.30	7.51	7.77[c]	8.46
Cost/kg. Gain	.40	.36	.39	.36	.39	.37[c]	.40
Daily Consumption	11.99	12.72	12.26	11.99	11.73	12.12	12.16

[a] 21-day feeding period.

[b] $P < .05$

[c] $P < .10$

Table 31. Combined Steer Performance During Period 5.[a,b]

	Additive					Non-Additive				
Fat Level	0%	2%	3%	4%	6%	0%	2%	3%	4%	6%
Ration Designation	4	4A	4B	4C	4D	4	4A	4B	4C	4D
Number of Steers	19	20	20	20	19	20	19	19	20	20
Ani. Response, kg.										
Initial Weight	412	420	422	420	424	431	428	426	426	425
Ave. Daily Gain	1.39	1.71	1.57	1.56	1.51	1.27	1.46	1.43	1.61	1.51
Feed/kg. Gain	8.83	7.80	7.80	7.68	7.65	10.57	8.47	8.74	7.86	7.68
Cost/kg. Gain	.38	.35	.37	.38	.39	.46	.39	.41	.38	.39
Daily Consump.	11.11	12.45	11.74	11.45	11.16	11.90	11.85	11.76	11.47	11.33

[a] 21-day feeding period.

[b] All steers used in period 5.

Table 32. Summary of Combined Steer Performance During Period 5.[a,b]

Ration 4	Fat Level 0%	2%	3%	4%	6%	Additive	Non-Additive
Number of Steers	39	39	39	40	39	98	98
Animal Response, kg.							
Initial Weight	422	424	424	423	425	420	425
Average Daily Gain	1.33[c]	1.59	1.50	1.58	1.51	1.55[e]	1.46
Feed/kg. Gain	9.70[d]	8.14	8.27	7.77	7.66	7.95[e]	8.66
Cost/kg. Gain	.42	.37	.39	.38	.39	.37[e]	.41
Daily Consumption	11.51	12.15	11.75	11.46	11.24	11.58	11.66

[a] 21-day feeding period.

[b] All steers used in period 5.

[c] $P < .01$

[d] $P < .05$

[e] $P < .10$

Digestion Trial

Average feed intake for the six-day collection period was 11.8 kg (as fed) per steer per day. Results are given in Tables 33 and 34. The additive improved the digestibility of crude protein ($P < .01$) and gross energy ($P < .05$). Ether extract digestibility was increased ($P < .01$) with the addition of fat (3, 4, and 6%) as compared to the 0 and 2% fat diets. Results of digestion trial in period 5 are in close agreement with results obtained in period 2 digestion trial. In summary, fat improved performance, as it did in period 2.

Period 6

One-hundred ninety-seven steers with an initial weight of 456 kg (1006 lb), all fed *ad libitum* in outside lots, were used in period 6 (20 days). Performance results are given in Tables 35 and 36. The additive increased average daily gain ($P < .01$) but depressed feed intake ($P < .01$). Animals without added fat had higher gains ($P < .05$). These results are not in agreement with any other results obtained in the experiment. Increased gains due to the additive were also seen in other periods. Performance results for the last 62-days are shown in Table 41, page 81. There were no significant differences.

The volatile fatty acid concentrations in rumen fluid are shown in Table 37. There were no significant differences

Table 33. Period 5 Digestion Coefficients.

	Additive					Non-Additive				
Fat Level	0%	2%	3%	4%	6%	0%	2%	3%	4%	6%
Ration Designation	4	4A	4B	4C	4D	4	4A	4B	4C	4D
Number of Steers	4	4	4	4	4	4	4	4	4	4
Crude Protein	54.02	50.91	54.21	51.28	51.49	45.37	49.54	50.23	49.41	48.87
Crude Fiber	-1.12	5.30	11.61	4.00	11.93	4.85	-1.90	7.35	4.72	2.74
Ether Extract	73.50	68.79	84.89	80.56	81.01	67.33	79.86	79.59	84.53	88.52
NFE	83.74	83.03	83.72	82.54	82.35	84.74	84.21	83.93	81.73	80.60
Dry Matter	70.85	69.76	72.18	64.75	70.78	69.37	70.97	71.34	69.08	68.93
Energy	70.51	69.09	71.61	74.09	69.02	68.01	68.99	69.37	67.26	67.48

Table 34. Summary of Period 5 Digestion Coefficients.

	Fat Level						
Ration 4	0%	2%	3%	4%	6%	Additive	Non-Additive
Number of Steers	8	8	8	8	8	20	20
Crude Protein	49.70	50.22	52.22	50.34	50.18	52.38[a]	48.68
Crude Fiber	1.87	1.70	9.48	4.36	7.33	6.35	3.55
Ether Extract	70.41	74.33	82.24[a]	82.55[a]	84.77[a]	77.75	79.97
NFE	84.24	83.62	83.83	82.13	81.47	83.08	83.04
Dry Matter	70.11	70.36	71.76	66.91	69.86	69.66	69.94
Energy	69.26	69.04	70.49	70.67	68.25	70.87[b]	68.22

[a] $P < .01$

[b] $P < .05$

Table 35. Steer Performance During Period 6.[a,b]

	Additive					Non-Additive				
Fat Level	0%	2%	3%	4%	6%	0%	2%	3%	4%	6%
Ration Designation	4	4A	4B	4C	4D	4	4A	4B	4C	4D
Number of Steers	19	20	20	20	19	20	20	19	20	20
Ani. Response, kg.										
Initial Weight	443	457	457	453	459	460	457	459	462	460
Ave. Daily Gain	1.69	1.72	1.37	1.49	1.32	1.42	1.25	1.18	1.52	1.34
Feed/kg. Gain	7.53	7.88	9.27	8.99	11.72	9.37	10.35	11.36	9.02	9.60
Cost/kg. Gain	.33	.36	.44	.44	.60	.40	.47	.54	.44	.50
Daily Consump.	11.96	12.42	11.71	11.77	11.82	12.59	12.34	12.26	12.74	11.61

[a] 20-day feeding period.

[b] All steers used in period 6.

Table 36. Summary of Steer Performance During Period 6.[a,b]

	Fat Level						
Ration 4	0%	2%	3%	4%	6%	Additive	Non-Additive
Number of Steers	39	40	39	40	39	98	99
Animal Response, kg.							
Initial Weight	452	457	458	458	459	454	459
Average Daily Gain	1.55[d]	1.48	1.28	1.50	1.33	1.52[c]	1.34
Feed/kg. Gain	8.45	9.11	10.31	9.01	10.66	9.06	9.92
Cost/kg. Gain	.37	.41	.49	.44	.55	.43	.47
Daily Consumption	12.27	12.38	11.99	12.25	11.71	11.94	12.31[c]

[a] 20-day feeding period.

[b] All steers used in period 6.

[c] $P < .01$

[d] $P < .05$

Table 37. Summary of Volatile Fatty Acid Determinations

	Fat Level						
Rations 4[a]	0%	2%	3%	4%	6%	Additive	Non-Additive
Number of Steers	8	8	8	8	8	20	20
Volatile fatty acids, molar %							
Acetic Acid	64.56	59.95	56.08	59.04	56.85	58.71	59.88
Propionic Acid	28.34	32.95	37.28	32.77	35.15	33.55	33.00
Butyric Acid	7.21	7.09	6.51	8.18	8.05	7.73	7.08
Acetic to Propionic ratio	2.47[b]	1.89	1.56	1.96	1.69	1.86	1.97

[a] Collected last day of period 5 from digestion steers on ration 4.

[b] $P < .05$

in molar percentages of acetic, propionic, and butyric acids. However, acetic to propionic ratio in the 0% fat diet was increased ($P < .05$).

Steaks were obtained from each of the forty digestion trial steers. The steaks were evaluated using shear bolt test, and a four member taste panel that scored the steaks according to flavor, juciness, tenderness, and over-all acceptability. All characteristics were scored on a scale from 1 to 9, with 9 representing highest desirability. Results of the shear test and taste panel evaluation of steaks are given in Table 38. There were no significant differences due to either fat levels or the surface-active additive.

Carcass evaluation results are shown in Tables 39 and 40. Fat addition improved quality grade ($P < .05$). The 6% fat diet during the last 62 days increased ($P < .001$) percent kidney knob.

Table 38. Steak Results Using Shear Test and Taste Panel.

	Fat Level[a]						
	0%	2%	3%	4%	6%	Additive	Non-Additive
Number of Steak	8	8	8	8	8	20	20
Shear Test[b]	5.39	6.26	5.71	6.48	5.82	5.91	5.95
Flavor Score[c]	7.78	7.75	7.72	7.86	7.56	7.62	7.84
Juiciness Score[c]	7.76	7.51	7.57	7.49	7.21	7.38	7.63
Tenderness Score[c]	7.69	7.05	7.89	7.48	7.39	7.42	7.58
Over-all Score[c]	7.53	7.26	7.77	7.57	7.26	7.37	7.59

[a] Fat level fed to steers the last 62 days on trial.

[b] Pounds of force needed to shear 1/2 inch core of cooked meat.

[c] Measured on a scale of 1 to 9, 9 being most desirable.

Table 39. Steer Carcass Evaluation.

	Additive					Non-Additive				
Fat Level	0%	2%	3%	4%	6%	0%	2%	3%	4%	6%
Ration last 62 days	4	4A	4B	4C	4D	4	4A	4B	4C	4D
Number of Steers	20	20	20	18	19	20	20	20	20	20
Quality Grade[c]	6.2	7.2	6.8	6.5	6.6	6.3	6.9	7.0	6.5	6.9
% Kidney Knob	2.8	2.9	2.8	2.8	3.4	2.7	3.0	2.8	3.1	3.0
Rib Eye Area[a]	11.9	11.7	11.3	11.6	11.9	12.4	11.8	12.1	11.6	11.9
Fat, 13th Rib[a]	.50	.49	.53	.51	.51	.51	.50	.52	.56	.57
Dressing %	62.7	63.3	61.9	62.6	62.5	63.4	62.8	61.9	62.0	61.9
Yield Grade[b]	2.9	2.9	3.2	3.0	3.1	2.8	3.1	2.9	3.3	3.2

[a] Measured in inches.

[b] Yield of cutability is measured on a scale from 1 to 5, with 1 most desirable.

[c] 8 average choice, 5 average good.

Table 40. Summary of Steer Carcass Evaluation.

	Fat Level						
	0%	2%	3%	4%	6%	Additive	Non-Additive
Number of Steers	40	40	40	38	39	97	100
Quality Grade[c]	6.2[e]	7.0	6.9	6.5	6.8	6.7	6.7
% Kidney Knob	2.7	2.9	2.8	2.9	3.2[d]	2.9	2.9
Rib Eye Area[a]	12.2	11.7	11.7	11.6	11.9	11.7	11.9
Fat, 13th Rib[a]	.50	.48	.52	.53	.54	.49	.53
Dressing %	63.0	63.1	61.9	62.3	62.2	62.5	62.4
Yield Grade[b]	2.9	3.0	3.1	3.2	3.1	3.1	3.1

[a] Measured in inches.

[b] Yield or cutability is measured on a scale from 1 to 5, with 1 most desirable.

[c] 8 average choice, 5 average good.

[d] $P < .001$

[e] $P < .05$

Table 41. Steer Performance for the Last 62-days.[a]

	Fat Level						
Ration 4	0%	2%	3%	4%	6%	Additive	Non-Additive
Number of Steers	39	40	39	40	39	98	99
Animal Response, kg.							
Initial Weight	386	398	398	395	399	390	400
Average Daily Gain	1.31	1.40	1.38	1.47	1.38	1.40	1.38
Feed/kg. Gain	8.55	9.18	8.70	8.19	8.59	8.37	8.91
Cost/kg. Gain	.37	.41	.41	.39	.44	.39	.42
Daily Consumption	11.73	12.14	11.85	11.88	11.64	11.71	11.99

[a] Combined performance from all steers.

CHAPTER V

SUMMARY AND CONCLUSIONS

One-hundred ninety-nine steers were used to study the effects of dietary fat and a surfactant (polydimethylsiloxane) on digestibility and animal performance. Three digestion trials were conducted during the 125-day trial. The experiment consisted of six periods. Fat was added at various amounts (0, 2, 3, 4 and 6%). All steers were fed *ad libitum* during the entire trial.

Digestion studies were carried out during periods 2, 3, and 5. The chromic oxide indicator method was used to calculate the digestibility coefficients. Diets and salt were given *ad libitum*. Five grams chromic oxide in a pelleted, highly palatable mixture were fed each A.M. Following a 14-day preliminary period, fecal samples were collected for 6 days by a randomized schedule.

Performance data for steers during the 125-day experiment were analyzed by periods. Performance data for periods 2, 3, and 5 consisted of three groups; individually fed steers (digestion trial steers), group fed steers (all outside lot steers), and combined steer performance group (all steers in period). The three digestion trials were analyzed by periods.

In period 1 of the experiment, when only additive and non-additive treatments were studied, the additive (surfactant) caused a depression ($P<.001$) in average daily gain. Daily consumption was also reduced ($P<.10$) slightly by the additive.

During period 2, additive and 2% added fat increased ($P<.001$) rate of gain and improved feed efficiency ($P<.05$). Daily consumption was higher in the ration without added fat. Increased gains and decreased consumption on rations with added fat were also seen by Bohman et al. (1957) and Edwards et al. (1961). The addition of 2% fat caused a significant ($P<.001$) increase in the digestibilities of crude protein, ether extract, dry matter, and gross energy. Crude fiber digestibility was improved ($P<.01$) due to 2% added fat. Increasing digestibility of nutrients in rations with added fat have not been seen in other studies. An increase in ether extract digestibility, as observed in this study, might be expected for two reasons: (1) the added fat may have a higher digestion coefficient than the ether extract in the basal diet; and (2) metabolic fecal fat would represent a much smaller percentage of the total fecal fat when fat is included in the diet. The surface agent improved crude protein digestibility ($P<.01$) and ether extract digestibility ($P<.001$).

In period 3, 4% added fat decreased ($P<.05$) rate of gain and daily consumption. The surface active additive treatment in the digestion trial depressed the digestibilities of crude fiber ($P<.01$), dry matter ($P<.01$), crude protein ($P<.001$), and gross energy ($P<.01$). There were no other significant differences.

These results are reversed as compared to results of period 2 digestion trial. There is no explanation for the differences in results.

The surface-active additive decreased average daily gain ($P<.05$) and feed consumption ($P<.001$) in period 4. There were no significant differences in performance of steers due to fat levels, indicating that fat was utilized well up to the highest level (6%) in the period.

In period 5, the surface-active additive increased ($P<.10$) gain, feed efficiency, and feed cost/kg gain, as well as digestibility of crude protein ($P<.01$) and gross energy ($P<.05$). Steers receiving no added fat gained slower ($P<.01$) and with less efficiency ($P<.05$). Ether extract digestibility was increased ($P<.01$) in 3, 4, and 6% fat diets. These data agree closely with the data obtained in period 2.

The surface-active additive in period 6 again improved rate of gain ($P<.01$), but decreased consumption ($P<.01$). Due to variability and few degrees of freedom, differences in feed efficiency were not significant.

Individual volatile fatty acid concentrations were not significantly different in either fat or additive treatments. There was an increase ($P<.05$) in the acetic to propionic ratio.

Steaks obtained from the forty digestion trial steers were evaluated by the shear test for tenderness, and by a four member taste panel that scored the steaks according to flavor, juciness, tenderness and over-all acceptability. There were no significant differences due to either fat levels or the surfactant.

Carcass evaluation for one-hundred ninety-seven steers showed a lower quality grade ($P < .05$) in steers receiving the no fat diets (last 62 days of trial). Six percent added fat during the last 62 days of the trial increased percent kidney knob ($P < .001$) over the control diet (0% fat).

Under the conditions of this experiment the following conclusions seemed justified:

1. Average daily consumption will be somewhat reduced by the addition of fat. This could be expected because of increased caloric density of the diet.

2. Rate of gain may be expected to increase due to the addition of fat to low energy rations.

3. If fat increases crude protein digestibility ($P < .001$ in period 2) then it might be possible to reduce protein level in fat containing diets.

4. The additive (polydimethylsiloxane) apparently improved performance of steers by increasing digestibilities of crude protein and gross energy ($P < .001$ in period 2). In period 5, digestibility of crude protein and gross energy were also increased ($P < .01$ and $P < .05$, respectively). However, much more research concerning surfactants is needed, particularly with adult ruminants.

5. Dietary fat can be utilized by steers when fed at 6% of the diet with no depression in steer performance.

LITERATURE CITED

Albin, R. C. and R. M. Durham. 1967. Restricted feeding and use of dehydrated alfalfa meal and beef tallow in an all-concentrate ration for fattening steers. J. Ani. Sci. 26:85.

Association of Official Agricultural Chemists. 1960. Official Methods of Analysis of the Association of Official Agricultural Chemists. Ninth Edition. Washington, D. C.

Barnicoat, C. R. 1945. Estimation of apparent digestibility coefficients by means of an inert reference-substance. New Zealand J. Sci. and Technology. 27:202.

Beeson, W. M., T. W. Perry, and P. J. Reynolds. 1953. The effect of surfactants on the growth rate of swine. J. Ani. Sci. 12:619.

Bohman, V. R., M. A. Wade and J. E. Hunter. 1957. The effect of chlortetracycline, stilbestrol and animal fat on fattening steers. J. Ani. Sci. 16:833.

Bohman, V. R., M. A. Wade and C. Torell. 1959. Effect of animal fat and protein supplements on range beef cattle. J. Ani. Sci. 18:567.

Bohman, V. R. and M. A. Wade. 1958. The effect of certain feed additives on the tissues of fattening beef cattle. J. Ani. Sci. 17:124.

Bolton, W. 1961. The effects of supplemental detergents on the digestibility of poultry diets. J. Agric. Sci. 57:83.

Bradley, N. W., R. M. Forbes, W. W. Albert, G. E. Mitchell, Jr., and A. L. Neumann. 1958. Use of the chromic oxide method for determining digestible energy and protein in complete pelleted steer rations. J. Ani. Sci. 17:1199.

Bradley, N. W., B. M. Jones, Jr., G. E. Mitchell, Jr., and C. O. Little. 1966. Fat and urea in finishing rations for steers. J. Ani. Sci. 25:480.

Brethour, J. R., R. J. Sirny and A. D. Tillman. 1958. Further studies concerning the effects of fat in sheep rations. J. Ani. Sci. 17:171.

Brooks, C. C., G. B. Garner, C. W. Gehrke, M. E. Muhrer and W. H. Pfander. 1954. The effect of added fat on the digestion of cellulose and protein by ovine rumen microorganisms. J. Ani. Sci. 13:758.

Cameron, C. W. and D. E. Hogue. 1968. Effect of varying dietary corn oil and hay-grain on lamb growth and fat characteristics. J. Ani. Sci. 27:553.

Crampton, E. W. and L. E. Lloyd. 1951. Studies with sheep on the use of chromic oxide as an index of digestibility of ruminant rations. J. Nutr. 45:319.

Davis, C. L., J. H. Byers, and L. E. Luber. 1958. An evaluation of chromic oxide method of determining digestibility. J. Dairy Sci. 41:152.

Davison, K. L. and W. Woods. 1960. Influence of fatty acids upon digestibility of ration components by lambs and upon cellulose digestion in vitro. J. Ani. Sci. 19:54.

Davison, K. L. and W. Woods. 1960b. Influence of minerals and fat addition upon ration digestibility and performance of fattening lambs. J. Ani. Sci. 19:1256.

Dyer, I. A., T. J. Davis, and A. E. Cullison. 1952. Certain surface active agents accelerate the rate of gain of pigs fed a corn-cottonseed meal ration. J. Ani. Sci. 11:760.

Dyer, I. A., M. E. Ensminger and R. L. Blue. 1957. Effects of fat, oxytetracycline, and stilbestrol on performance and hepatic stores or carotene and vitamin A in steers. J. Ani. Sci. 76:828.

Edwards, R. L., S. B. Tove, T. N. Blumer and E. R. Barrick. 1961. Effects of added dietary fat on fatty acid composition and carcass characteristics of fattening steers. J. Ani. Sci. 20:712.

Ellis, I. J., Jr., M. B. Wise, T. N. Blumer, and E. R. Barrick. 1962. Influence of degree of saturation of fats fed to steers in drylot. J. Ani. Sci. 21:994.

Ely, C. M. and S. Schott. 1952. Surface active agents as growth stimulators in chick rations. Proc. Distillers Feed Conf. 7:72.

Embry, L. B., J. K. Turner and F. G. Gastler. 1957. Digestibility of rations and nitrogen balance by lambs as influenced by animal fat, urea, soybean oil meal and linseed oil meal. J. Ani. Sci. 16:1080.

Erwin, E. S., I. A. Dyer and M. E. Ensminger. 1956. Effects of chlortetracycline, inedible animal fat, stilbestrol and high and low quality roughage on performance of yearling steers. I. Feed consumption and rates of gain. J. Ani. Sci. 15:710.

Erwin, E. S., I. A. Dyer and M. E. Ensminger. 1956b. Effects of chlortetracycline, inedible animal fat, stilbestrol and high and low quality roughage on performance of yearling steers. II. Digestibility of dry matter, crude fiber, crude protein, and ether extract. J. Ani. Sci. 17:717.

Esplin, G., W. H. Hale, F. Hubbert, Jr., and B. Taylor. 1963. Effect of animal tallow and hydrolyzed vegetable and animal fat on ration utilization and rumen volatile fatty acid production with fattening steers. J. Ani. Sci. 22:695.

Figroid, W., W. H. Hale, B. Theurer, J. Marchello and F. Dryden. 1971. Utilization of added dietary fat by steers as affected by ration concentrate level and level of fat addition. Arizona Cattle Feeders' Day, University of Arizona, Tucson, May 6, 1971.

Garton, G. A., P. N. Hobson and A. K. Lough. 1958. Lipolysis in the rumen. Nature 182:1511.

Grainger, R. B. and J. W. Stroud. 1959. An effect of neutral fat, calcium and corn distillers dried solubles on roughage utilization by ruminants. Proc. Distillers Feed Conf. 14:16.

Grainger, R. B., M. C. Bell, J. W. Stroud, and F. H. Baker. 1961. Effect of various cations and corn oil on crude cellulose digestibility of sheep. J. Ani. Sci. 20:319.

Hardison, W. A., R. W. Engle, W. N. Linkous, H. C. Sweeney, and G. C. Graf. 1956. Fecal chromic oxide concentrations in 12 dairy cows as related to time and frequency of administration and to feeding schedule. J. Nutr. 58:11.

Hentges, J. F., Jr., A. M. Pearson, and C. A. Tucker. 1954. Waste beef fat in steer fattening rations and its effect upon the carcass. J. Ani. Sci. 13:970.

Hill, F. D., J. H. Saylor, R. S. Allen, and N. L. Jacobson. 1960. In vitro lipolysis by rumen ingesta. J. Ani. Sci. 19:1266.

Hoflund, S., J. Holmberg, and G. Sellmann. 1956. Investigations on fat digestion and fat metabolism in ruminants. II. Feeding unsaturated fats to dairy calves. III. Influence of the rumen flora on fat digestion by sheep. Cornell Vet. 46:51.

Hubbert, F., Jr., B. Taylor, E. B. Stanley, W. H. Hale, and J. Kuhn. 1961. Factors influencing tallow utilization in Arizona feedlot rations. J. Ani. Sci. 20:669.

Jones, B. M., Jr., N. W. Bradley and R. B. Grainger. 1961. Effect of fat and urea in fattening rations for beef steers. J. Ani. Sci. 20:396.

Kane, E. A., W. C. Jacobson, and L. A. Moore. 1949. Digestibility studies on dairy cattle; a comparison of total collection methods; conventional verus chromium oxide and lignin techniques. J. Ani. Sci. 8:623.

Kane, E. A., W. C. Jacobson, and L. A. Moore. 1950. A comparison of techniques used in digestibility studies with dairy cattle. J. Nutr. 41:583.

Kane, E. A., R. E. Ely, W. C. Jacobson, and L. A. Moore. 1953. A comparison of various digestion trial techniques with dairy cows. J. Dairy Sci. 36:325.

Lassiter, C. A., T. W. Denton, and G. M. Bastin. 1955. The value of certain surfactants and other growth stimulants in the rations of young dairy calves. J. Dairy Sci. 38:407.

Lassiter, J. W., V. Alligood, and C. H. McGaughey. 1966. Chromic oxide as an index of digestibility of all-concentrate rations for sheep. J. Ani. Sci. 25:44.

Lillie, R. J., J. R. Sizemore, and C. A. Denton. 1958. A study of surface active agents in broiler diets. J. Poultry Sci. 37:288.

Lucas, H. L. and J. K. Loosli. 1944. The effect of fat upon the digestion of nutrients by dairy cows. J. Ani. Sci. 3:3.

Luecke, R. W., J. A. Hoefer and F. Thorp, Jr. 1952. The growth promoting effect on pigs of a surface-active agent. Mich. Agr. Exp. Sta. Quart. Bul. 34:331.

March, B. E., M. Burdett and J. Biely. 1954. Antibiotics and surface active agents in chick nutrition. Poultry Sci. 33:300.

Matsushima, J. and T. W. Dowe. 1954. Use of animal fats in rations for beef cattle. J. Am. Oil Chemists 31:54.

McGuire, R. L., N. W. Bradley and C. O. Little. 1966. Effects of frequency of feeding on excretion of chromic oxide, crude protein and gross energy and on nutrient digestibility by steers. J. Ani. Sci. 25:185.

Morrison, F. B. 1949. "Feeds and Feeding". 21st Edition, The Morrison Publishing Company.

Parks, J. 1970. Control of feed intake in ruminants: A semi-purified liquid diet for continuous intraruminal infusion. M. S. Thesis. Kansas State University, Manhattan.

Perry, T. W., W. M. Beeson and B. W. Vosteen. 1953. The effect of an antibiotic or a surfactant on the growth and carcass composition of swine. J. Ani. Sci. 12.310.

Phar, P. A., N. W. Bradley, C. O. Little, L. V. Cundiff and J. A. Boling. 1971. Nutrient digestibility using fecal collection apparatus and indicator method for steers fed ad libitum. J. Ani. Sci. 33:695.

Putnam, P. A., R. R. Oltjen and J. Bond. 1969. Effect of soybean oil, urea, roughage and a progestigin on the utilization of corn based finishing rations by beef cattle. J. Ani. Sci. 28:256.

Roberts, W. K. and J. A. Mckirdy. 1964. Weight gains, carcass fat characteristics and ration digestibility in steers as affected by dietary rapeseed oil, sunflowerseed oil and animal tallow. J. Ani. Sci. 23:682.

Schendel, H. E. and B. C. Johnson. 1952. Effect of antibiotics, arsanilic acid, surfactants and sulfas on the growth of baby pigs fed synthetic diets. J. Ani. Sci. 11:775.

Schurch, A. F., L. E. Lloyd and E. W. Crampton. 1950. The use of chromic oxide as an index for determining the digestibility of a diet. J. Nutr. 41:629.

Schweigert, B. S. and O. H. M. Wilder. 1955. Utilization of animal fats by beef cattle. Ann. Rept. Amer. Meat Inst. Found. Bul. No. 22.

Scott, H. M., B. C. Johnson and E. A. Goffi. 1952. Effect of surface active agents on chick growth. Poultry Sci. 31:746.

Sheffy, B. E., A. J. Clawson and J. P. Willman. 1953. The value of surfactants in rations for growing-fattening pigs. J. Ani. Sci. 12:931.

Shorland, F. B., R. O. Weenink and A. T. Johns. 1955. Effect of the rumen on dietary fat. Nature 175:1129.

Snyder, J. M., B. C. Johnson and H. M. Scott. 1953. Surface active agents and the time of their effect on chick growth with special reference to vitamin B_{12} and aureomycin interrelationships. Poultry Sci. 32:527.

Stirton, A. J. 1954. Fat-based surface-active agents. J. Am. Oil Chemists 31:579.

Summers, C. E., F. H. Baker and R. B. Grainger. 1957. Cellulolytic interrelationships of carbohydrates, fat and trace minerals in sheep rations. J. Ani. Sci. 16:781.

Swift, R. W., E. J. Thacker, A. Black, J. W. Bratzler and W. H. James. 1947. Digestibility of rations for ruminants as affected by proportions of nutrients. J. Ani. Sci. 6:432.

Thompson, J. T., N. W. Bradley and C. O. Little. 1967. Utilization of urea and fat in meal and pelleted rations for steers. J. Ani. Sci. 26:830.

Tillman, A. D., R. J. Sirny and R. MacVicar. 1954a. The effect of alfalfa ash upon the digestibility and utilization of cottonseed hulls by sheep. J. Ani. Sci. 13:726.

Tove, S. B. and R. D. Mochrie. 1963. Effect of dietary and injected fat on the fatty acid composition of bovine depot fat and milk fat. J. Dairy Sci. 46:686.

Voelker, H. H., R. S. Allen, N. L. Jacobson and J. T. Blake. 1954. In vivo (dairy calves) and in vitro studies with surface-active agents. J. Dairy Sci. 37:737.

Ward, J. K., C. W. Tefft, R. J. Sirny, H. N. Edwards and A. D. Tillman. 1957. Further studies concerning the effect of alfalfa ash upon the utilization of low-quality roughages by ruminant animals. J. Ani. Sci. 16:633.

White, T. W., R. B. Grainger, F. H. Baker and J. W. Stroud. 1958. Effect of supplemental fat on digestion and the ruminal calcium requirement of sheep. J. Ani. Sci. 17:797.

Willey, N. B., J. K. Riggs, R. W. Colby, O. D. Butler, Jr., and R. Reiser. 1952. The influence of level of fat and energy in the ration upon feedlot performance and carcass composition of fattening steers. J. Ani. Sci. 11:705.

Wise, M. B., T. H. Jackson, E. R. Barrick and T. N. Blumer. 1959. Influence of sources of added fat on performance and carcass characteristics of growing-finishing beef steers. J. Ani. Sci. 18:1525.

Wise, M. B., T. N. Blumer and E. R. Barrick. 1963. Influence of urea, fat and alfalfa meal on performance, rumen epithelium and livers of steers fed all-concentrate diets. J. Ani. Sci. 22:849.

THE EFFECTS OF DIETARY FAT AND A SURFACTANT ON THE DIGESTIBILITY AND PERFORMANCE OF STEERS

by

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One-hundred ninety-nine yearling steers were randomly alloted to forty pens to study the effects of dietary fat and a surface-active agent (polydimethylsiloxane) on nutrient digestibility and animal performance. The 125-day trial consisted of six periods, and including three digestion trials with forty steers. All steers were fed *ad libitum* during the entire trial. Average initial weight for all steers was 307 kg.

Ration ingredients were corn and sorghum silage, dehydrated alfalfa, steam flaked sorghum grain, a commercial hydrolyzed animal and vegetable fat, and a protein supplement containing 72% soybean meal, 10% urea, dicalcium phosphate, ground limestone, trace minerals, aureomycin, diethylstilbestrol and vitamin A. Salt was given *ad libitum*. Five levels of fat were fed (0, 2, 3, 4, and 6% of the diet) during the 125-day trial.

Performance and digestion data were analyzed by periods. There were five 21-day periods and one 20-day period in the trial, with the ending weight for one period serving as the starting weight for the next.

Digestion studies were conducted during periods 2, 3, and 5. The chromic oxide indicator method was used to calculate the digestibility coefficients. Diets and salt were given *ad libitum*. Five grams chromic oxide (pelleted mixture; 88 gm ground sorghum, 7 gm dried molasses and 5 gm chromic oxide) were fed each A.M. Following a 14-day preliminary period, fecal samples were collected for 6 days by a randomized schedule.

The "grab" technique was used to collect feces unless steers defecated at the time of collection; then an ordinary ice cream dipper was used to collect the feces.

In period 1, only additive and non-additive treatments were studied. The additive (surfactant) caused a depression ($P<.001$) in rate of gain and daily feed consumption ($P<.10$).

During period 2, both the additive and 2% added fat increased ($P<.001$) gain and improved feed efficiency. Consumption favored ($P<.05$) diets without added fat. Addition of 2% fat increased the digestibilities of crude protein, ether extract, dry matter, gross energy ($P<.001$), and crude fiber ($P<.01$). The surface-active additive improved digestibilities of protein ($P<.01$) and ether extract ($P<.001$).

In period 3, 4% added fat decreased rate of gain and feed consumption ($P<.05$). The additive depressed the digestibility coefficients of crude fiber ($P<.01$), dry matter ($P<.01$), crude protein ($P<.001$), and gross energy ($P<.01$).

Both gain and feed consumption were decreased in period 4 of the trial ($P<.05$, $P<.001$, respectively) due to the additive.

Period 5 showed a beneficial response ($P<.10$) to the surface-active additive in rate of gain, feed efficiency, and cost/kg gain (feed cost only). A similar response was observed in the digestibility of crude protein ($P<.01$) and gross energy ($P<.05$). Ether extract digestibility was improved ($P<.01$) for 3, 4, and 6% fat diets.

The surface-active additive in period 6 once again showed a beneficial response in rate of gain ($P < .01$), but decreased feed intake ($P < .01$). Due to variability and few degrees of freedom, differences in feed efficiency were not significant.

Steaks obtained from the digestion trial steers (forty) were evaluated using the shear bolt test and a four member taste panel that scored the steaks according to flavor, juciness, tenderness, and over-all acceptability. There were no significant differences due to either fat levels or the surfactant.

Carcass results were taken from one-hundred ninety-seven steers. Steers receiving no fat (last 62 days of trial) had a decrease in quality grade ($P < .05$). An increase in percent kidney knob ($P < .001$) was observed for steers receiving 6% added fat (last 62 days of trial) as compared to the control diet (0% fat).

Volatile fatty acid concentrations were not significant in either fat or additive treatments. There was an increase in the acetic to propionic ratio ($P < .05$).