POLYETHYLENE IN COMPLETE RATIONS
FOR DAIRY CATTLE

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Bachelor of Science

Oklahoma State University

Stillwater, Oklahoma

1969

Submitted to the faculty of the Graduate College
of the Oklahoma State University
in partial fulfillment of the requirements
for the degree of
MASTER OF SCIENCE
July, 1971

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ACKNOWLEDGMENTS

The author wishes to express sincere appreciation to Dr. Linville J. Bush for his advise, guidance, personal interest and invaluable assistance during the course of this study and the preparation of this thesis.

Appreciation is also extended to Dr. J. V. Whiteman, Dr. J. E. McCroskey and Dr. M. W. Wells for their interest and assistance in conducting this study and preparing this manuscript.

I am also indebted to Mr. Barry Steevens, Mr. Richard Beams, Mr. Mario Gonzalez, graduate students; and Mr. Larry Krieg for their help, assistance and suggestions in the collection and handling of the experimental animals and data. Thanks is also extended to Mr. Glendon Adams and Mr. Harley Miller for their help in selection and care of the research animals.

The author wishes to thank Mrs. Nancy Fancy for her work in the typing and editing of this study. Special appreciation is expressed to the author's wife, Sharon, for her patience, assistance and encouragement during this study and preparing of this thesis. Appreciation is expressed to the author's parents Mr. and Mrs. John Cunningham and Mr. and Mrs. Edwin Krieg for their encouragement.

The author is also grateful to Farmland Industries, Inc., Kansas City, Missouri for providing funds for partial support of this research project and to the Department of Animal Sciences and Industry for financial assistance during this graduate program.

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CHAPTER I

INTRODUCTION

The general trend of concentrating dairy cattle in large herds is causing new emphasis to be placed on automation of both feeding and handling facilities. To minimize labor requirements and maximize automation, dairymen are blending the concentrate and roughage portions of the ration to form complete or blended feeds.

There are two major needs for complete rations. The amount of time a dairy animal spends in the parlor has been greatly reduced by recent advances in parlor design, cow handling and milking procedures. At the same time, the time available for eating concentrates has also been reduced, especially for high producing cows. Under these conditions, it would be a great advantage to feed the concentrates with roughage as a complete ration and eliminate all feeding in the milking parlor. The second major need for a complete ration is to minimize labor requirements and maximize automation. With the use of complete feeds, feeding time can be reduced considerably and automated equipment used to the fullest extent.

Some concern has been expressed over the possibility that the use of complete feeds, particularly on a long-term basis, may result in health problems. The basis for this concern seems to be very much related to the difficulties that have been encountered with high concentrate rations. Rumen parakeratosis, liver abscesses, bloat, joint stiffness and milk fat depression have been associated with feeding rations containing relatively small amounts of roughages or no roughage at all. Therefore, interest has been generated in identifying roughage substitutes which can be readily obtained at low cost, are uniform in chemical and physical characteristics, can be blended in complete rations and yet maintain normal rumen function and animal health.

The purpose of this study was to evaluate the effectiveness of polyethylene "squares" as a roughage substitute in complete rations for dairy cattle. The criteria used were: yield and composition of milk; biochemical characteristics of the rumen content; and the incidence of digestive disorders.

CHAPTER II

LITERATURE REVIEW

Complete Ration for Dairy Cows

It seems reasonable to expect that many more dairy operations in the future will be specialized units which manage, feed and milk cows, while purchasing most or all of the feed inputs. Under such conditions, it would be most desirable to know the extent to which forages and concentrates can be substituted for each other and their relative value under various conditions in order to minimize feed cost. Even though the rations fed might vary widely, it seems probable that many of them would be fed as complete feeds (Miller and O'Dell, 1969).

The most important question is whether dairy cows will respond equally well on complete and conventional rations. Ronning and Laben (1966) reported on research done at the University of California testing complete rations with roughage to concentrate ratios of 90:10, 60:40, 30:70, 0:100. The highest production was obtained from the all-grain ration, but milk fat was severely depressed. The best performers, considering all aspects, were cows receiving the 60:40 ratio and the next best were cows fed the 30:70 ratio indicating that the optimum level of concentrates was probably somewhere between these two combinations. Olson (1965) pointed out that this feeding method (complete ration) may be used to induce cows to consume roughage and concentrates in the proper proportion for maximum milk production.

Generally feed intake and milk production of cows fed a complete ration has been comparable to that of those fed concentrates and roughage separately (Putman and Davis, 1961; Johnson, Reed and Olson, 1967; Leighton and Helm, 1967; and Drude, Escano and Rusoff, 1971). A study made by Villavicencio, et al. (1968) compared a conventional ration with roughage and concentrate offered separately with three complete feeds containing 1% urea and different sources of roughages using four groups of lactating cows during a 120-day period. Daily milk yield and fat percentage were not significantly different ($P<.05$).

Muller, Harshbarger and Olver (1967) compared free choice group feeding of corn silage mixed with 100, approximately 50 or 0 % of the concentrate ration. From the results, they concluded that lactating dairy cows can efficiently utilize a complete ration mixture of corn silage and concentrates. Hooven, Johnson and Plowman (1971) obtained similar results in an experiment in which silage and concentrates were mixed in a ratio of 60:40 at the time of ensiling.

Owen, Miller and Bridge (1969) successfully self-fed complete diets to dairy cows over a whole lactation. The results confirmed that cows can perform normally when given complete diets for extended periods. They concluded that complete diets based mainly on barley or sugar beet pulp should contain a minimum of about 24 to 32% of coarsely milled straw and estimated that metabolizable energy intake and production were depressed by including straw at higher levels.

Larkin and Fosgate (1970) compared group fed Holsteins receiving complete feeds and Holsteins receiving corn silage and concentrates for three consecutive lactations. Complete rations and concentrate and silage rations were very similar in their ability to maintain milk, fat and protein production.

Production Response with Different Roughage Sources

Conventional Roughages. Materials such as corn cobs and cottonseed hulls have been successfully used as roughage sources. McCoy *et al.* (1966) and Villavicencio *et al.* (1968) indicated that cottonseed hulls and corn cobs in a complete feed containing 30% roughage and 70% concentrates are readily consumed by lactating cows and support high levels of milk production, and an acceptable percentage of milk fat and other milk constituents. Wise *et al.* (1967) compared a basal all-concentrate ration to a similar ration in which 10% of either corn cobs or cottonseed hulls replaced a similar amount of ground shelled corn. There was a slight but nonsignificant increase in weight gain resulting from feeding the roughage; however, feed conversion values favored the basal ration without roughage. Other supporters of these findings are Lofgren and Warner (1970); Wilder *et al.* (1964); Thrasher *et al.* (1964); and Anthony, Harris and Starling (1961).

McCoy *et al.* (1965) compared three roughages in complete feeds, i.e., chopped alfalfa-orchard grass hay, ground corn cobs, and cottonseed hulls where each complete feed containing 30% roughage and 70% concentrate was fed *ad libitum*. The cows on hay and cottonseed hulls produced significantly ($P<.05$) more milk than those on corn cobs. However, there was no significant difference in milk fat yield.

Hunt, Cummings and Lusk (1971) compared three levels of cottonseed hulls, i.e., 25, 35 and 45% in complete rations for dairy cattle and found that the average daily milk production and milk fat were about the same. However, they noted some problems of off-feed and diarrhea with these rations.

Other Roughage Sources

Mertens, Campbell and Martz (1971) tested rations containing 2.3 kg of alfalfa hay and the following roughage sources: 10% paper and 10% cottonseed hulls or 20% paper. They found that 10% paper in the ration would nearly maintain milk fat percentage without significantly reducing actual milk production.

Hensen, Furr and Sherrod (1969) found that cattle fed 15% paper gained 5% faster than animals fed an all-grain sorghum ration and 9% faster than animals fed a grain sorghum ration containing 15% alfalfa. Daniels et al. (1970) reported that newspaper may replace at least 12% of the diet of growing dairy steers without reducing feed efficiency, gain and carcass grade.

Anthony and Cunningham (1968) conducted an experiment in which hardwood sawdust was fed at 2.5 and 10% of the ration. The highest rate of gains for lambs and steers was produced on a mixture containing 2.5% hardwood sawdust. The mixture containing 10% sawdust supported gains equal to gains of cattle fed a basal ration. No deleterious effects resulted from feeding hardwood sawdust. Satter, Baker and Millett (1970) found no significant effects on milk yield, but highly significant differences ($P < .01$) between milk fat percentages when aspen sawdust replaced up to 32% of the hay in a 50:50 ration. Satter et al. (1970) found that aspen sawdust was effective as a partial roughage substitute in a high-grain dairy ration. Cows receiving 2.3 kg of hay and about 17 kg of pelleted concentrate mix, one third of which was aspen sawdust, maintained a normal milk fat level. Cows receiving a similar ration without sawdust had a milk fat content half as great. There were no significant effects of ration on the quantity of milk produced. Dinius et al. (1970) used several potential roughage sources for sheep at 10% of the complete ration. Material evaluated included: wood products (sawdust, shaving, flooring waste), verxites, kaolin clays and sugar cane bagasses with ground corn cobs serving as the control. Dry matter intakes of the rations containing wood by-products, clay or verxite were not significantly different from that of the control ration. El-Sabban, Long and Baumgardt (1971) concluded that fine or coarse oak sawdust constituting 5 or 15% of high-concentrate beef finishing ration could substitute for 5% ground timothy hay as the sole roughage source without significantly affecting rate of gain. Feed efficiency was highest, however, for the 5% timothy ration. Abscessed livers were present in all treatment groups.

White and Reynolds (1969) and White, Reynolds and Klett (1969) fed two levels of rice hulls and rice straw to beef steers and found that 20% rice hulls decreased concentrate intake, gain and carcass weight as compared to all-concentrate ration. Bloat was frequently observed in steers fed rice hulls. However, gains were higher ($P<.05$) when ration contained 20% rice straw than for all other treatments. They generally concluded that the response to roughage level depends on the source of roughage used for fattening rations.

Recently oyster shell has been used as a roughage replacer in fattening beef cattle rations. Perry et al. (1968) found consumption of an oyster shell ration was 13% less as compared to a ground corn cob ration. Gains were significantly faster (about 2.5%) for the ground corn cob ration. Also, liver condemnations were higher in steers fed oyster shell (48%), than in steers fed a corn-cob roughage (36%). Haskins et al. (1969) and Williams et al. (1970) found oyster shell to be ineffective in improving the performance of steers fed a high grain finishing ration. Addition of oyster shell resulted in decreased gain and feed consumption and lower feed efficiency. Oyster shell increased the incidence of bloat and abscessed livers.

Oltjen, Sirny and Tillman (1962) reported that the inclusion of ground polyethylene to a purified diet for sheep increased the amount of rumination, improved the consistency of feces and eliminated intestinal compaction. The addition of 1, 2, and 4% polyethylene increased ruminating time and the response did not differ significantly from linearity. However, rumination on the highest level was much less than on a natural diet. Pearce and Moir (1964) found the daily addition of 70 grams of polyethylene flake (approximately 3/4 inch long, 1/4 inch wide and 1/32 inch thick) to a low ruminating ration increased rumination time in sheep to approximately the same level as observed with the same ration unground. Virtanen (1966) reported that about 0.5 kg per day of polyethylene pellets in purified diets for dairy cows promoted an increase in rumination.

Ott et al. (1964) added 3 mm polyethylene cubes at a 2% level to purified diets for lambs. The result was a significant increase in the percentage of butyric and valeric acids and a corresponding decrease in acetic acid.

Campling and Freer (1962) studied the effects of several materials on the mean retention time of inert particles. They concluded mean retention time of inert particles of specific gravity 1.20 was directly related to the size of particles within the range 17 to 58 mm^3. The largest particles were found to be retained in the alimentary tract about 12% more time than the smallest ones. There was almost a linear relationship between diameter of the particles and mean retention time. Derrickson et al. (1965) used inert plastic (specific gravity 1.425) with physical characteristics similar to concentrates to study the rate of passage of different size particles. The effects of particle sizes were studied by separating the plastic into groups having a mean diameter of 4.76, 2.38, 1.19 and 0.60 mm. As the size of particles increased in diameter the rate of passage decreased.

Boling et al. (1967) fed steers diets containing from 14.2 to 29.3% shredded polyethylene having a specfic gravity of 0.91 to 0.96. A trend toward compensatory feed intake to meet energy requirement was observed when increased fill, dietary density, palatability or quality were not factors decreasing feed intake. The average daily gain adjusted for fill was less for all steers consuming polyethylene as a part of the diet, although the decrease was significant in only two experiments. The most profound effect of diets containing polyethylene on gastro-intestinal fill was apparent in the reticulo-rumen. There appeared to be some evidence that the polyethylene accumulated in the rumen until some maximum level was reached regardless of the level in the diets.

In one experiment, no difference was observed in percent polyethylene (85.3 and 86.1) in the dry matter of the rumen contents of steers fed two levels of polyethylene (14.7 and 29.3% respectively). Boling, Kowalczyk, and Hauser (1969) investigated the short term effect on voluntary feed intake of diet diluted with 10 and 20% polyethylene particles. They concluded that the reticulo-rumen fill limited feed intake when steers were fed an 80% estimated net energy (ENE) diet and increased fill was due to polyethylene accumulation. With differential feeding of colored and white polyethylene they showed there was not a stasis of polyethylene particles in the rumen, but rather a continuous turnover. Hughes et al. (1964) reported promising results as greater consumption was obtained when 20% of the concentrate ration to steers was polyethylene.

In a study on voluntary intake feeding polyethylene at 4.0, 7.5, 13.5, and 22.6% of the total ration Carr and Jacobson (1967) found that feed intake (not including polyethylene) was reduced by 3.1, 4.4, 6.0 and 25.6%; whereas total intake (including the polyethylene cubes) changed by 0.8, 3.5, 9.0 and -3.9 respectively. With 4.0 and 7.5% cubes in the diet there was little effect on intake while at the very high levels the animals discriminated against the cubes.

Welch (1967) reported that the introduction of polyethylene fiber (7.5, 7.0, 15 and 30 cm in length) into rumen of wethers caused marked reduction in chopped hay intakes. Longer fibers caused longer and more prolonged intake reduction of hay. The fiber introduction into the rumen caused intake reduction greater in magnitude than the proportional amount of fiber added. White and Reynolds (1969) and Haskins et al. (1969) also found non-beneficial results when feeding polyethylene.

Dyer and Frazier (1970) fed steers polyethylene pellets ("squares") at a rate of 1/2 pound each day for 6 days at the start of a 55-day fattening trial. The daily rate of gain was 3.61 pounds for both the steers on polyethylene and on the hay for roughage. The steers fed the polyethylene used feed more efficiently, i.e., 7.11 pounds of feed per pound of gain as compared to 7.55 pounds for steers fed hay as a roughage source.

Welch and Smith (1971) conducted two experiments evaluating the use of polypropylene ribbon in milk fat depressing diets for dairy cows. Polypropylene was fed at a level to bring rumination activity back to normal. The polypropylene feeding produced no increase in milk fat percent.

Bush used polyethylene "squares" having a density of 0.93 and dimensions of approximately 25 x 20 x 10 mm in trials with dairy cows. Under conditions of individual feeding a large variation was noted among cows in their acceptance of polyethylene squares in the feed. Some cows tended to sort out the polyethylene material; however, this problem was largely overcome by using a concentrate mixture with a high percentage of rolled grains. The addition of the polyethylene at levels of 1% of the grain mixture did not prevent a rather marked depression in milk fat test when the percentage of concentrates in the ration was increased to 90%. The amount of polyethylene material recovered from the rumens of fistulated steers was directly related to the amount of polyethylene consumed although there was a large animal variation in the extent to which ingested material was subsequently regurgiated and discarded. The polyethylene was found to comprise approximately 30% of the ingesta dry matter in one fistulated steer fed a 2% level of the material for a two week period.

Additional work by Gonzalez _et al_. (1971) evaluated the effects of different amounts of polyethylene and alfalfa hay in rations using a 3 x 3 factorial arrangement of treatments with three levels of hay and three levels of polyethylene. Levels of polyethylene were: none, 1.8 kg at start of trial, and 1.8 kg at start plus 1% of the daily allotment of grain. Neither level of hay nor level of polyethylene had a significant effect on milk yield and there was not a significant interaction between the two factors. The cows receiving no hay exhibited a substantial decrease in milk fat percentage, whereas a smaller decline was evident in the groups fed either 10 or 20% hay. There were no significant differences between the two groups receiving hay. Thus, feeding of polyethylene under conditions of this trial was not an effective means of maintaining desirable fat percentage in milk of cows fed high grain rations.

Physiological Response with High Energy Rations

Milk Composition. One of the problems that has arisen due to the increased use of high energy rations has been the maintenance of a normal fat test, especially in individual cows of high milk producing ability. The depression of milk fat by feeding rations containing a high proportion of concentrates has been observed many times. Baumgardt (1967) suggested that about 60% concentrates is a maximum level that will sustain normal fat percentages. Earlier, Kesler and Spahr (1964) reported that rations containing 50 to 60% concentrates (14 to 16% dietary fiber) appeared to be adequate to prevent serious fat test problems provided that the roughage was not finely ground. Villavicencio *et al.* (1968) fed rations with a 30:70 ratio of roughage to grain and observed no significant differences in the milk fat percent, although a slight trend was observed in decreased fat percentage of cows on long alfalfa hay and cottonseed hulls. They generally conceded that a 40:60 ratio of roughage to grain is near the upper limit for maintaining fat test.

Knestrick, Ramage and Mather (1970), McCoy et al. (1966) and Rakes (1969) found no significant influence on the fat test as a result of feeding a concentrate ration having a grain to roughage ratio of 75:25, 70:30 and 70:30 respectively. Also, Bloom et al. (1957) reported no depression of fat percentages from feeding rations in which 85% of the estimated net energy was from concentrates. Stallcup (1968) summarized that approximately one third of the ration as forages is necessary. He stated the protection against milk fat depression afforded by a roughage is influenced by its physical form and fiber content. It takes less poor-quality, high-fiber forage to maintain fat test than it does of low-fiber forage.

However, several workers (Ronning and Laben, 1966; Meyers, 1966; Swanson, Hinton and Miles, 1967; and Nelson et al., 1968) have reported a highly significant decrease in milk fat percentage as the proportion of concentrate is increased over 60% in the total ration.

In a review article, Van Soest (1963) discussed three theories which have been advanced to explain the profound depression in milk fat concentration that occurs when lactating cows are fed a completely ground ration of concentrate and roughage. The first and most widely supported theory, suggested by Tyznik (1951) and further advocated by Balch et al. (1955a) is that milk fat depression is caused by a deficiency in the amount of acetate supplied by the rumen microorganisms.

Ghorban, Knox and Ward (1966) pointed out that the presence of low acetic to propionic (A/P) ratios of ruminal fluids could aid to explain the known cases of milk fat depression. In addition, the concentration of ruminal lactate or the total ruminal concentration of VFA may be a factor in determining whether a feed will produce a depression in the percentage of milk fat. Kelley (1967) completed studies on rumen infusion of VFA in high producing, low producing, and non-lactating cows and showed a correlation ($r = +.77$) between milk fat percentage and rumen acetic acid concentration, but a correlation of only $r = +.17$ between milk fat test and molar percentage of this acid.

However, there is no conclusive evidence that an acetate deficiency really exists (Davis, 1967; Van Soest, 1963) and the absolute concentrations of rumen acetate are not significantly less on restricted roughage or high concentrate diets (Balch et al. 1955a; Van Soest and Allen, 1959).

Another theory of milk fat depression is that the level of blood ketones decrease in a manner associated with the depressed milk fat as a result of a deficiency of beta-hydroxy butyric acid (BHBA) in the mammary gland. It has been demonstrated by Shaw and Knodt (1941) and Shaw et al. (1959) that BHBA is an essential precursor of the short-chain fatty acid in milk fat. However, Palmquist et al. (1969) concluded that in cows fed high-grain, low-roughage diets, a deficiency of BHBA for milk fatty acids synthesis is not a causative factor in depressed production of milk fat.

Van Soest (1963) listed a third intriguing theory of low milk fat. He stated that McClymont and Vallance (1962) suggested the glucogenic response during high-propionate production on high-concentrate diets suppresses the mobilization of fat from the tissue and thereby causes a decline in blood lipids required for milk fat synthesis. The theory holds that infused glucose causes an increased secretion of insulin, which in turn inhibits a pituitary fat mobilization factor. This in turn lowers the blood glyceride, nonesterified fatty acids (NEFA) level (Annison, 1960) and synthesis of glycerides in the liver.

Some researchers (Jorgensen, Schultz and Barr, 1965; Palmquist et al., 1969; Chalupa et al., 1970; and Opstvedt and Ronning, 1967) concluded that one of the major factors influencing milk fat changes was an alteration in adipose tissue metabolism, probably caused by an increase in ruminal propionate that tends to stimulate a fattening type of metabolism at the expense of milk fat synthesis.

In a review, Storry (1970) noted that several basic mechanisms are involved in the low milk fat syndrome. Milk fat depressing diets produce a fall in rumen pH and changes in the proportions of rumen volatile fatty acids, generally characterized by decreased proportion of acetate and sometimes of butyrate and by increased proportion of propionate and valerate. The initial fall in pH is thought to be due to a diminished secretion of saliva and hense buffering capacity of rumen digesta, which then allows the survival of a microorganism producing the change in pattern of volatile fatty acids. Changes in rumen microorganisms may also have important reprocussions on the synthesis and metabolism of lipids in the rumen, especially in view of the known role of protozoa in the hydrogenation of unsaturated acid. These findings suggest that on a low roughage diet fatty acid utilization is directed towards deposition in adipose tissue rather than secretion in milk fat and is in line with the findings of higher body weight gains on low roughages than on high roughage diets.

Balch et al. (1955b), Thomas et al. (1968) and Yamdagni, Warner, and Loosli (1967) studied the effects of feed processing and type of starch in concentrates and forages on milk composition. Balch *et al.* (1955b) and Yamdagni *et al.* (1967) showed the type of starch in the concentrate (maize *vs.* barley and oats) on diets low in hay is of great importance in determining the extent of depression in milk fat percentage. Thomas *et al.* (1968) found that a medium ground hay appeared to be on the borderline of producing a milk fat depression effect. It also appeared from the results that the degree of particle size reduction of ground hay had more influence on fat content of milk and ratio of rumen VFA than heating or pelleting the medium ground hay.

Rumination

Rumination involves regurgitation of ingesta from the reticulo-rumen, swallowing of regurgitated liquids, remastication of the solids accompanied by re-insalivation and reswallowing of the bolus. The time spent ruminating is generally divided into many periods with intervals of feeding, drinking and rest interspersed.

Pearce (1965 a,b,c) studied a number of factors influencing the normal pattern of rumination. When sheep were fed once daily the pattern of rumination was characterized by a period of inactivity after eating, followed by a period of increasing intensity of rumination leading to a maximum intensity in the early hours of the morning, then a period of reduced activity up to the next feeding time. A high level of roughage feeding was associated with a shortened lag period, while a low level of roughage feeding resulted in a prolonged lag period. When fed *ad libitum*, rumination tended to be distributed without apparent order over the whole day. The lag period was progressively shortened when increasing proportion of a ration of oat and alfalfa chaff were administered via rumen fistulas.

Welch and Smith (1968) studied the effect of fasting on rumination activity. They found the peak of rumination activity occurred during the night. Fasting produced a rapid decline in normal rumination activity which ceased after 37 hours of fasting. Normal rumination was partially replaced by intermediate regurgitation patterns. Upon feeding, rumination was initiated soon after the end of the first meal and increased to normal levels within 24 hours. During normal feeding periods the average time spent ruminating per 24 hours was 8 hours and 57 minutes in one experiment and 8 hours and 35 minutes in another. Schalk and Amadon (1928) presented data with respect to cattle which is quite variable, but which would average about 30 ruminating periods per day for cattle on dry feed.

All of the factors stimulating or inhibiting rumination have not been defined clearly. However, Schalk and Amadon (1928) demonstrated tactile stimulation of reticular and ruminal epithelium proved to be a powerful stimulus which was most effective when applied to the anterior wall of the reticulum. When the rumen was packed with hay, rumination began within a few minutes. Feeding only grain or finely ground hay resulted in a cessation of rumination. These observations indicated rather clearly that rumination was initiated, at least partially, as a result of tactile stimulation of the epithelia from roughage in the reticulo-rumen. Hardison et al. (1956) reported that rumination activity occurred during 4 or 5 major periods throughout the day. The periods of rumination varied from 31 to 51 minutes and averaged 42.9 minutes for both trials. A major portion of the ruminating was done during the hours of darkness and in the lying position. The average time spent ruminating per day was 8 hours and 35 minutes. Rumination occupied 34% of the cows' time during trial I and 38% during trial II.

Freer and Campling (1965) observed cows ruminated an average of 9 hours and 15 minutes per day when offered hay _ad libitum_ or 26.8 minutes per pound of hay consumed. When the cows were fed dried grass _ad libitum_ rumination dropped to 6 hours and 40 minutes per day or 13.9 minutes per pound of grass. Rumination did not occur with ground hay or with concentrates, although short periods of regurgitation were observed. The regurgitated digesta were swallowed shortly after reaching the mouth and regular jaw movements were absent. These results are in agreement with Balch (1952) who observed grinding all the hay in the diet caused a great reduction in the amount of rumination apparently due to the absence of the stimulus for the regurgitation reflex.

As noted previously, feeding grain only, or finely ground roughages resulted in cessation of rumination or in pseudorumination (Balch, 1952; Freer and Campling, 1965). In pseudorumination, the time spent ruminating is greatly reduced in total and for each bolus. In this situation there does not appear to be an adequate stimulus to the epithelia or the amount of coarse material regurgitated is so limited that there is very little material for the animal to chew. Pseudorumination is characterized by regurgitation, a brief interval of chewing and reswallowing of the material after a short time.

Saliva Secretion

One of the principle functions of saliva in the ruminant is as a natural buffering agent which aids in maintaining the pH of rumen content within the fairly wide limits that are favorable to normal rumen function. There is evidence that the volume of saliva secreted by ruminants is variable and that the variability is related to the quantity and characteristics of feed eaten (Hawkins and Little, 1968). However, the effect of the ration, nature of the ration, (roughage versus concentrates) on the total amount of saliva secreted and the buffering capacity are not entirely clear. Wilson (1963) observed the amount of time spent ruminating is considerably less when ground hay is given than when long hay is fed. Because of the decrease in rumination time, the total saliva secreted during rumination was almost halved, but this decrease was offset by a large increase in the saliva secreted during rest. Wilson and Tribe (1963) found with a constant food intake, the secretion was increased by 25% when the hay ration was ground through a 1/16 inch screen, but was decreased by 61% when ground through a 1/32 inch screen. They concluded that food intake was of greater importance than other dietary factors, excluding fine grinding, in determining the volume of parotid saliva secreted.

Balch (1958) demonstrated that for every 10 pounds of hay consumed 43 to 57 pounds of saliva were added during eating, but with every 10 pounds of concentrates only 12 to 15 pounds of saliva were added. Putman, Lettmann, and Davis (1966) studied the effects of feed intakes on total daily mixed salivary secretion. Total daily salivary secretion increased linearly with increasing feed intake. At feed intake of 0.8, 1.4, 2.0 and 2.6% of body weight, salivary secretion was 33.5, 45.2, 52.0 and 54.1 liters per day respectively. However, Rumsy, Putman and Williams (1969) reported a statistically nonsignificant ($P>.05$) tendency toward an increase in salivary flow with increase feed intake of a pelleted high roughage diet.

Oltjen, et al. (1967) obtained salivary collection from steers for 90 minutes on 2 consecutive days starting 2 hours after the morning feeding. Saliva was collected at 15 minute intervals six times. They found salivary secretion was significantly lower ($P<.05$) when steers were fed a milo ration compared to when they were fed corn diets. The ration with the greatest amount of fines had the lowest salivary flow. There did not appear to be a pronounced depression in salivary flow due to the removal of the roughage resulting in an all-concentrate ration. Although the flow appeared to be depressed in two of the rations (wheat and milo) the buffering capacity per unit of saliva secreted did not change. Oltjen, Putman and Williams (1969) found the saliva pH and buffering capacity both increased from 2 to 6 hours after feeding and thought this may be related to the increased flow rate on saliva.

Davis, Brown and Beitz (1964) and Balch (1958) stated the buffering capacity of the rumen is dependent on the amount of saliva produced which in turn is highly dependent on the amount of time spent in rumination by the animal. Diets high in readily fermentable starch and sugars are known to cause a marked reduction in rumination which in turn reduced flow of saliva during rumination. This reduction may cause the rumen buffering capacity to decrease allowing the pH to remain low.

Digestive Disturbances

Several health difficulties related directly to the use of high concentrate rations are rumen parakeratosis, liver abscesses, acidosis and other digestive disturbances.

Uhart and Carroll (1967) and Tremere, Merrill and Loosli (1968) found that very high levels of lactic acid production in steers and dairy heifers caused acidosis.

Tremere *et al*. (1968) also found that when ruminants are changed from a primarily forage diet to one of increasing rate of dairy concentrate intake a point is reached when acute indigestion or "off-feed" occurs. At the time of "off-feed" there was a drop in ruminal pH (below 5.5) and a consistant rise in lactic acid and VFA concentration. A daily increment of somewhat less than 7.0 g of concentrate per unit of metabolic body size, in combination with a feeding frequency of at least 2 times per day, was necessary to avoid "off-feed" in heifers. An adaption period of at least 3 weeks was necessary for heifers used in this study.

Haskins *et al*. (1969), Perry *et al*. (1968) and Williams *et al*. (1970) observed the rumens of steers on all-concentrate ration and ration containing oyster shell to have severely damaged ruminal tissue as indicated by chronic rumenitis. Oyster shell greatly increased the incidence of bloat and the number of abscessed livers was highest in the steers fed all-concentrate ration followed by ration containing oyster shell.

CHAPTER III

EXPERIMENTAL PROCEDURE

This research explored the possibility of using a small amount of inert polyethylene "squares" as a complete roughage substitute in rations for dairy cows. The criteria used to evaluate the effectiveness of the inert polyethylene were:

(1) acceptability of polyethylene by the cows,

(2) yield and composition of milk,

(3) volatile fatty acid characteristics of the rumen content,

(4) the incidence of digestive disorders.

Earlier work by Gonzalez *et al*. (1971) revealed some important factors that may have influenced the acceptance of the polyethylene material. Under the conditions of the trial some of the cows showed a distinct dislike for the polyethylene "squares" when withdrawal of the roughage from the ration and introduction of the polyethylene occurred simultaneously. Another factor was the larger amount of polyethylene being introduced over a relative short period of time.

The purposes of trial I were to evaluate a system of removing all the roughage from the diet before introduction of the polyethylene. In addition, the amount of time allowed to introduce the polyethylene was increased to a 12-day period compared to a 4-day period used by Gonzalez *et al*. (1971). Also, the amount of polyethylene fed was increased to 2.7 kg compared to 1.8 kg used by Gonzalez *et al*. (1971).

Trial II was conducted using the same criteria to compare the response of cows fed polyethylene "squares" prior to calving with that of cows fed the material at 8 weeks after calving under conditions of all-concentrate feeding.

Trial I

Experimental Design

Eithteen mature dairy cows (nine Ayrshires, six Holsteins and three Jerseys), ranging from 455 to 682 kg body weight, were selected from the Oklahoma State University dairy herd about 4 weeks after calving. The animals were assigned to six groups (blocks) of three cows each based on breed and season of calving. Within each block, cows were randomly assigned to one of three treatments as follows:

(1) Positive control - fed a 50:50 ratio of alfalfa hay and grain.

(2) Negative control - fed grain mixture only.

(3) Grain plus polyethylene - fed 2.7 kg of polyethylene over a 12 day period.

Feeding and Management of the Animals

During a pre-trial period starting approximately 4 weeks after calving and extending to 8 weeks after calving, the cows were fed a 50:50 ratio of grain to hay to maximum consumption. At the beginning of the 8-week comparison period, feed allowances were adjusted to meet net energy requirements. The rations were calculated on the basis of live body weight, milk yield and milk fat percentage using net energy requirements as listed by Richardson (1967) for lactating dairy cows. Initial milk production was calculated from the average of the five days immediately prior to the initiation of the treatment period and initial milk fat test was the average of the fat tests for the previous three weeks.

The grain mixture (table I) was calculated to contain 1.65 Mcal estimated net energy (ENE) per kilogram and 74% total digestible nutrients (TDN); the alfalfa hay was estimated to contain 0.88 Mcal. ENE/kg and 51% TDN. The concentrate ration was mixed by the Stillwater Milling Co., Stillwater, Oklahoma, with the mixing being supervised by a member of the dairy research group.

TABLE I

CONCENTRATE RATION (TRIAL I AND TRIAL II)

Ingredient	Percent
Corn, crimped	33.75
Barley, crimped	11.0
Sorghum grain, crimped	20.0
Wheat bran	15.0
Molasses, liquid	7.0
Soybean oil meal (44%)	10.0
Trace mineral salt	1.0
Calcium phosphate (16-24% Ca; 18-21% P)	1.0
Calcium carbonate	1.25

The amount of energy required by each cow for maintenance and production was determined at the beginning of the comparison period. During a 10-day period the roughage was withdrawn and replaced with sufficient concentrate to maintain the net energy intake at the required level for the "all-grain" and "grain plus polyethylene" treatments. An example of the procedure for changing from a 50:50 grain to hay ration to that required for the stipulated treatment is shown in tables 2 and 3, using one of the cows which received no hay during the comparison period.

TABLE 2

CALCULATED INITIAL FEED ALLOWANCES FOR ONE COW IN TRIAL I

Item	Requirements (Mcal ENE)
Maintenance (684.8 kg body weight)	9.06
Milk production (28.5 kg/day; 3.4% fat)	21.8
Total estimated net energy required	30.86

Grain allowance was fed to each cow in two equal parts approximately one hour before each milking in conventional stanchions with the manger partitioned for individual feeding. Any feed refused from the previous pm and am feeding was weighed back and recorded in the morning. Grain allowances and refusals were weighed with a Toledo fan scale.

TABLE 3

CHANGES IN GRAIN TO HAY RATIOS AND FEED ALLOWANCES DURING THE TRANSITION PERIOD FOR ONE COW IN TRIAL I

Day	Ratio of grain to hay	Mcal/kg of ration	Total theoretical amt. fed/day kg	Actual fed/day, Grain	Amount kg Hay
0	50:50	1.27[a]	24.4[b]	12.2	12.2
1	55:45	1.30	23.7	13.0	10.7
2	60:40	1.34	22.9	13.8	9.1
3	65:35	1.39	22.2	14.4	7.8
4	70:30	1.41	21.9	15.3	6.6
5	75:25	1.48	20.9	15.7	5.2
6	80:20	1.50	20.6	16.5	4.1
7	85:15	1.54	20.0	17.0	3.0
8	90:10	1.57	19.7	17.7	2.0
9	95:5	1.59	19.4	18.4	1.0
10	100:0	1.65	18.7	18.7	0

[a] Grain Mixture (1.65) + alfalfa hay (0.88) = $\frac{2.53}{2} \doteqdot 1.27$

[b] Calculated as total ENE required: $\frac{30.86}{1.27} = 24.4$

On the second day of the "no roughage" regimen, feeding of the polyethylene began. The polyethylene fed was one-half size corrugated polyethylene "squares" (10 x 7 x 5 mm) supplied by Farmland, Industries, Inc. The designated animals were fed 2.7 kg of polyethylene at the rate of 113.5 g per feeding. No additional polyethylene was given to the animals after the 2.7 kg polyethylene had been fed. Any polyethylene refused during the initial 12-day period was fed again to the animal at the next feeding. This was continued until all the polyethylene was consumed. The polyethylene was weighed in 113.5 g allotments and stored in small brown paper bags until needed. At the time of feeding, one bag of polyethylene was mixed by hand with the grain allowance of each animal designated to receive the polyethylene.

The positive control cows designated to receive alfalfa hay were fed their daily allotment which was weighed separately for each cow and fed in an individual stall in a loafing barn about 4 hours before the pm milking. Animals refusing any hay in the afternoon were given access to it again at 8 am. Cows were kept in an outside holding lot during the day with water available both in the holding lot and the stanchion barn where the grain was fed. Block salt was available to all cows in the lots. All grasses and forages were removed from the holding lots throughout the trial.

Data Collection

Daily milk production was recorded at each milking for each cow throughout the entire trial. Individual milk samples were obtained at four consecutive milkings beginning with the Monday pm milking of each week. The four samples were then warmed to 37°C in a water bath and composited in proportion to the cow's milk weight corresponding with each sample. To determine total solids, 3 ml. of milk from the composite sample were placed in an aluminum dish and dried for 4 hours at 100°C in a forced air oven. Milk fat was determined according to the Babcock procedure.

Body weights of the cows were recorded for 3 consecutive days prior to the beginning of the comparison period.

Rumen samples were taken from each cow at 2, 4 and 6 hours after the pm grain feeding at 2, 4, 6 and 8 weeks of the trial for volatile fatty acid (VFA) analysis. Samples were taken by passing a stomach tube with a stainless steel filter down the esophagus into the rumen. A hand-operated suction pump was used to obtain the sample. The pump, tube and collection container were flushed with water between each sampling. It took approximately 2 minutes to collect a sample from each animal. When several animals were sampled on the same day, the feeding time was adjusted so each animal was sampled 2, 4 and 6 hours after feeding. The pH of the rumen fluid was determined immediately with a Beckman pH meter. Bacterial action in the rumen fluid was inhibited by the addition of 0.3 ml saturated mercuric chloride per 50 ml of rumen fluid. Samples were then centrifuged and the supernatant kept under refrigeration until analyzed for VFA.

VFA analysis was determined by gas-chromatography using a technique described by Erwin, Marco and Emery (1961). An Aerograph Model 600-D was used in conducting the VFA analysis. Operating conditions of the instrument were as follows: 1) oven temperature 132°C, 2) injection temperature 200°C, 3) carrier gas (nitrogen) flow rate at detector head, 20 ml/min., 4) hydrogen flow rate to detector, 20ml/min., 5) column material, neopentylglycol succinate (20% NPGS on 60/80 firebrick treated with 3% H_3PO_4).

A VFA standard (table 4) similar in concentration and molar percentage to that normally found in rumen fluid was prepared for use in the quantitative determination of the individual acids in the rumen fluid samples. The VFA were calculated as micromoles per 100 ml of rumen fluid. The individual acids were expressed as a percentage of the total molar concentration.

TABLE 4

STANDARD VFA SOLUTION FOR TRIALS I AND II

Acid	g/liter	mM/100 ml	Mole percent
Acetic	4.5724	7.6138	58.78
Propionic	2.3273	3.1416	24.26
N-Butyric	1.7752	2.0148	15.56
N-Valeric	0.1851	0.1813	1.40

Trial II

Experimental Design

Trial II was conducted concurrently with Trial I. Twelve cows (nine Ayrshires and three Holsteins) ranging from 590 kg to 770 kg body weight, were selected at about 4 weeks before calving. The animals were assigned to 4 groups (blocks) of three cows each based on breed and season of calving and randomly assigned to one of three treatments as follows:

(1) Positive control - 25:75 ratio of grain to hay prior to calving and 50:50 ratio thereafter,

(2) Negative control - grain mixture only, prior to and after calving,

(3) Grain plus polyethylene - 2.7 kg of polyethylene over a 12-day period.

Feeding and Management of the Animals

During a standardization period of approximately 2 weeks, the cows were adjusted to a ration containing 25% grain (table 1) and 75% hay (one-half alfalfa and one-half prairie). The energy requirements used to establish feed allowances during the dry period were calculated during the standardization period just prior to the transition period (from the preliminary feeding to the experimental rations described in table 3). Feed allowances were calculated on the basis of live body weight and pregnancy requirements using net energy requirements as listed by Richardson (1967) for dairy cattle. From the time of calving until the 8 weeks after calving all animals were fed to maximum consumption while maintaining a 50:50 grain to hay ratio for the positive control animals. Body weight, milk yield and milk fat percentage recorded during the 7th week of lactation were used to calculate the feed allowances for the remainder of the trial. The feeding and housing of the animals in trial II followed exactly those described in trial I.

Data Collection

Daily milk production was recorded at each milking for each cow throughout the entire trial. The same methods were used for determining milk composition for individual cows as described in trial I.

Rumen samples were obtained, processed and analyzed exactly as described in trial I. However, rumen samples were collected at 4, 8, 12 and 16 weeks from the time of initial feeding of the polyethylene.

CHAPTER IV

RESULTS AND DISCUSSION

Trial I

Feed Consumption and Digestive Disturbances

The difference in total feed intake between the group fed grain plus hay, and the other two groups fed grain only or grain plus polyethylene, was largely a reflection of the difference in the grain:hay ratio. Although air-dry feed intake by the group fed grain plus hay and the all-grain group differed (figure 1), the energy intake for these two groups was about the same (table 5). These results are in agreement with Montgomery and Baumgardt (1965) who found that when the nutritive value of a ration was increased by grinding, pelleting or by the addition of increments of concentrates to the diet, dry matter intake decreased and energy intake remained relatively constant.

During the week when polyethylene was introduced, feed intake by the cows fed polyethylene dropped below that of the other group fed only grain. Reduced intake by the polyethylene group may be partially explained by the fact that three animals in this group went "off-feed" during the adjustment period and one never fully recovered feed intake equal to that of the other animals. Average feed intake by the polyethylene group gradually increased through the fifth week when three of the animals again went "off-feed" causing a decline which was never

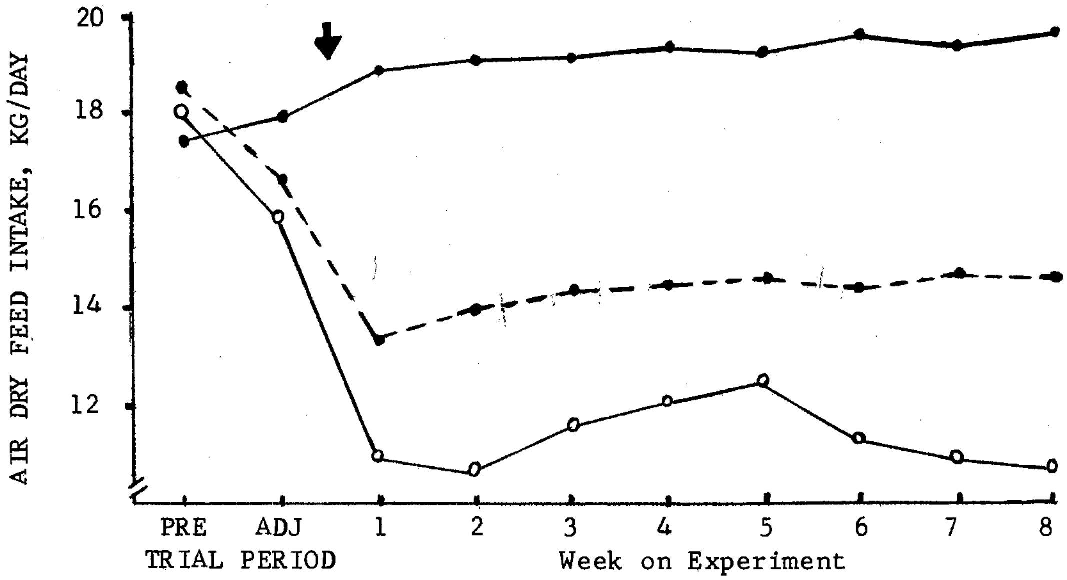

Figure 1. Average Feed Intake of Cows in Trial I. (Arrow indicates point at which polyethylene was first introduced in ration). (Treatment rations: ●———● grain + hay; ●----● all-grain; ○———○ all-grain + polyethylene).

TABLE 5

AVERAGE DAILY FEED INTAKE AND MILK PRODUCTION - TRIAL I

Item	Treatment		
	Grain + hay 50:50	All-grain	Grain + polyethylene
Air-dry feed intake, kg/day	19.3	14.4	11.3
Milk yield, kg/day	19.0[a]	19.3[a]	14.2[b]
Fat, %	4.1	3.4	3.5
Total solids, %	13.0	12.4	12.3
ENE intake Mcal/day	24.6	23.7	18.8

[ab] Means on the same line with different superscripts are significantly different (P<.05) according to Duncan's multiple range test.

regained before the end of the trial (table 6; Figure 1).

TABLE 6

INCIDENCE OF "OFF-FEED" CONDITIONS[a] DURING EIGHT WEEK TRIAL

Treatment	Week on trial									Total for 8-week period
	Adj. Period	1	2	3	4	5	6	7	8	
Grain + Hay	0	0	0	0	0	0	0	0	0	0
All-grain	2	3	1	0	1	0	1	1	0	7
Grain + polyethylene	3	1	0	1	1	0	3	1	1	8

[a] "Off-feed" is defined as the refusal of 10% or more of the daily feed allowance on two consecutive days.

Acceptance of the polyethylene was better than in previous trials Gonzalez _et al_. (1971) where 1.8 kg of polyethylene was introduced over a 4-day period instead of 2.7 kg polyethylene over 12 days. This was probably due to the smaller amount being offered each feeding. However, there was one animal, as mentioned earlier that did not readily consume the concentrate or polyethylene.

"Off-feed" was defined as refusal of 10% or more of the daily feed allowance on two consecutive days. Cows in the polyethylene group had a slightly higher incidence of "off-feed" conditions compared to cows fed an all-grain ration. No incidences were observed in the group fed grain plus hay (table 6). The addition of the polyethylene in this trial did not appear to reduce the incidence of "off-feed" conditions. All the animals fed the all-grain and all-grain plus polyethylene rations returned to normal feed consumption within two or three days after going "off-feed", except one animal in the polyethylene group. This indicated that these animals did not develop a very serious acidosis condition. However, one animal in the polyethylene group never fully recovered feed intake equal to that of the others in her group, indicating a possible case of acidosis. The above results are in contrast to what Gonzalez et al. (1971) reported. In their work, the incidence of animals being "off-feed" over all levels of hay were higher in the group receiving no polyethylene than in the other groups, the incidences being 12, 3 and 3 cases for the 0, 1.8 kg, and 1.8 kg + 1% daily levels of polyethylene, respectively.

There are several possible reasons to account for the differences observed between the two studies. The first factor considered should be the different methods of introduction of the polyethylene material. Gonzalez et al. (1971) introduced the polyethylene in equal increments at each feeding over a 4-day period while the hay in the ration was reduced simultaneously by equal increments to the designated level assigned. In this study, hay was removed from the ration over a 10-day period before the polyethylene was fed to animals designated to receive it. It is possible that more rapid introduction of the polyethylene in the previous study reduced the incidences of "off-feed" as continued feeding of polyethylene at 1% of the grain allowance was not beneficial.

Another factor to consider would be the differences in feed intake between the two studies. The average feed intakes for the animals in both studies on an all-grain diet with no polyethylene were about the same at 14 to 15 kg per day. The animals fed polyethylene in the study by Gonzalez et al. (1971) were consuming at a higher feed intake level than the group fed in this trial. It would seem that animals consuming more feed would show a higher incidence of going "off-feed", compared to animals on a lower rate of intake. Therefore, it would appear that level of feed intake was not the reason for the observed difference between the two trials. No other explanations are available for the difference in incidences of "off-feed" between the two trials.

Observations of Rumination

A limited rumination study was conducted using three blocks of animals. Observations were made 12 days after the initial feeding of the polyethylene "squares" to determine their effect on rumination (table 7). Cows on the grain plus hay diet definitely showed more rumination time than cows on the two all-grain diets. The grain plus hay ration resulted in a 2-hour lag period in rumination after grain feeding. Then there was a general increase in rumination with a total time ruminating for the 6-hour period of 85 minutes. The hay was fed 4 hours before the grain which may account for the lag period observed. These findings are in general agreement with Pearce (1965 a,b,c) who observed that a high level of roughage feeding was associated with a shortened lag period and a low level of roughage feeding resulted in a prolonged lag period. In contrast, cows fed all-grain diets show very little rumination with behavior resembling pseudorumination. These animals would regurgitate, with or without chewing and then re-swallow the material after a very short time. Freer and Campling (1965) and

Balch (1952) reported rumination did not occur with ground hay or with concentrates, although with ground hay and concentrate short periods of regurgitation were observed. The regurgitated digesta were swallowed shortly after reaching the mouth and regular jaw movements were absent.

TABLE 7

OBSERVATIONS ON RUMINATION TIME DURING A SIX-HOUR PERIOD 12 DAYS AFTER INITIATION OF TRIAL I

Treatment	Hour after feeding						Total for 6 hr.
	2nd	3rd	4th	5th	6th	7th	
	Time spent ruminating (minutes)						
Grain + hay	0	10	17	17	21	20	85
All-grain	0	0	0	1/3	2/3	6	7
Grain + Polyethylene	0	0	0	0	0	3	3

In terms of number of boluses and chewing time per bolus (table 8), the grain plus hay group was consistant in the time spent chewing a bolus with an average of 46 seconds per bolus. The total rumination time, over a 6-hour period for cows on the all-grain diet was slightly longer than for cows on the all-grain plus polyethylene diet. Evidence of this was 7 minutes spent ruminating by the all-grain group as compared to 3 minutes rumination time for the polyethylene group. However, in terms of the time spent chewing each bolus, there was a large difference between the two treatments. The polyethylene group was observed chewing each bolus an average of 90 seconds, possibly due to the polyethylene material in the diet, in comparison to 21 seconds per bolus for the all-grain cows (table 8).

TABLE 8

OBSERVATIONS ON FREQUENCY OF REGURGITATION DURING A SIX-HOUR PERIOD 12-DAYS AFTER INITIATION OF TRIAL I

Treatment	Hour after feeding						Total for 6 hr.	Time spent chewing/bolus
	2nd	3rd	4th	5th	6th	7th		
								Seconds
Grain + hay	0	12	24	22	26	26	110	46
All-grain	0	0	0	1	4	17	22	21
Grain + polyethylene	0	0	0	0	0	2	2	90

Oltjen *et al*. (1962) found the addition of 1, 2 and 4% polyethylene to a urea basal ration increased the time spent ruminating. However, when compared to a natural diet, which was composed of corn and alfalfa hay, there was actually very little increase in rumination on any of the purified diets. White and Reynolds (1969) observed rumination in steers fed a 20% level of polyethylene pellets but did not state the time spent ruminating.

Under the conditions of this trial, polyethylene did not promote an increase in rumination as observed in other studies, possibly due to feeding the polyethylene only one time rather than on a continuous basis.

Ruminal Volatile Fatty Acid Characteristics

The differences in molar percentages of volatile fatty acids (VFA) among treatments were fairly consistent throughout the trial (table 18 in the Appendix). Therefore, the average molar percentages of VFA were summarized over all periods at 2, 4 and 6 hours after feeding concentrates (table 9). Cows fed grain plus hay had significantly higher percentages of acetic acid ($P<.01$) and a lower percentage of propionic and valeric acid ($P<.05$) in comparison to both all-grain rations. After all hay was removed from the ration, a definite change occurred in the molar percentage of all the VFA. The results of removing hay from the ration were to lower percentages of acetic acid and correspondingly increase percentages of propionic and valeric acids in the rumen fluid of both all-grain diets. Cows consuming a 50:50 ratio of grain to hay had typical molar percentages of VFA. Tyznik and Allen (1951) stated that the ratios of rumen volatile fatty acids for cows on normal roughage intake were relatively constant with about 65% acetic, 20% propionic and 15% butyric acid. The addition of polyethylene to the ration in this study appeared to have no effect on proportion of VFA at 2, 4 or 6 hours after feeding. This was evident as the differences between the two all-grain groups were small and inconsistent (table 9).

Haskins et al. (1969) reported that steers at 66 and 115 days on a fattening ration with 5% ground polyethylene had a lower acetic and

TABLE 9

MOLAR PERCENTAGES OF VOLATILE FATTY ACIDS AVERAGED OVER ALL WEEKS - TRIAL I

Acid	Treatment	Hours after feeding 2	4	6
		Moles/100 ml		
Acetic	Grain + hay	62.87[c]	62.30[c]	65.17[c]
	All-grain	51.93[d]	52.04[d]	50.56[d]
	Grain + polyethylene	52.65[d]	51.13[d]	50.65[d]
Propionic	Grain + hay	22.69[a]	22.87[c]	21.19[c]
	All-grain	31.66[b]	31.87[d]	32.22[d]
	Grain + polyethylene	29.44[b]	30.64[d]	30.97[d]
N-Butyric	Grain + hay	12.72	13.26	12.24[a]
	All-grain	13.95	13.76	14.42[b]
	Grain + polyethylene	15.25	15.27	15.28[b]
N-Valeric	Grain + hay	1.69[a]	1.55[a]	1.39
	All-grain	2.42[b]	2.30[b]	2.78
	Grain + polyethylene	2.62[b]	2.93[b]	3.06

[ab] Means in the same column for each acid with different superscripts are significantly different ($P<.05$) according to Duncan's multiple range test.

[cd] Means in the same column for each acid with different superscripts are significantly different ($P<.01$) according to Duncan's multiple range test.

higher butyric acid percentage as compared to an all-concentrate ration. Ott *et al*. (1964) reported that the addition of a 2% level of polyethylene cubes to a purified diet for lambs resulted in a significant increase in butyric and valeric acids with a corresponding decrease in acetic acid. In contrast, Boling *et al*. (1969) observed that the percent of acetate tended to increase and the percent of propionate to decrease as the level of polyethylene was increased up to 10% to 20% in the diet.

The acetic to propionic ratios at 2, 4 and 6 hours after feeding concentrate are shown in table 11. The acetic to propionic ratios for cows on grain plus hay started out lower than would be expected but gradually increased as the trial progressed and also increased as hours after feeding increased. This could be a reflection of a slower rate of fermentation by these cows as the total concentration also increased with time after feeding (tables 10 and 11). The mean acetic to propionic ratios for this group were in the range 2.5 to 3.0. Baumgardt (1967) observed that the same ratio range promoted maximum gross efficiency and prevented a decline in milk fat test. In contrast, cows fed all-grain rations in the present work showed a definite decrease in acetic to propionic ratio in comparison with those fed grain plus hay, with the polyethylene group having a slightly higher acetic to propionic ratio over the all-grain ration (table 11). Boling *et al*. (1969) reported acetic to propionic ratios of 1.87, 2.03 and 2.90 for steers fed all-concentrate, all-concentrate plus 10 and 20% polyethylene particles (similar to that of hay ground on a 1.3 cm screen), respectively. However, Haskins *et al*. (1969) reported acetic to propionic ratios less than 1.0 (0.83 and 0.93 at 66 and 115 days on feed) when steers were fed

5% ground polyethylene as compared to 1.09 acetic to propionic ratios on all-concentrate ration.

TABLE 10

AVERAGE TOTAL RUMINAL VFA CONCENTRATIONS AVERAGED OVER ALL WEEKS - TRIAL I

	Hours after feeding		
Treatment	2	4	6
		mM/100 ml	
Grain + hay	9.67	9.57	10.74
All-grain	11.05	11.19	11.32
Grain + polyethylene	11.62	12.53	10.91

The acetic to propionic ratios were consistent with the decline in milk fat in the two all-grain groups. Since there were very few differences between the acetic to propionic ratios for the cows receiving all-grain and all-grain plus polyethylene, it would seem that the polyethylene did not substitute for roughage in terms of maintaining normal fermentation pattern in the rumen.

Higher energy diets usually result in higher concentrations of total VFA and higher percentages of propionate relative to acetate than do low energy diets (Balch *et al.*, 1955a) Diets rich in starch favor propionic acid production and, in general, feeds which are rapidly

TABLE 11

ACETIC TO PROPIONIC ACID RATIOS AT INTERVALS AFTER FEEDING DURING WEEKS ON TRIAL I

Weeks on trial	Treatments								
	Grain + hay			All-grain			Grain + polyethylene		
	Hours after feeding			Hours after feeding			Hours after feeding		
	2	4	6	2	4	6	2	4	6
2	2.35	2.20	2.80	1.62	1.89	1.73	1.69	1.43	1.43
4	2.73	2.82	3.59	1.62	1.52	1.55	1.83	1.74	1.67
6	2.86	2.78	2.72	1.62	1.62	1.48	1.76	1.75	1.74
8	3.13	3.12	3.34	1.70	1.54	1.53	1.88	1.78	1.73
Mean	2.77	2.72	3.08	1.64	1.63	1.57	1.79	1.67	1.64

fermented in the rumen give rise to less acetic acid (Balch _et_ _al_., 1955a; Chalupa _et_ _al_., 1970).

There was a non-significant increase in total concentration of VFA for the cows on both all-grain rations compared to the grain plus hay ration (table 10). These results are in agreement with Davis (1967) who found the difference in total VFA concentrations were not significant, although there was a trend toward a higher VFA concentration in the rumen of cows fed a high grain diet.

Milk Yield and Composition

Average milk production for the cows fed polyethylene during the adjustment period was essentially the same as that of the other groups. However, as noted earlier, feed intake of the polyethylene group dropped below that of the group fed only grain during the week the polyethylene was introduced (figure 1). This may account for the lower milk production by this group. Milk production was significantly lower ($P<.05$) during the sixth, seventh and eighth weeks of the trial (table 12). The point where milk production is significantly lower also corresponds to the time that three animals of the polyethylene group went "off-feed" causing a reduction in feed intake (table 6; figure 2). In general, milk yields were a reflection of feed intake. These findings are in agreement with Ronning and Laben (1966), Putman and Davis (1969) and Nelson _et_ _al_. (1968) who found no significant response in milk production with an increase of concentrates in the ration above 75 percent.

The percentages of milk fat were about the same for all three treatments until the third week of the comparison period. At this

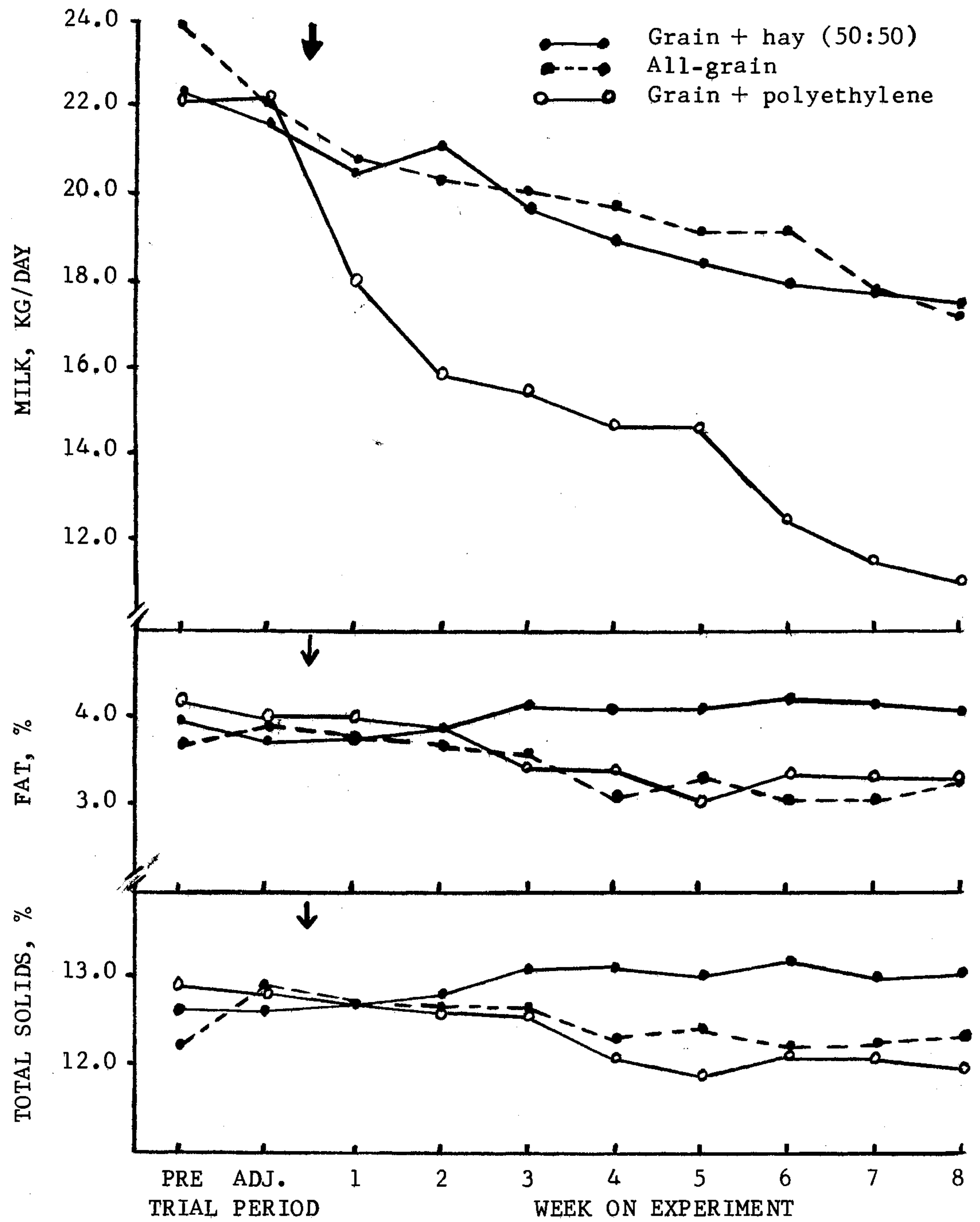

Figure 2. Average Daily Milk Yield and Composition for Cows in Trial I. (Arrow indicates point at which polyethylene was first introduced in ration.)

TABLE 12

AVERAGE DAILY MILK YIELD AND COMPOSITION - TRIAL I

		Week on experiment							
Item	Treatment	1	2	3	4	5	6	7	8
Milk Yield kg/day	Grain + hay	20.5	21.2	19.9	18.9	18.5	18.0^{a}	17.8^{a}	17.5^{c}
	All-grain	20.9	20.4	20.1	19.7	19.2	19.2^{a}	17.8^{a}	17.3^{c}
	Grain + polyethylene	17.9	15.8	15.5	14.7	14.7	12.7^{b}	11.6^{b}	11.1^{d}
Milk fat percentage	Grain + hay	3.8	3.9	4.1	4.1^{a}	4.1^{a}	4.2	4.2	4.1
	All-grain	3.8	3.7	3.6	3.1^{b}	3.3^{b}	3.4	3.3	3.3
	Grain + polyethylene	4.0	3.9	3.5	3.4^{a}	3.1^{b}	3.4	3.3	3.3
Total solids percentage	Grain + hay	12.7	12.8	13.1	13.2	13.1	13.2	13.0	13.0
	All-grain	12.8	12.6	12.7	12.3	12.4	12.2	12.3	12.4
	Grain + polyethylene	12.7	12.6	12.6	12.1	11.9	12.1	12.1	12.0

^{ab} Means in the same column for each item with different superscripts are significantly different ($P<.05$) according to Duncan's multiple range test.

^{cd} Means in the same column for each item with different superscripts are significantly different ($P<.01$) according to Duncan's multiple range test.

point, the cows fed all-grain diets dropped approximately 0.8% lower than the group fed hay and grain (figure 2). An increase in milk fat percentage was observed for the grain plus hay group when milk production was on the decline and the feed intake remained the same. The pattern of milk fat percentage observed for the all-grain diets seemed to be due to two factors working at the same time. A general decrease in milk fat percentage would be expected from cows fed an all-grain diet. Also, there would be an expected increase in milk fat percentages as milk production decreased. The combination of these two conditions gave rise to a lower and more stable milk fat production after the third week rather than a greater decline in milk fat percentage. These results are in general agreement with work reported previously by others (Ronning and Laben, 1966; Nelson et al., 1968; and Gonzalez et al., 1971).

The percentages of total solids were insignificantly lower for cows fed all-grain than in the group fed hay and grain (table 12). The total solids were a reflection of the milk fat percent and changed very little until the third week when the milk fat percentage changed.

Both all-grain treatments had the same effect on milk composition during the eight-week trial. In general, milk composition reflected VFA patterns in the rumen and was related to the decline in actual milk production which was influenced by feed intake.

Under conditions of this experiment, polyethylene was not an effective substitute for natural roughage in maintaining milk composition in terms of milk fat and total solids.

Trial II

Feed Consumption and Digestive Disturbances

Feed intake during trial II followed the general pattern observed in trial I. The differences in total air-dry intakes were reflections of the changes in the grain to hay ratio. However, the overall average intakes for all groups were lower than in trial I (table 13). The lower intakes in trial II resulted from the differences in feed requirement because the animals in the two trials were in different stages of lactation. The animals in trial II were consuming feed at a lower rate than those in trial I until six or seven weeks after calving. After the eighth week of the experiment, the animals in trial II consumed feed at nearly the same rate as animals in trial I during the first week. Energy intake by cows fed all-grain rations did not reach the same level as that of cows fed the grain plus hay ration (table 13). Intakes of both all-grain rations steadily increased through the seventh week after which the cows fed the polyethylene ration decreased in feed intake. After this drop in feed intake, the cows fed polyethylene steadily increased in feed consumption until the end of the trial. Cows on the all-grain diet dropped in feed intake to about the same level as the polyethylene group during the eleventh week of lactation (figure 3).

The decrease in intake of both all-grain diets corresponds to the periods when animals in each group exhibited "off-feed" conditions. The lower intake of cows fed polyethylene as compared to those fed the all-grain diet were generally a reflection of the incidences of "off-feed" (table 14). Cows fed polyethylene had a higher frequency of

TABLE 13

AVERAGE FEED INTAKE AND MILK PRODUCTION OF COWS AFTER CALVING - TRIAL II

Item	Ration treatment: Grain + hay	Ration treatment: All-grain	Ration treatment: Grain + polyethylene
Air-dry feed intake, kg/day	18.9	11.5	9.9
Milk yield, kg/day	22.4	18.4	18.5
Fat, %	3.9	4.0	3.7
Total solids, %	13.01	12.75	12.01
ENE intake, Mcal/day	24.0	18.9	16.2

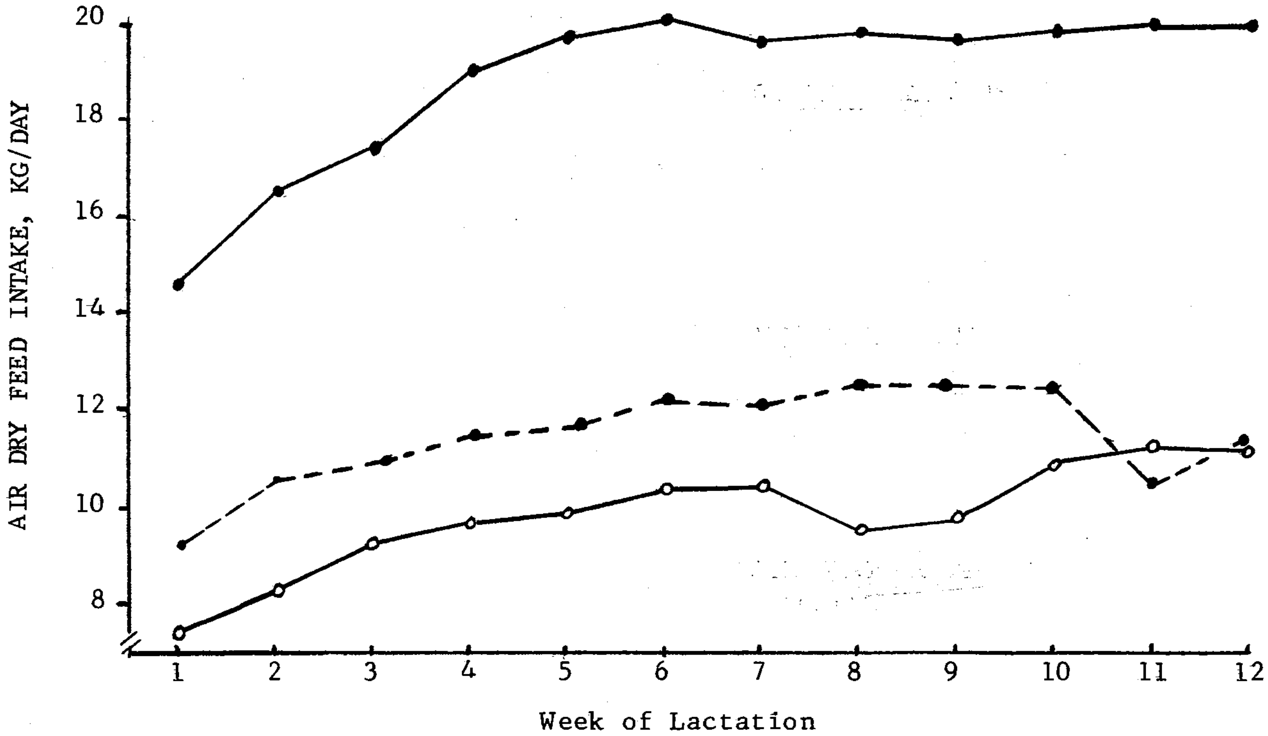

Figure 3. Average Feed Intake of Cows After Calving in Trail II (Treatment rations: ●——● Grain + hay; ●----● All-grain; o——o All-grain + polyethylene).

TABLE 14

INCIDENCE OF "OFF-FEED" CONDITIONS[a] DURING TWELVE WEEK LACTATION PERIOD - TRIAL II

Treatment	Weeks of lactation												
	1	2	3	4	5	6	7	8	9	10	11	12	Total for 12-week period
Grain + hay	0	0	0	0	0	0	0	0	0	0	0	0	0
All-grain	0	1	1	1	0	2	0	1	0	2	0	1	9
Grain + polyethylene	0	2	2	2	1	1	0	2	0	1	0	1	12

[a] "Off-feed" is defined as the refusal of 10% or more of the daily feed allowance on two consecutive days.

"off-feed" condition during the early weeks of lactation, whereas those fed all-grain had higher frequency of "off-feed" condition during the latter weeks of lactation. The pattern of incidence of "off-feed" conditions follows that observed in trial I. However, the incidence of "off-feed" conditions were higher for trial II probably due to the fact that the animals were on experiment for a longer period of time.

<u>Ruminal Volatile Fatty Acids Characteristics</u>

The average molar percentages of volatile fatty acids at 2, 4 and 6 hours after feeding are shown in table 15. The overall means for all three rations were higher for acetic acid and lower for propionic acid for trial II than in trial I (tables 9 and 15). However, the general trends exhibited among the treatments were about the same for the two trials. These observed differences between trial I and trial II may be due to a longer adaptation period and a lower level of intake during the initial stages of the comparison period for the animals in trial II. Cows fed grain plus hay had acetic and propionic acid values typical for this kind of ration. Acetic acid was higher and propionic acid lower than in cows in the two all-grain diets.

The percentages of acetic acid in the cows fed all-grain were slightly higher than in those fed the polyethylene diet. However, both groups followed the same downward trend as hours after feeding increased (table 15). At the same time, the cows fed polyethylene had a slightly higher percentage of propionic acid than those fed the all-grain diet, and both had a steady increase in percentage of propionic acid as hours after feeding increased.

All the acetic to propionic ratios were higher for the three treat-

TABLE 15

MOLAR PERCENTAGES OF VOLATILE FATTY ACIDS AVERAGED OVER ALL WEEKS - TRIAL II

Acid	Treatment	Hours after feeding 2	4	6
		Moles/100 ml		
Acetic	Grain + hay	65.49[c]	66.56[c]	66.21[c]
	All-grain	56.75[d]	57.73[d]	54.45[d]
	Grain + polyethylene	55.41[d]	56.01[d]	52.90[d]
Propionic	Grain + hay	20.72[c]	20.53[a]	20.82[a]
	All-grain	26.77[d]	26.14[b]	27.77[b]
	Grain + polyethylene	27.49[d]	28.11[b]	29.53[b]
N-Butyric	Grain + hay	12.39	11.52	11.71[a]
	All-grain	14.44	13.96	15.55[b]
	Grain + polyethylene	14.62	13.06	14.49[b]
N-Valeric	Grain + hay	1.37[a]	1.37[c]	1.23[a]
	All-grain	2.04[b]	2.17[d]	2.24[a]
	Grain + polyethylene	2.46[b]	2.81[d]	3.07[b]

[ab] Means in the same column for each acid with different superscripts are significantly different (P<.05) according to Duncan's multiple range test.

[cd] Means in the same column for each acid with different superscripts are significantly different (P<.01) according to Duncan's multiple range test.

ments in trial II than those observed in trial I (tables 11 and 16). The acetic to propionic ratios for cows fed grain plus hay were more in the range expected for a 50:50 ration of grain to hay than in the first trial. The acetic to propionic ratios were higher for both all-grain diets than those found in trial I and in contrast to those observed by Oltjen and Davis (1965). They reported acetic to propionic ratio of 1:1 in rumen fluid of steers receiving all-concentrate ration. However, the cows fed polyethylene had a slightly lower acetic to propionic ratio compared to those fed the all-grain diet, whereas in trial I the reverse was the case. Cows on both diets had a general decrease in acetic to propionic ratio through the twelveth week and then showed an increase again by the sixteenth week. The acetic to propionic ratios were generally consistent with the milk fat test observed for the two all-grain groups. The small difference between the two all-grain diets indicated that the addition of polyethylene to the grain ration had no effect on proportion of VFA at 2, 4 and 6 hours after feeding.

Total concentrations of VFA were lower, although not significantly, for cows on the all-grain diet as compared to the grain plus hay group (table 17). This is in contrast to the results observed in trial I where the cows fed all-grain diets had higher total concentration of VFA than the grain plus hay group. Balch _et al_. (1955a) found that high energy diets usually resulted in higher concentrations of total VFA. The cows fed grain plus hay diets exhibited a different pattern of total VFA than was observed in trial I. In trial I, the total VFA increased as the time after feeding increased while in trial II total VFA was higher and showed a decrease with time after feeding.

TABLE 16

ACETIC TO PROPIONIC ACID RATIOS AT INTERVALS AFTER FEEDING DURING WEEKS ON TRIAL II

Weeks on Trial	Treatments								
	Grain + hay			All-grain			Grain + polyethylene		
	Hours after feeding			Hours after feeding			Hours after feeding		
	2	4	6	2	4	6	2	4	6
4	3.12	3.39	3.14	2.51	2.51	2.15	2.33	2.56	2.19
8	3.18	3.35	3.39	2.13	2.56	2.43	2.03	2.05	1.83
12	3.53	3.24	3.11	1.76	1.72	1.70	1.80	1.78	1.54
16	2.87	3.01	2.93	2.00	2.19	1.69	1.93	1.71	1.68
Mean	3.16	3.25	3.18	2.12	2.21	1.96	2.01	1.99	1.79

These differences are probably due to the difference in feed intake for the two trials. In trial II, feed intake was less than feed intake by cows on trial I. The rate of fermentation for the cows in trial II reached a peak sooner than the cows in trial I. This was probably due to less substrate available for the microorganisms to synthesize acids in trial II than in trial I.

TABLE 17

AVERAGE TOTAL RUMINAL VFA CONCENTRATIONS AVERAGED OVER ALL WEEKS - TRIAL II

	Hours after feeding		
Treatment	2	4	6
		mM/100 ml	
Grain + hay	10.24	10.02	9.49
All-grain	9.06	9.79	8.32
Grain + polyethylene	10.06	10.61	10.70

Milk Yield and Composition

The average milk yield for the cows on the three rations in trial II are shown in table 13 and figure 4. The cows fed all-grain rations were lower in production than the cows fed grain plus hay. These results are in contrast to those in trial I where the animals fed all-grain ration had nearly the same production level as the grain plus

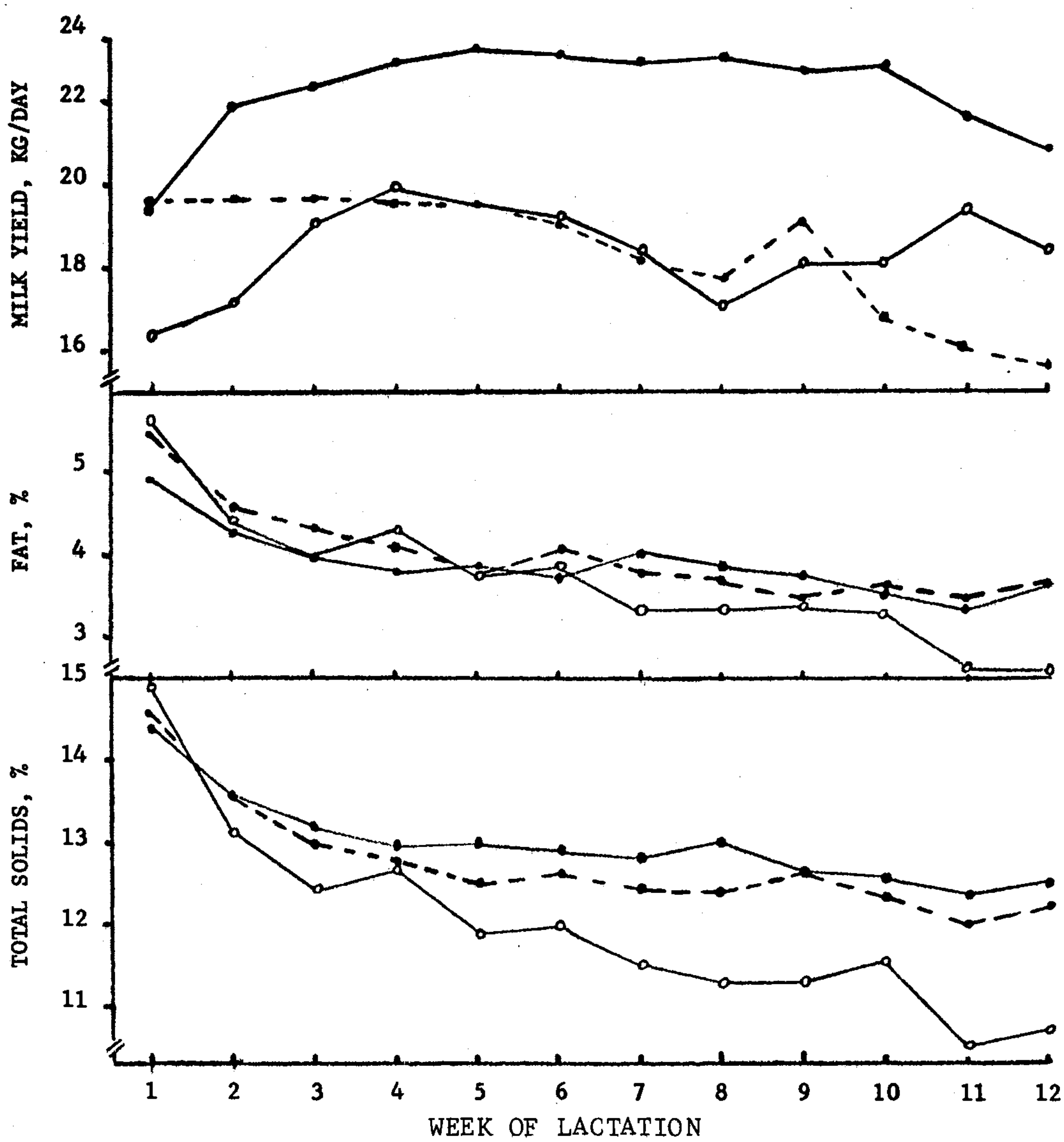

Figure 4. Average Daily Milk Yield and Composition for Cows in Trial II. (Treatment rations: ●———● grain + hay; ●----● all-grain; ○———○ all-grain + polyethylene).

polyethylene group. The lower production by cows on the all-grain diets probably reflects the lower feed intake by these groups compared to those of trial I. Milk production of the cows on these two rations was nearly the same except for the first two weeks and the last three weeks on trial. Production by the cows fed all-grain ration during the first two weeks was higher than the cows fed polyethylene, whereas during the last three weeks production was lower for the cows fed grain plus polyethylene ration. These differences are a reflection of feed intake for cows on the two rations.

Data for milk fat percentages are presented in table 13 and figure 4. The general trend for the cows on the three rations was a steady decrease in milk fat percentage until the fifth week of lactation where all three rations had nearly the same milk fat percentages. From this point, the cows fed the grain plus polyethylene fell slowly below the other two diets reflecting an increase milk production by this group (figure 4). Apparently, body stores were used for milk synthesis during the first 10 weeks following calving with the result that distinct differences in fat test due to different rations did not become apparent.

In general, the percent total solids were a reflection of milk fat test (figure 4). Cows fed polyethylene had a slightly faster rate of drop in percent total solids than the other two control groups which became significant during the eleventh and twelveth weeks after calving. In contrast to trial I, the percentage of total solids for cows fed the all-grain ration followed the same pattern as cows on the grain plus hay diet rather than the other all-grain ration.

Under the conditions of this trial, polyethylene added to the ration before calving did not substitute for roughage by maintaining milk composition in terms of milk fat and total solids percentages.

CHAPTER V

SUMMARY AND CONCLUSIONS

This study was conducted to evaluate the effectiveness of polyethylene "squares" as a substitute for natural roughage sources in dairy cattle rations. Two trials were used to evaluate different methods of introducing the polyethylene material in the diet.

In trial I, eighteen lactating dairy cows (nine Ayrshires, six Holsteins and three Jerseys) were selected 8 weeks after calving. The cows were divided into blocks of three on the basis of breed, season of calving and lactation number. Within blocks, the animals were randomly assigned to one of three treatments as follows: 1) grain plus hay (50:50), 2) all-grain and 3) all-grain plus 2.7 kg of polyethylene fed over a 12-day period at the beginning of the trial. The experimental rations were fed for an 8-week period.

In trial II, twelve cows (nine Ayrshires and three Holsteins) were selected at about 4 weeks before calving. The animals were assigned to four blocks of three cows each based on breed and season of calving, and randomly assigned to one of the same experimental rations in trial I. The polyethylene material was fed to the cows before calving at the level of 2.7 kg over a 12-day period.

Under the conditions of these trials, the addition of polyethylene "squares" in the ration did not appear to have any appreciable effect on feed intake or total milk yield. The polyethylene did not appear to be effective as a roughage substitute in terms of maintaining milk fat and total solids percentage during the trials.

It could be concluded on the basis of the proportions of volatile fatty acids in the rumen of cows fed polyethylene "squares" that this material did not substitute effectively for roughage in terms of maintaining a typical fermentation pattern in the rumen.

The incidence of "off-feed" conditions were not reduced by the inclusion of polyethylene "squares" in the diets of cows fed all-concentrates.

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APPENDIX

TABLE 18

AVERAGE WEEKLY MOLAR PERCENTAGE OF VOLATILE FATTY ACIDS AT FOUR HOURS AFTER FEEDING ON TRIAL I

Acid	Week on Trial	Treatments		
		Grain + Hay	All-grain	Grain + Polyethylene
			moles/100 ml	
Acetic	2	56.64	54.08	47.67
	4	63.18	51.25	50.37
	6	63.25	51.88	53.05
	8	65.33	50.95	53.43
Propionic	2	25.74	28.62	33.27
	4	22.42	33.73	29.00
	6	22.78	32.00	30.32
	8	20.95	33.15	29.98
N-Butyric	2	16.04	15.12	16.55
	4	12.96	12.90	17.33
	6	12.35	13.58	13.53
	8	12.12	13.45	13.67
N-Valeric	2	1.54	2.17	2.52
	4	1.44	2.10	3.27
	6	1.60	2.50	3.03
	8	1.58	2.43	2.90

TABLE 19

AVERAGE WEEKLY MOLAR PERCENTAGE OF VOLATILE FATTY ACIDS AT FOUR HOURS AFTER FEEDING ON TRIAL II

Acid	Week on Trial	Treatments		
		Grain + Hay	All-grain	Grain + Polyethylene
			moles/100 ml	
Acetic	4	67.50	58.77	59.85
	8	66.82	60.90	58.92
	12	66.35	53.17	50.82
	16	65.55	58.07	54.45
Propionic	4	19.90	23.40	23.37
	8	19.97	23.75	28.75
	12	20.50	30.95	28.55
	16	21.75	26.45	31.75
N-Butyric	4	11.37	15.42	14.10
	8	12.00	13.55	10.47
	12	11.62	13.77	15.87
	16	11.10	13.07	11.77
N-Valeric	4	1.15	2.40	2.65
	8	1.20	1.77	1.85
	12	1.55	2.10	4.72
	16	1.60	2.42	2.02

TABLE 20

WEEKLY FEED INTAKE FOR EACH COW ON TRIAL I

Treatment	Cow No.	Week on Experiment							
		1	2	3	4	5	6	7	8
		Kg							
Grain + Hay	775	70.7	76.2	73.0	74.9	76.2	77.1	77.5	77.5
	887	78.7	78.7	78.7	78.7	78.7	78.7	78.7	78.7
	404	62.9	62.9	62.9	62.9	62.9	62.9	62.9	62.9
	845	64.8	66.7	66.7	66.7	66.7	69.8	67.9	70.6
	912	51.4	51.4	51.4	51.4	51.4	51.4	51.4	48.2
	875	75.6	75.6	75.6	75.6	75.6	75.6	75.6	75.6
All-grain	674	101.7	116.4	117.9	120.5	122.5	125.4	126.4	119.6
	864	118.1	118.1	117.9	118.1	118.1	118.4	118.4	118.4
	802	106.0	109.8	118.7	120.2	118.5	121.1	122.9	110.9
	869	97.1	97.1	91.9	97.1	97.1	97.1	91.8	97.1
	738	46.3	56.4	62.6	57.0	64.8	52.5	65.8	70.7
	900	94.6	89.9	94.6	94.6	94.6	94.6	93.3	94.6
Grain + Polyethylene	902	90.9	80.7	87.1	92.1	100.7	111.6	109.7	99.9
	866	114.3	111.8	112.3	112.6	114.3	110.8	114.3	114.3
	876	24.4	17.4	29.9	27.3	34.4	30.5	34.1	29.1
	749	72.6	70.9	83.4	99.1	100.2	101.6	95.2	97.3
	810	95.5	94.6	90.9	89.2	94.3	84.6	80.6	71.0
	729	65.2	72.1	83.0	88.1	81.9	34.2	21.8	37.8

TABLE 21

WEEKLY FEED INTAKE FOR EACH COW FOR THE FIRST
12 WEEKS OF LACTATION - TRIAL II

Treatment	Cow No.	Week on experiment											
		1	2	3	4	5	6	7	8	9	10	11	12
		kg											
Grain + hay	896	60.8	64.6	65.8	66.7	69.8	65.5	59.7	59.7	59.7	59.7	59.7	59.7
	899	59.0	69.8	73.5	66.7	81.3	81.8	85.1	85.1	85.1	85.1	85.1	85.1
	679	45.8	52.6	59.9	68.6	71.1	71.1	71.1	71.1	69.2	69.8	71.1	69.0
	789	41.7	47.2	53.5	54.0	56.7	64.0	66.0	65.2	66.0	66.0	66.0	66.0
All-grain	854	62.3	75.1	78.1	81.0	75.1	81.0	76.8	93.9	91.7	99.1	55.4	64.6
	913	78.9	88.9	93.2	96.5	99.8	107.9	107.9	100.4	91.8	78.6	65.3	77.0
	742	65.3	76.2	81.6	88.9	90.2	92.9	93.3	93.3	93.3	93.3	93.3	92.2
	776	51.9	55.0	52.4	55.1	58.9	62.8	60.6	65.8	71.7	77.6	80.1	84.4
Grain + polyethylene	692	59.4	61.1	75.4	85.7	85.3	90.2	92.6	95.5	88.1	96.5	93.5	82.3
	819	80.7	90.7	96.6	99.8	107.0	109.3	110.8	90.9	102.9	110.2	115.6	118.8
	659	21.7	34.6	35.6	34.4	33.7	30.0	33.1	39.6	34.7	38.1	42.0	43.1
	773	47.3	44.7	53.3	52.2	51.1	60.0	54.0	39.8	47.3	59.9	65.1	68.5

TABLE 22

AVERAGE pH VALUES OF RUMEN FLUID FOR DIFFERENT WEEKS AT 2, 4 AND 6 HOURS AFTER FEEDING FOR TRIAL I

Weeks on Trial	Grain + hay			All-grain			Grain + polyethylene		
	Hours after feeding			Hours after feeding			Hours after feeding		
	2	4	6	2	4	6	2	4	6
2	6.50	6.58	6.62	5.92	6.10	6.52	5.72	5.65	5.83
4	6.36	6.56	6.48	5.67	5.95	5.83	5.43	5.88	6.02
6	6.60	6.72	6.58	5.92	6.18	6.08	5.61	5.62	5.97
8	6.50	6.30	6.60	6.08	5.78	5.90	5.70	5.78	5.75
Mean	6.50^{c}	6.54^{c}	6.57^{c}	5.90^{d}	6.00^{d}	6.08^{d}	5.62^{d}	5.73^{d}	5.89^{d}

^{cd} Means for each hour with different superscripts are significantly different ($P<.01$) according to Duncan's multiple range test.

TABLE 23

AVERAGE pH VALUES OF RUMEN FLUID FOR DIFFERENT WEEKS AT 2, 4 AND 6 HOURS AFTER FEEDING FOR TRIAL II

Weeks on Trial	Grain + hay: Hours after feeding 2	4	6	All-grain: Hours after feeding 2	4	6	Grain + polyethylene: Hours after feeding 2	4	6
4	6.32	6.42	6.77	6.67	6.77	6.75	6.20	6.20	5.95
8	6.40	6.50	6.62	6.22	6.37	6.55	5.70	5.82	6.15
12	6.30	6.52	6.67	5.77	5.87	6.15	5.52	5.40	5.82
16	6.60	6.50	6.37	6.37	6.35	6.45	5.70	6.07	5.85

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