USE OF POLYETHYLENE AS A ROUGHAGE SUBSTITUTE IN RATIONS FOR DAIRY CATTLE

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

CHAPTER I

INTRODUCTION

Considerable interest in all-concentrate rations for ruminants has been stimulated by recent data, mechanized feeding systems and a scarcity of economical roughage. However, all-concentrate rations are not compatible with proper physiological function and health of dairy cows. This is evident by the marked depression in the content and yield of fat in milk, the acidosis syndrome, cattle going "off feed," and other digestive disorders.

Several materials (cottonseed hulls, pineapple bran, ground corn cobs, rice hulls, newspaper, sawdust) have been used as a substitute for the usual roughage sources in complete rations that can be fed to dairy cows by means of automated equipment. Since these materials are not universally available and may be rather costly, the search continues for other material which can substitute effectively for the roughage component in the ration.

The possibility of replacing part or all of the roughage in dairy rations with an inert material that would remain in the rumen longer than usual feed ingredients merits investigation. If such material (i.e., polyethylene) could be substituted for roughage in the ration at a relatively low level with no impairment of the normal physiological function, it could be used to a great extent in complete rations for lactating dairy cows.

The objective of the work reported here was to evaluate the effectiveness of different levels of inert polyethylene "squares" as a partial or complete roughage substitute in rations for lactating dairy cows. The criteria used were: a) yield and composition of milk; b) biochemical characteristics of the rumen content; c) the rate of passage of ingesta from the rumen, and d) the incidence of digestive disorders.

A preliminary report of a portion of this work appeared earlier in abstract form (González et al. 1969).

CHAPTER II

LITERATURE REVIEW

Only a limited number of papers have appeared which deal directly with the use of materials that substitute for natural roughages sources. Other work related to feeding complete rations to cattle and the effect of ration variation on milk composition is also reviewed because of its relevance to the overall problem.

Complete Rations

In recent reviews on the subject of complete rations or blended feed, Rakes (1969) and Miller and O'Dell (1969) pointed out that the traditional methods for supplying nutrients to dairy cattle are being revaluated. The trend in some areas where cattle are milked in large herds is to use self-feeders or mechanical feeding devices to supply a complete feed as a labor saving management practice. According to Bath (1969) this practice requires only three hours of labor per day in comparison to 20 hours per day for conventional feeding. Moreover, the complete ration may induce the cows to consume roughage and concentrates in the proper proportions for maximum milk production.

The feed intake and the milk production of cows fed complete feeds have generally been comparable to that of those fed the roughage and concentrate portions of the ration separately (Putman and Davis, 1961). Villavicencio et al. (1968) evaluated three complete feed rations containing different sources of roughage and 1% urea against a conventional dairy cow ration in a 120 day-trial. Daily milk yield by the different groups was not significantly different ($P > .05$).

Voluntary Feed Intake

Voluntary feed intake is probably one of the most important factors determining total energy intake and output of ruminants. The nature of the stimuli involved in the control of voluntary feed intake by a ruminant has not been clearly established.

In most of the experiments in which widely varying ratios of grain to roughage have been fed to dairy cows the proportion of roughage included usually has been considerable, i. e., at least 20%. In a study to relate hay to concentrate ratio to voluntary feed consumption by lactating cows, Ward and Kelley (1969) fed alfalfa hay ad libitum and a concentrate mixture in specified test ratios: all-hay; 5.5:1; 2.2:1; 1:1. Variation among cows in consuming high-grain rations was greater than the variation resulting from different ratios of hay to concentrate (correlation +.83, ($P < 0.1$), and the authors concluded that physical fill regulates consumption of rations including 40% or more forage.

Cowsert and Montgomery (1969) conducted a study with Holstein heifers to determine whether the ruminant fed isonitrogenous rations of different energy concentration ranging from 0 to 67% concentrate has the ability to regulate the amount of food consumed to maintain a constant energy intake. Voluntary intake in this study appeared to be regulated to maintain equivalent intakes of energy, however, all the rations used were pelleted, possibly eliminating body fill as a factor regulating consumption.

Swanson et al. (1967) determined the effect of replacing half of the roughage with equivalent TDN from concentrate using 20 pairs of high producing cows during a complete lactation. Average daily dry matter consumption was not significantly different between the two groups (15.6 versus 15.7 kg), and changes in feed consumption paralleled changes in milk yield.

Freer and Campling (1963), found that the amount of indigestible residues remaining in the rumen was less with a concentrate ration than with hay rations, and it was concluded that the remanent present in the rumen at the time of feeding was not the factor limiting intake of concentrate rations.

In ruminants with diets of high energy concentration, voluntary food intake is thought to be regulated according to nutrient requirements for maintenance (metabolic size) and production. At low energy concentration, it appears to be dependent of rumen capacity, rate of passage and dry matter digestibility (Montgomery and Baumgardt, 1965; Forbes, 1970). Conrad et al. (1964), estimated that with dry matter digestibility up to 66%, intake was controlled by stomach capacity and related factors, whereas at higher digestibilities intake appears to be dependent on metabolic size, production and digestibility. This concept was also supported by the findings of Kesler and Spahr (1964) that maximum energy intake expressed as total digestible nutrients (TDN), was attained when concentrates comprised approximately 50-55% of the ration. McCullough (1969) also reported that daily dry matter intake was maximum when a diet of long hay and grain, fed separately, contained 80% concentrates and the net energy intake increased as the proportion of concentrates in the rations went from 60 to 90%, thereafter remained constant. Baile (1968) concluded that there is not evidence available to show that the mechanisms making possible long-term energy balance regulation is different in ruminants and non-ruminants, although it is quite likely that feedbacks and also the the receptors involved in the control of meal size or hunger and satiety do differ in the monogastric and in ruminant animals.

Efficiency of Milk Production

The net and gross energetic efficiencies for milk production have been studied by various authors. Coppock et al. (1964) found the net energetic efficiency for milk production was near maximal (or 65%) when the rations contained only 37% of concentrates. Owen et al. (1969) concluded that complete rations based on rolled barley should for maximum production include somewhere around 24-32% of a roughage similar to the coarsely milled barley straw used in their trial. No significant increases in milk production were reported by other authors (Bloom et al., 1957; Nelson et al., 1968) as a result of feeding lactating cows rations with levels of concentrates higher than approximately 50%.

Milk Composition.

The depression of the fat percentage in cow's milk by feeding rations containing high proportions of concentrates has been observed repeatedly. A widely accepted figure of 60% is given by Baumgardt (1967) as the maximum level of concentrates that will sustain normal fat percentage. In the opinion of Rakes (1969), 30% roughage is the level below which a definite drop in the fat content can be expected.

Several workers (Ronning and Laben, 1966; Myers, 1966; Swanson et al., 1967; Nelson, et al., 1968) have reported that there is a highly significant decrease in milk fat percentage as the proportion of concentrate is increased over 60% in the total ration. Kelley (1967), also reported that milk fat percentage was depressed by rations with 80% TDN supplied by concentrate. On the other hand, non-significant depression of the milk fat was noted by McCoy et al. (1966) as the result of feeding complete feeds having 70% concentrates, and Knestric et al. (1970) found no significant influence on the fat test when a high-concentrate ration having a 4:1 grain to hay ratio was fed at 4 levels of intake. Bloom et al. (1957) also reported no depression of fat percentage from feeding rations in which 85% of the estimated net energy was from concentrates. A significantly higher ($P < .05$) percentage of total milk solids was reported by Zeremski et al. (1965) as a result of feeding a similar high-grain ration.

Van Soest (1963) has discussed extensively the metabolic factors related to the depression of the fat percentage in milk. Several authors (Ghorban et al., 1966; McCullough, 1966) have 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. Kelley (1967) completed studies on rumen infusion of volatile fatty acids (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. On the other hand, Davis (1967) concluded that an absolute shortage of acetate because of a reduction in the amount of acetate produced in the rumen was not responsible for the depression in the milk fat percentage.

Other researchers (Jorgensen et al., 1965; Opstvedt and Ronning, 1967; Chalupa et al., 1970) working with cows on milk fat depressing rations have concluded that one of the major factors influencing milk fat changes was an alteration in the 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. McCullough et al. (1969) reported that a small insignificant increase in milk fat test from sodium acetate and a non-significant decrease in test from sodium propionate when the compounds were included as additives to all-in-one rations for milk production. The composition of the grain mixture, the type of carbohydrate, and the source of fiber are additional factors studied in connection with reduced milk fat content and major changes in VFA ratios (Balch et al. 1955 a,b; Kellogg, 1969; Lofgren and Warner, 1970.)

Storry (1970) summarized the problem by stating that although findings differ in detail from one worker to another owing to the wide variety of diets and breeds of cow used, it is now becoming evident 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 proportion of ruminal VFA generally characterized by decrease of acetate and butyrate and increasing proportion of propionate and valerate. The initial fall in pH is thought to be due to a diminished secretion of saliva and hence buffering capacity of rumen digesta, which then allows the survival of a microflora producing the change in pattern of VFA. There is a marked fall in the rate of cellulose digestion and an absence of protozoa in the rumens of cows on low roughage diets and with depressed milk fat secretion. In addition, this author suggested that these changes in rumen microflora may also have important repercussions in the synthesis and metabolism of lipids in the rumen, especially in view of the role of protozoa in the hydrogenation of unsaturated acids and the fact that fat from cows established on low roughage diets have increased proportions of unsaturated and decreased proportions of saturated acids.

Saliva Secretion

The effect of the nature of the ration (roughage versus concentrates) on the total amount of saliva secreted and its buffering effect on the rumen contents which influences ruminal pH and VFA values is not entirely clear. Wise et al. (1968) stated in a review on work with rations for finishing beef cattle that buffering capacity of the rumen is dependent on amount of saliva produced which in turn is highly dependent upon the amount of time spent in rumination. Diets high in readily fermentable starch and sugars are known to cause a marked reduction in rumination which in turn reduces flow of saliva. This reduction may cause the rumen buffering capacity to decrease (saliva is high in bicarbonates), allowing the pH to remain low.

Rumsey et al. (1969) reported a statistically non-significant ($P < .05$) tendency toward an increase in salivary flow with increased feed intake of a pelleted high roughage (81.0%) diet.

Hawkins and Little (1968) made a study to determine some of the metabolic effects of substituting $NaHCO_3$ solution for saliva and of varying the quantity of saliva entering the rumen of dairy cattle over periods of several days. There was evidence that as the amount of saliva or other buffer entering the rumen increased, the mean pH or rumen contents increased. When two times the volume of saliva secreted was added to the rumen of steers it had a pronounced ($P < .05$) depressing effect on rumen VFA concentration and absorption.

Oltjen et al. (1967), found that total salivary secretion during a 90-minute period starting at 2 hours after feeding was significantly lower ($P < 0.05$) when steers were fed an all-concentrate milo ration compared to a corn diet. 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 the all-concentrate rations. Buffering capacity of the collected saliva did not differ statistically between diets, although the flow appears to be depressed in two of the rations (wheat and milo). Oltjen et al. (1969) found that saliva pH and buffering capacity both increase from 2 to 6 hours after feeding and concluded that this may be related to the increased flow rate. Ruminal pH _per se_ seemed to have little influence on saliva flow.

Wilson and Tribe (1963) found that the effect of feed grinding depended on the size of particles produced. The daily parotid secretion was increased by 25% when hay was ground through a 1/16 in. screen, but was decreased by 61% when ground through a finer screen. Balch (1958) found that for 10 lb. of hay consumed 43 to 57 lbs. of saliva were added during eating, but consumption of 10 lb. of concentrates resulted in the production of only 12 to 15 lb. of saliva.

Digestive Disturbances

Several health difficulties related directly to the use of high concentrate rations are rumen parakeratosis, liver abcesses, laminitis and other digestive disturbances. Myers (1966) found some indigestion in cows fed a ration with more than 70% concentrate, but gave no specific figures.

Tremere et al. (1968), working with yearling dairy heifers, tested the hypothesis that a limitation to rapid adaptation to high intake of concentrate feeds is due to high concentrations of organic acids within the rumen, particularly lactic acid, which results in low rumen pH. A daily increment of somewhat less than 7.0 g concentrate per unit of metabolic body size in combination with a feeding frequency of at least two times per day was necessary to avoid "off-feed" in yearling dairy heifers. An adaptation period of at least three weeks was necessary to prevent this problem in heifers used in this study. High rumen acidity did not appear to be the only cause for animals to go off-feed since buffers administered either by intraruminal infusion or feeding did not prevent the problem.

Roughage Substitutes

The concept of complete rations has served to develop considerable interest concerning the use of new products for roughages substitutes which would eliminate the adverse metabolic effects of feeding very high levels of grain.

The kind of materials that have been found satisfactory as substitutes for the usual roughage sources in complete rations for ruminants include native grass hay, cottonseed hulls, and ground corn cobs as reported by McCoy et al. (1966) and Villavicencio, et al. (1968).

Bringe and Schultz (1969) fed lactating cows four rations with a grain:roughage ration of 3:1 to investigate the effects of roughage type or added bentonite in maintaining milk fat test. There was no difference between different forms of roughage in their ability to maintain fat percentage when the rations were fed at the rate of 3:1 (grain:hay). Sodium bentonite was studied here as a possible roughage replacement or bulking agent that has characteristics suggesting a beneficial effect in maintaining milk fat test when high levels of concentrate are fed to cows.

Hansen et al. (1969) reported that 15% paper added to a grain sorghum ration for feed lot cattle resulted in weight gains that were 9% greater than those of animals fed the same basal ration with 15% alfalfa hay, and Daniels et al. (1970) concluded that ground newspaper may replace at least 12% of the diet of growing dairy steers without reducing feed efficiency, gain, grade and carcass quality. Oyster shell has been used extensively as a roughage replacer in fattening beef cattle rations with variable results (Perry et al., 1968; Williams et al., 1970). White et al. (1969) fed two levels of rice hulls, rice straw and alfalfa hay to beef steers and concluded that the response to roughage level depends on the source of roughage used for fattening rations. Baker and Millett (1970) found no significant effects on milk yield, but highly significant differences ($P < .01$) between means for milk fat percentage when Aspen sawdust replaced up to 32% of the hay in a 50:50 ration.

Hughes et al. (1964) reported promising results when 20% of the concentrate ration fed to steers was polyethylene, but Carr and Jacobson (1967) in a study on feed intake with steers found that the inclusion of a very high level of polyethylene cubes, 22.6% of the ration, resulted in discrimination against the cubes. Ott et al. (1964), added 3 mm polyethylene cubes to a purified diet for lambs at a 2% level with the result that there was a significant increase in the percentage of butyric and valeric acids and a corresponding decrease in acetic acid. Smith (personal communication) fed semi-purified ration to calves with polyethylene cubes at a 3% level in comparison to the same ration without added inert material. Weight gains of the calves receiving polyethylene cubes was 1.45 lb./day compared to 1.75 lb./day for the control calves. Ruminal VFA, pH and buffering capacity were not affected by the addition of the inert material. Also, no improvement in rumination was noted.

In contrast, Virtanen (1966) reported that the inclusion of 0.5 kg per day of polyethylene pellets in purified diets for dairy cows promoted a marked increase in rumination.

Boling et al. (1967) fed steers diets containing from 14.2 to 29.3% shredded polyethylene having a specific gravity of .91 to .96. A trend toward compensatory feed intake to meet energy requirements was observed when increased fill and dietary density, palatability or quality were not factors decreasing feed intake. The average again 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 effects of diets containing polyethylene on gastrointestinal fill were apparent in the reticulorumen, with little effect on the weight of small and large intestine contents. 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 diet. 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, i.e., 14.7 and 29.3%, respectively. Later Boling, et al. (1969) investigated the short-term effects of total diet dilution with 10% and 20% polyethylene particles and concluded that the reticulo-rumen fill limited feed intake when steers were fed an 80% ENE diet and that increased fill was due to polyethylene accumulation. The relative percentage of ruminal VFA were not significantly altered by total diet dilution with polyethylene; however, a trend of increased acetate and decreased propionate was observed in those steers fed the diluted diet. A continuous turnover of polyethylene particles in the rumen also was observed.

Derrickson et al. (1965) found that the rate of passage of inert plastic particles, having a specific gravity of 1.425 and physical characteristics similar to feed, through the digestive tract of steers decreased as the size of particles increased in diameter within the range of 0.6 to 4.76 mm. Similar results were reported by Campling and Freer (1962) who tested several materials in four experiments with cows and concluded that the mean retention time of inert particles of sp.gr. 1.20 was directly related to the size of particles within the range 17-58 mm^3. The largest particles were found to be retained an average of 12% longer than the smallest ones. There was an almost linear relationship between diameter of particles and mean retention time.

Welch (1967) introduced polypropylene fibers of various lengths (3.5, 7.0, 15.0 and 30.0 cm) similar to hay stems in shape and texture into rumina of wethers. Fiber introductions into the rumen caused reduction in hay intake greater in magnitude than the proportional amount of fiber added.

Bush and Stout (unpublished data) used polyethylene "squares" having a density of .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 a level of 1% of the grain mixture did not prevent a rather marked depression in milk fat test when the percentage of concentrate 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 regurgitated 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.

Dinius et al. (1970) tried fourteen potential roughage substitutes included at a level of 10% of the complete rations fed ad lib. to sheep in a meal form. These materials were: Aspen sawdust, oak sawdust #1, oak sawdust #2, hardwood shavings, oak flooring waste, verxite expanded, verxite flakes, kaolin clay #60W, kaolin clay #52, 3% clay 60W + 7% sawdust #2, 3% clay #52 + 7% sawdust #2, ground corn cobs, furfural (corn cob) residue, sugar cane bagasse. No adverse effect on digestible energy intake was evident, and no noticeable food selection was practiced by the animals on any of the materials, except flooring waste, expanded verxite, and bagasse.

CHAPTER III

EXPERIMENTAL PROCEDURE

Trial I

Design of Experiment

Eighteen Holstein cows (9 mature and 9 first lactation animals) were used in an eight-week trial in which ration treatments were assigned according to a 3 x 3 factorial design with three levels of polyethylene and three levels of alfalfa hay as follows:

The levels of polyethylene squares were:

(1) None.

(2) 1.8 kg introduced during first four days of trial.

(3) 1.8 kg feed during the first four days of trial plus 1% of the grain allowance daily. (This amount actually ranged from 100 to 170 grams per day.)

Levels of hay were:

(1) None.

(2) 10% of total ration (air-dry basis).

(3) 20% of total ration (air-dry basis).

The cows were divided into two blocks of mature and first lactation cows for the purpose of assigning ration treatments. Within each block, the cows were assigned at random to the nine treatments.

Selection, Feeding and Management of the Animals

During a pre-trial period starting three weeks before calving and extending to nine weeks after calving the cows were fed a 50:50 ratio of grain to hay to maximum consumption. At the beginning of the comparison period, and at the end of the fourth week of the trial, feed allowances were adjusted to meet net energy requirements. The rations were calculated on the basis of live body weight, age, milk yield, and 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 comparison period, and initial fat test was the average of the fat test for the previous three weeks.

The grain mixture (Table I) was calculated to contain 1.65 Mcal estimated net energy (ENE)/kg and 74% 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 operation being supervised by a member of the dairy research group.

At the start of the trial, 1.8 kg of polyethylene pellets were fed to each animal, except those in the zero level group, in equal increments at each feeding over a four-day period. The percentage of hay in the ration was reduced simultaneously by equal increments to the designated level. 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 Table II, using one of the cows which received no hay during the comparison period.

TABLE I

CONCENTRATE RATION, USED IN BOTH TRIAL I AND II

Ingredient	(%)
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

TABLE II

CALCULATION OF INITIAL FEED ALLOWANCE FOR ONE COW IN TRIAL I

Item	
Requirements (Mcal ENE):	
Maintenance (625 kg body weight)	8.4
Growth (first lactation)	1.5
Milk production (25.0 kg/day; 3.0% fat)	18.0
Total estimated net energy required	27.9
Amount of feed needed:	

Day	Ratio of Grain to Hay	Mcal/kg of Ration	Total Theoretical Amount Feed/Day,kg	Actual Amount Fed/Day, kg	
				Grain	Hay
0	50 :50	1.27[a]	22.0[b]	10.5	10.5[c]
1	62.5:37.5	1.36	20.5	12.8	7.7
2	75 :25	1.46	19.1	14.3	4.8
3	87.5:12.5	1.55	18.0	15.8	2.2
4	100 :0	1.65	16.9	16.9	0.0

[a] Grain mixture (1.65 ÷ 2) + alfalfa hay (0.88 ÷ 2).
[b] Calculated as total ENE required: 27.9 ÷ 1.27 = 23.5 kg.
[c] The amount for the first day was adjusted to the actual feed consumption.

Any polyethylene refused during the initial four-day period was fed again to the animal at the next feeding. This procedure was continued for 2 to 3 days beyond the initial four days as necessary to insure that essentially all of the 1.8 kg. of plastic was consumed. Two cows which refused to consume the plastic material during this period of time were eliminated from the trial and replaced with other cows.

The groups designated to receive polyethylene on a continuous basis were afterward fed a one percent level of polyethylene with the grain mixture. At each feeding this was added to the grain and mixed before feeding. Any of the daily allotment of plastic which was refused was discarded along with the refused feed. No attempt was made to measure the amount of the daily allowance of plastic which was refused.

A Toledo fan scale was used for weighing the feed and polyethylene. Feed consumption was recorded daily. Each cow was assigned a manger in a conventional stanchion barn and the grain allowance was fed in two equal amounts one hour prior to each milking; the feed remaining in the morning, after the P.M. and A.M. feeding, was weighed back and recorded. The daily allotment of hay was weighed separately for each cow and fed in the same individual stall at the same time that the grain was fed. The cows ate readily the mount of hay offered; thus, the refusal of hay was practically negligible. Water was available both in the stanchion and in the holding lots. The cows were milked twice daily and kept in an outside holding lot during the day.

Data Collection

Daily milk production records were kept throughout the entire experiment. Individual milk samples corresponding to four milkings during the two consecutive days were taken every week starting with the Monday P.M. milking, and kept under refrigeration until time for analysis. The four samples were then warmed to $37^{\circ}C$ in a water bath and composited in proportion to the milk weight corresponding to each sample. The composite samples were assayed for milk fat percentage by the Babcock procedure. The total solids were determined by drying a 3 ml milk sample placed in a special aluminum foil dish for 4 hr. at $100^{\circ}C$ in a forced-air oven.

Body weights of the cows were recorded for three consecutive days prior to the day of the beginning of the trial, four weeks later, and at the end of the trial. The weights were always taken after the P.M. milking.

Ruminal ingesta was sampled at four hours after feeding prior to the comparison period and during the second, fourth, and eighth weeks of the trial. Prior to the trial and during the second week, samples were also taken before feeding and at 2,6, and 8 hours afterwards. Samples were collected by passing a stomach tube equipped with a stainless steel filter through the esophagus into the rumen. A hand-operated suction pump was used. The pump stomach tube and collection container were flushed with water between each sampling. The pH of the rumen ingesta was determined immediately with a glass electrode Beckman pH meter. Bacterial action in the rumen fluid was inhibited by the addition of 0.3 ml of a saturated solution of mercuric chloride per 50 mo. of rumen fluid. The samples were then centrifuged, and the supernatant kept under refrigeration until the samples were prepared to be analyzed for VFA by gas-liquid chromatography, using the technique described by Erwin et al. (1961).

An Aerograph Model 600-D was used for making the VFA analysis. Operating conditions of the instrument were as follows: 1) Oven temperature 135°C., 2) injector temperature 160°C., 3) carrier gas (Nitrogen) flow rate at detector head, 20 ml per min., 4) hydrogen flow rate to detector, 20 ml per min., 5) column material, neopentylglycol succinate (20% NPGS on 60/80 firebrick treated with 3% H_3PO_4).

A VFA standard solution (Table III) of the acids 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 in micromoles per 100 ml of rumen fluid and the individual acids expressed as a percentage of the total molar concentration.

Trial II

Experimental Design and Management of the Animals

Three fistulated animals, i.e., two steers and one non-lactating cow, were used in a 12-week study to find the rate of disappearance of ingested polyethylene from the rumen-reticulum. The animals were randomly assigned to a rotational type design (Latin square) with three periods and three levels of polyethylene as used in Trial I (Table IV). A two-week interval between periods was established to take care of any carry-over effects. The animals were kept in individual pens, each

TABLE III

STANDARD VFA SOLUTION FOR TRIAL I

Acid	g/liter	mM/100 ml	Mole Percent
Acetic	4.4310	7.3750	63.44
Propionic	2.0139	2.7167	23.37
n-Butyric	0.9157	1.0417	8.96
iso-Butyric	0.1846	0.2083	1.80
n-Valeric	0.1684	0.1667	1.43
iso-Valeric	0.1151	0.1167	1.00

TABLE IV

DISTRIBUTION OF THE FISTULATED ANIMALS IN THE EXPERIMENTAL DESIGN[a]

Periods (1969)	None	1.8 kg initially	1.8 kg initially plus 1% of the grain ration, daily
I April 19 to May 16	333	469	526
II May 31 to June 27	469	526	333
III July 12 to Aug. 8	526	333	469

[a]Numbers 469 and 526 corresponded to the steers; Number 333 was a cow.

having an adequate dry lot for exercise, automatic drinking cups and shade. Sand was used for bedding since the animals developed a craving appetite for regular bedding materials. During a three-week pre-trial period the animals were fed a 50:50 ratio of grain to alfalfa hay.

Feed allowances (grain and hay) were calculated at twice the maintenance energy requirements (Lofgreen and Garret, 1968), to allow for a moderate gain in body weight.

The composition of the concentrate portion and the feeding of the initial 1.8 kg of polyethylene was done as in trial I, but alfalfa hay was included only at the level of 10% for all treatments. The total ration was fed in two equal portions, 9 a m and 4 p m. Feed weight-backs were recorded every morning and the refused polyethylene was separated from the grain and introduced through the rumen fistula. Thereafter the 1.0% level was fed mixed with the grain portion in two equal amounts at each feeding time, as in the first trial.

Data Collection

Rumen fluid samples were taken from the three animals before feeding and at 2, 4, 6 and 8 hours after feeding during the pre-trial week and during the second and fourth week of each period, but for the first and third weeks of the trial samples were taken only at four hours after feeding. The samples of ingesta were collected from the animals in the same sequence at each period, and a thorough mixing of rumen contents was performed by hand at each time. Each sample was strained through four layers of gauze cloth and the pH value determined immediately as in trial I. Once the samples were properly labeled, they were stored under refrigeration until VFA could be determined as described for the first trial. Also, a representative sample, about 500 g, was taken at the four-hour sampling during each sampling period for determination of the amount of ingesta dry matter (DM) and polyethylene.

At the end of each period of four weeks, the rumen-reticulum was completely emptied and cleared of any food residues; a motor vacuum pump was used to aid in this task and the weight of the total wet contents was recorded. At this time, two more representative samples of rumen ingesta were taken from the container, one of about 5 kg for the purpose of finding the proportion of polyethylene as related to total DM of the contents, and the other sample of about 500 g to determine ingesta dry matter. After these samples were taken, a portion of the remaining rumen contents was strained through a double layer of metal screen and the juice (about 2 liters), with no solid material, was placed back into the rumen via the rumen fistula. Then, the opening was properly closed and the animal fed a 50:50 hay and grain ration for the following two weeks until the next experimental period.

The samples for determination of dry matter were placed for 24 hours in an oven at 100°C, and the DM content was established by weight difference. In the large sample, the polyethylene was separated from the ingesta using a specially adapted 20-liter container supplied with slow running tap water where the juice was washed away, the solid and organic material deposited in the bottom, and the polyethylene floated and skimmed carefully without any loss. The plastic was dried, cleaned of any foreign material and weighed. The DM percentage figures obtained with the smaller samples were used to calculate the total ingesta DM of the rumen and thus the proportion of polyethylene to dry matter in the rumen was calculated. In addition, the total amount of polyethylene in the rumen at the time it was emptied was calculated.

CHAPTER IV

RESULTS AND DISCUSSION

Trial I

Feed Consumption

Feed consumption (air-dry basis) by the cows in this experiment was generally satisfactory. However, there were numerous incidents of temporary "off-feed" conditions, where individual cows refused a large percentage of their daily feed allowance. There was no statistically significant interaction ($P > .05$) of hay and polyethylene levels with regard to total feed intake; therefore, values for the main treatments are presented (Table V; Figures 1 and 2).

In general, the differences among groups in feed intake were a reflexion of the feed allowances. The group of cows fed no hay declined more during the first four weeks than the other group fed some hay, although total consumption for the four weeks was not statistically different ($P > .05$) among groups. As mentioned in the procedure, feed allowances were adjusted at the end of four weeks in accordance with current standards. This resulted in a lower intake during the last four weeks in accordance with current standard. This resulted in a lower intake during the last four weeks of the trial, particularly in the group fed no hay. Feed consumption by levels of polyethylene were very similar (Figure 2). It may be concluded that the amounts

TABLE V

AVERAGE DAILY AIR-DRY FEED INTAKE - TRIAL I.

Ration[a]	Pre-trial	Weeks on experiment 1 to 4	Weeks on experiment 5 to 8
	(kg/day)		
Polyethylene group			
No polyethylene	18.4	16.23	14.38
1.8 kg initially	19.1	16.70	14.55
1.8 kg initially + 1% daily	19.7	15.50	13.94
Hay group			
No hay	20.3	15.58	13.04
10% hay	18.8	16.70	14.70
20% hay	18.1	16.20	15.16

[a]Polyethylene group (over all hay levels); Hay group (over all polyethylene levels).

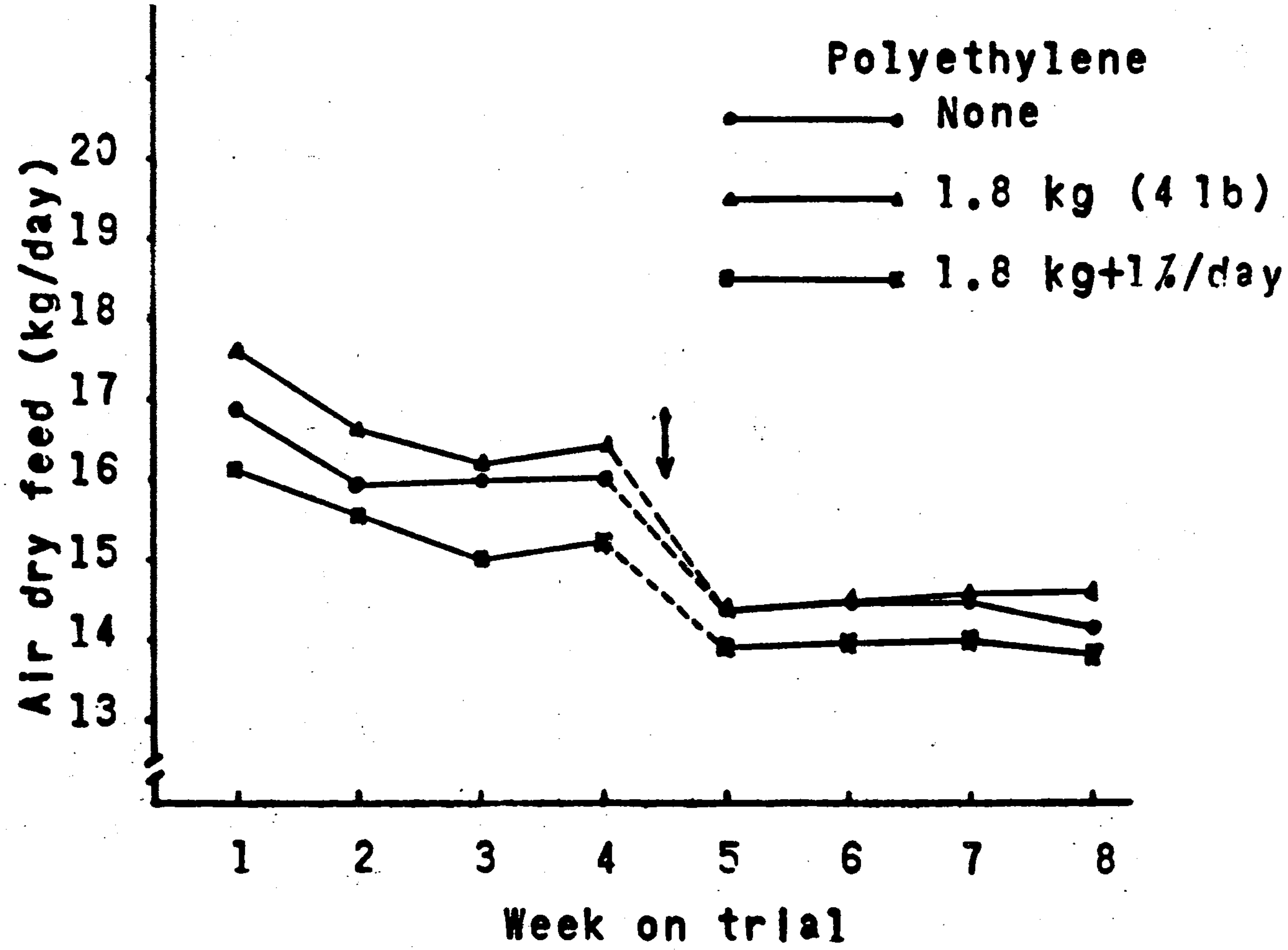

Figure 1. Average Feed Intake of Cows by Polyethylene Groups
(Arrow indicates adjustment in feed allowances)

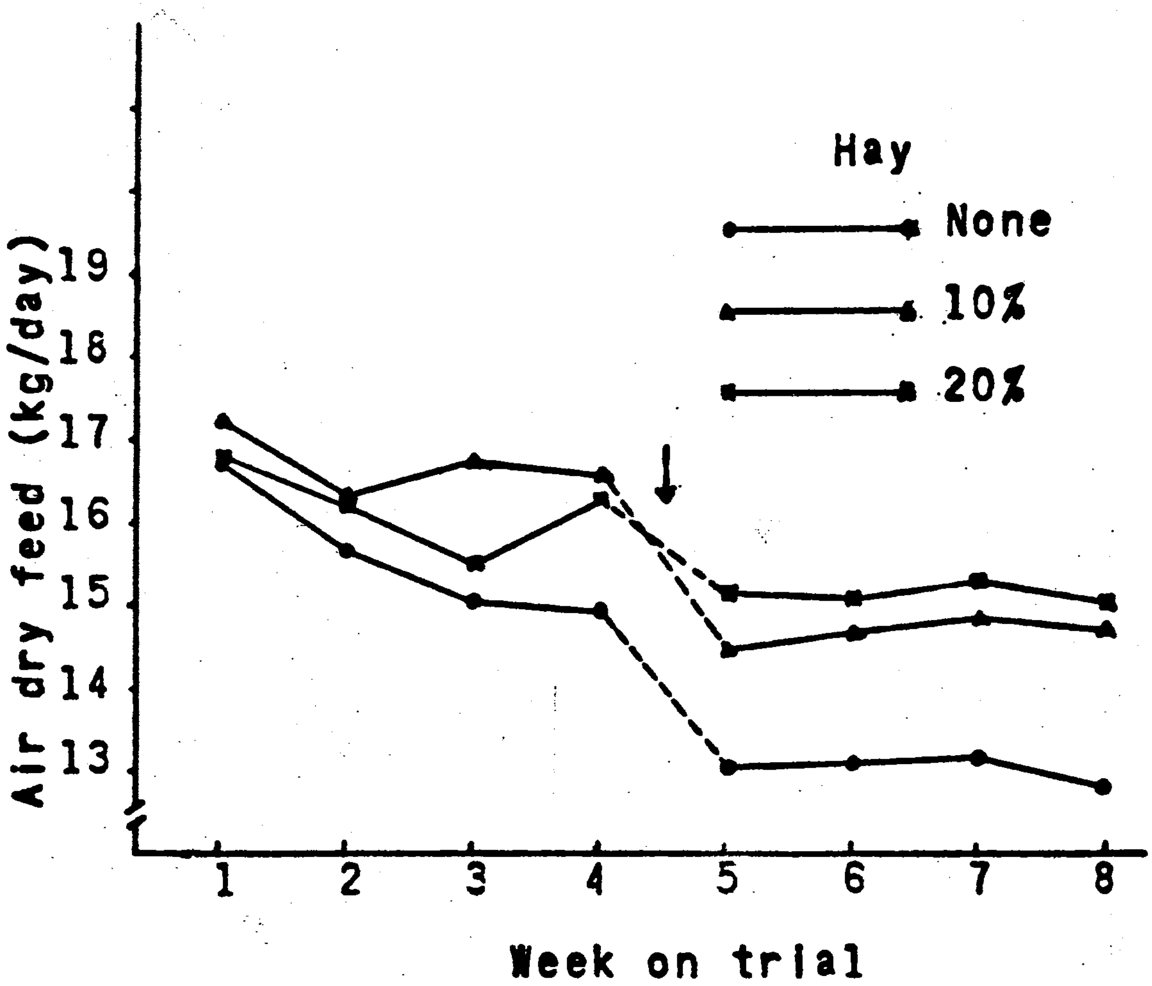

Figure 2. Average Feed Intake of Cows by Hay Groups.
(Arrow indicates adjustment in feed allowances).

and duration of polyethylene feeding in this experiment had no effect on feed consumption.

The difference in total feed intake during the pre-trial period and the first week of the experiment was a reflection of the change in the grain:hay ratio and the fact that a few cows were consuming feed in excess of their actual requirements during the pre-trial period.

Milk Yield and Composition

Data on milk yield and composition are presented in Table VI. The average daily milk yield has been summarized by two time periods, viz., the first four weeks and the second four-weeks of the trial to facilitate the comparison among treatments since changes in the feed allowances were made at the end of the first four weeks. These adjustments are thought to be partially responsible for the drop in milk yield because at that moment most of the cows were consuming somewhat higher feed levels than required by the standards. The curve of lactation approaches the normal for all treatments (Figures 3 and 4), although actual milk production was at a moderate level. Neither levels of hay nor levels of polyethylene had a significant effect ($P > .05$) on milk yield, and there was no significant interaction between the two factors. In general, milk yields were simply a reflection of feed intake by the different groups. The lack of any appreciable difference among hay groups is in agreement with the findings of other workers (Ronning and Laben, 1966; Nelson et al. 1968), who likewise found no significant response in milk production attributable to an increase in percentage of concentrates in the ration within a similar range of concentrate percentages.

TABLE VI

AVERAGE DAILY MILK YIELD AND COMPOSITION

Treatment group	Pre-trial	1-4 Weeks			5-8 Weeks		
	Milk (kg)	Milk (kg)	Fat (%)	T.S. (%)	Milk (kg)	Fat (%)	T.S. (%)
No hay							
No polyethylene	23.1	20.5	3.0	11.65	17.1	3.1	11.79
1.8 kg	22.6	19.2	3.1	11.81	16.4	2.9	11.48
1.8 kg + 1% daily	26.2	23.1	2.7	11.75	21.1	2.9	11.85
Average	24.0	20.9	2.91[a]	11.74[a]	18.2	2.97	11.72
10% hay							
No polyethylene	23.4	21.7	3.3	12.30	20.6	3.6	12.52
1.8 kg	23.5	22.3	3.7	12.74	18.8	3.5	12.32
1.8 kg + 1% daily	20.4	19.6	3.5	12.50	17.8	3.2	12.08
Average	22.4	21.1	3.47[b]	12.51[b]	19.1	3.43	12.31
20% hay							
No polyethylene	21.8	21.1	3.7	12.49	18.1	3.8	12.83
1.8 kg	23.2	20.6	3.5	12.57	19.1	3.3	12.40
1.8 kg + 1% daily	21.1	19.4	3.0	11.50	17.3	3.0	11.35
Average	22.0	20.4	3.4[b]	12.19[ab]	18.2	3.33	12.19

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

The decrease in milk fat percentage during the first four weeks for the cows receiving no hay was in agreement with work previously reported by others (Baker, 1970; Jorgensen, 1965; Opstvedt, 1967). The percentage of milk fat in the group receiving no hay averaged over the four-week period, was significantly lower ($P < .05$) than that of the groups receiving hay, but there was no significant difference between the two hay groups (Table VI).

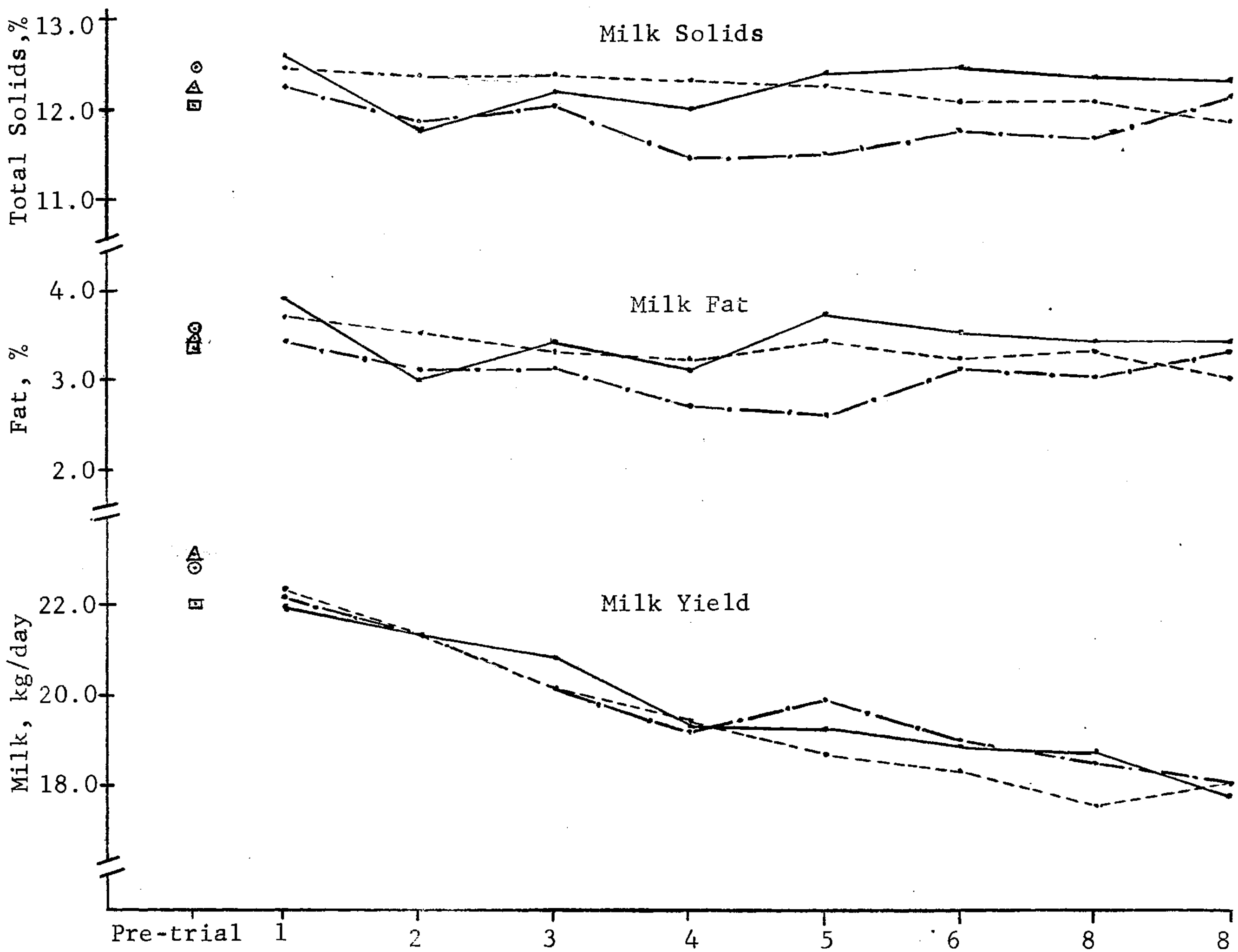

Figure 3. Average Daily Milk Yield as Influenced by Polytheylene Level (Level of polyethylene: o——— None; Δ- - - - 1.8 kg; □—·—·—1.8 kg plus 1.0%)

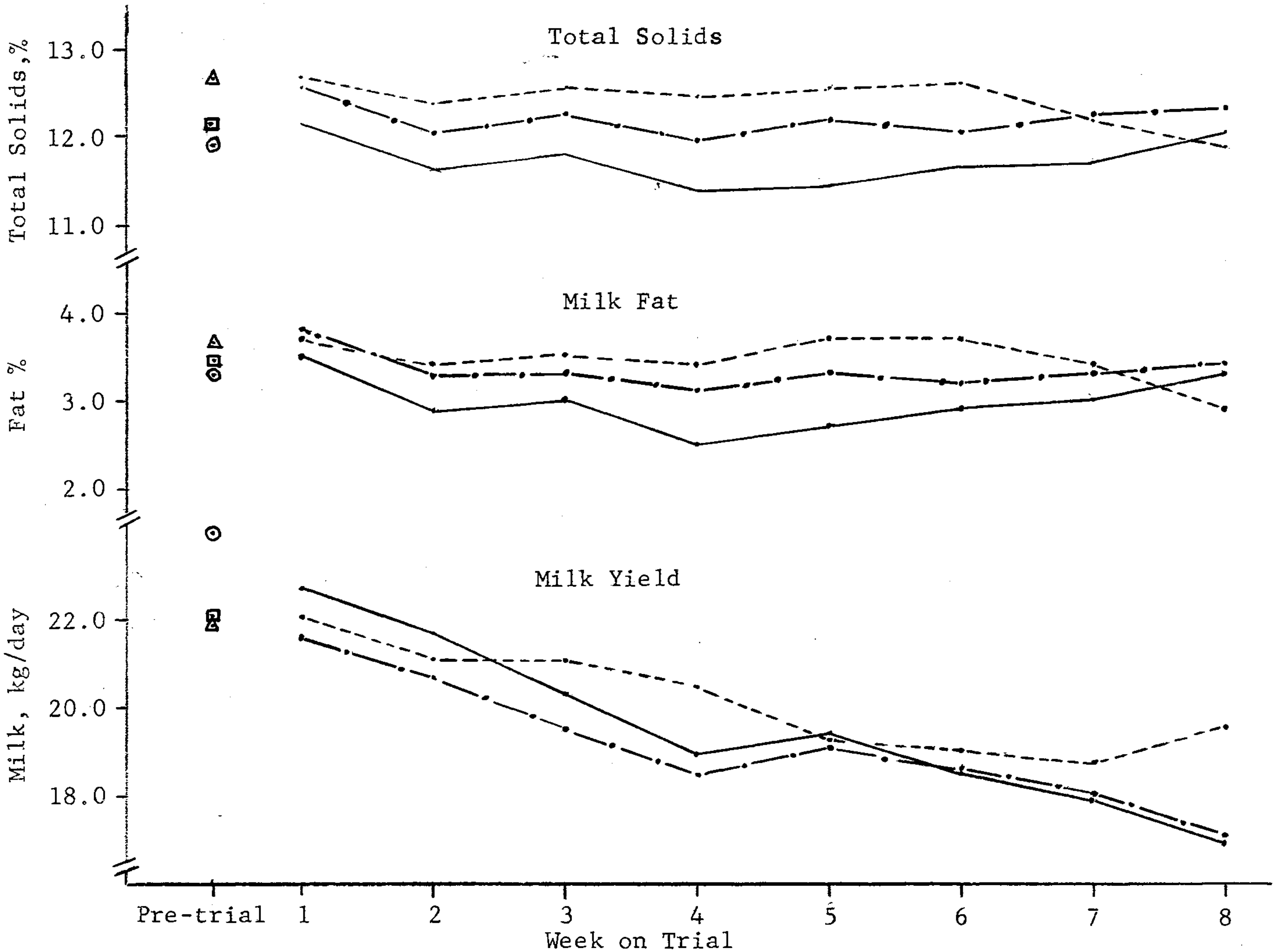

Figure 4. Average Daily Milk Yield as Influenced by Hay (Level of hay: o——none; Δ----10%; □—·—20%)

Explanations for the decreased fat test are abundant in the scientific literature. Van Soest (1963) concluded that the major cause of milk fat depression of cows fed pelleted forages or high concentrate diets involved three aspects: a) a shortage of acetate produced during rumen fermentation, b) a deficiency of beta-hydroxybutyric acid available to the mammary gland, c) a suppression of fat mobilization from tissues due to the glucogenic response resulting from increased ruminal propionate. The first two theories have been recently investigated by Davis (1967) and Palmquist et al. (1969) with the conclusion that neither an absolute shortage of acetate nor a deficiency of B-hydroxybutyric acid is responsible for the milk fat depression produced by feeding high-concentrate, restricted forage rations. The third theory listed by Van Soest (1963) was based upon work in which milk fat depressions were induced by glucose infusions and postulated to be due to a decreased release rate of fatty acids from adipose tissue caused by increased insulin output. In this respect, Orskov et al. (1969) suggested that the low percentage of milk fat found when cows are given concentrates could result from a decreased extent of starch fermentation in the rumen, allowing greater glucose absorption in the small intestine.

The percentage of total solids followed the same pattern and was largely a reflection of the milk fat percentage (Figures 3 and 4). The level of hay had a relatively small and inconsistent effect on non-fat solids percentage. Thus changes in the percentage of hay within the limits involved in this trial did not result in an increase in non-fat solids as is generally observed as the percentage of hay is decreased (Huber, 1966).

The ration treatments tended to have the same effect on milk composition during the last four weeks of the trial as during the first four weeks; however the average differences among groups were small and statistically nonsignificant ($P > .05$). Changes with time appeared to be related partly to the decline of total milk yield, however, a slow recuperation toward the normal level was noticed in the fat percentage curve (Figure 3) for the group with the highest level of polyethylene.

Under the conditions of this experiment, the addition of polyethylene to the ration did not substitute for roughage in terms of maintaining milk fat and total solids percentage.

Ruminal VFA Characteristics

The average molar percentage of volatile fatty acids at four hours after feeding is shown in Tables VII and VIII. The molar percentage of VFA during the pre-trial period (Zero week) were typical of values expected for cows consuming a 50:50 ration of grain to hay. When all of the hay was removed from the ration, an appreciable change in molar percentage of all the VFA occurred. In several papers (Nelson et al., 1968; Ronning and Laben, 1966) it is reported that high energy diets usually result in higher concentration of total volatile fatty acids and higher percentage of propionate relative to acetate than do low energy diet. Diets rich in starch (Balch et al., 1955b) or sucrose (Kellogg, 1969) favor propionate production, and, in general, feedstuffs which are rapidly fermented in the rumen give rise to less acetic acid (Balch et al., 1955b; Woods et al., 1962).

TABLE VII

AVERAGE MOLAR PERCENTAGE OF VOLATILE FATTY ACIDS AT FOUR HOURS AFTER FEEDING

Ration	Acid	Week on Trial			
		0	2	4	8
		moles/100 g			
Polyethylene Group (over all hay levels)					
No polyethylene	Acetic	68.6	59.7	56.9	59.0
	Propionic	16.9	23.3	30.4	24.8
	n-Butyric	13.4	14.9	10.3	14.2
	n-Valeric	1.3	2.0	2.1	2.0
1.8 kg initially	Acetic	68.0	56.8	58.1	57.6
	Propionic	20.5	25.5	25.5	26.6
	n-Butyric	10.3	15.4	14.0	13.2
	n-Valeric	1.1	2.3	2.5	2.6
1.8 kg initially + 1% daily	Acetic	64.4	56.5	54.9	56.6
	Propionic	22.4	21.7	29.0	25.2
	n-Butyric	11.9	19.5	13.1	16.7
	n-Valeric	1.4	1.9	3.0	1.4

TABLE VIII

AVERAGE MOLAR PERCENTAGE OF VOLATILE FATTY ACIDS AT FOUR HOURS AFTER FEEDING

Ration	Acid	Week on Trial 0	2	4	8
			moles/100 g		
Hay Group (over all polyethylene levels)					
No Hay	Acetic	64.7	50.7	53.5	56.8
	Propionic	23.2	29.9	32.6	26.8
	n-Butyric	10.7	17.0	11.5	14.5
	n-Valeric	1.4	2.5	3.4	1.9
10% Hay	Acetic	67.8	59.8	58.8	58.8
	Propionic	19.7	22.2	26.5	24.3
	n-Butyric	11.4	15.7	12.6	14.6
	n-Valeric	1.4	2.1	2.1	2.4
20% Hay	Acetic	68.6	62.5	57.8	58.9
	Propionic	15.5	18.7	26.8	23.6
	n-Butyric	13.5	17.1	13.3	15.7
	n-Valeric	1.1	1.7	2.1	1.8

In general, the inclusion of hay in the ration had the expected effect on VFA proportions, viz, a higher percentage of acetic and butyric acids and a correspondingly lower percentage of propionic acid in comparison to the all-grain ration; valeric acids values did not show a consistent pattern. Wise et al. (1968), stated that when roughage is deleted from a ruminant ration, several of the required nutrients are decreased and certain physiological factors may be removed. Bulk or "roughness-factors" would be removed along with the roughage; one approach to the problem of supplementation has been an attempt to correct deviations from the normal by addition of various bulky materials.

The addition of polyethylene to the ration appeared to have no effect on proportion of VFA four hours after feeding. Differences among polyethylene group were relatively small and inconsistent. This observation is in agreement with that of Smith (personal communication) with dairy calves fed a diet containing 3% polyethylene pellets, and to some extent with the results of Boling et al. (1969). The latter workers observed a trend of increased acetate and decreased propionate in the rumen of steers fed rations with either 10 or 20% polyethylene; however, these changes in VFA percentages due to diet dilution were not statistically significants ($P > .05$). In contrast, Ott et al. (1964) reported that the addition of a 2% level of polyethylene cubes to a purified diet for lanbs resulted in a significant increase in butyric and valeric acids with a corresponding decrease in acetic acid.

The pattern of acetic to propionic ratios at 2-hour intervals after feeding for the second week of trial are shown in Figure 5. The addition of hay to the ration had a consistent effect on the acetic to propionic ratios, throughout the 8-hour period after feeding. The acetic to propionic ratios were progressively greater as the percentage of hay in the ration increase from none to 20%. There was a tendency for the groups fed hay to have a peak of acetate production in relation to propionate at about four hours after feeding, whereas this was not observed in the group fed no hay.

In contrast, the polyethylene apparently had no consistent effect on the acetic to propionic acid ratio. While one of the groups fed polyethylene had a higher acetic to propionic ratio the other polyethylene group had the lowest ratio and the group fed no polyethylene was intermediate.

Oltjen and Davis (1965), reported an acetic to propionic ratio of 1:1 in rumen fluid of steers receiving all concentrate rations, and McCullough (1969) found that a diet of 100 percent concentrates resulted in the lowest concentration of acetic and highest concentration of propionic and butyric acids in rumen liquor. Balch et al. (1955a), found that the percentage of acetic acid decreased and the propionic acid increased with a decrease in the hay:grain ratio in the ration. They suggested that marked differences in carbohydrate intake accompanying the decrease in level of hay in the diet would encourage the starch digesting organisms at the expense of those digesting fibrous carbohydrates. Then, it seems logical to assume that rations with no roughage at all would further enhance this change. On the basis of experiments with sheep, Sutton et al. (1970), suggested that more fatty acids

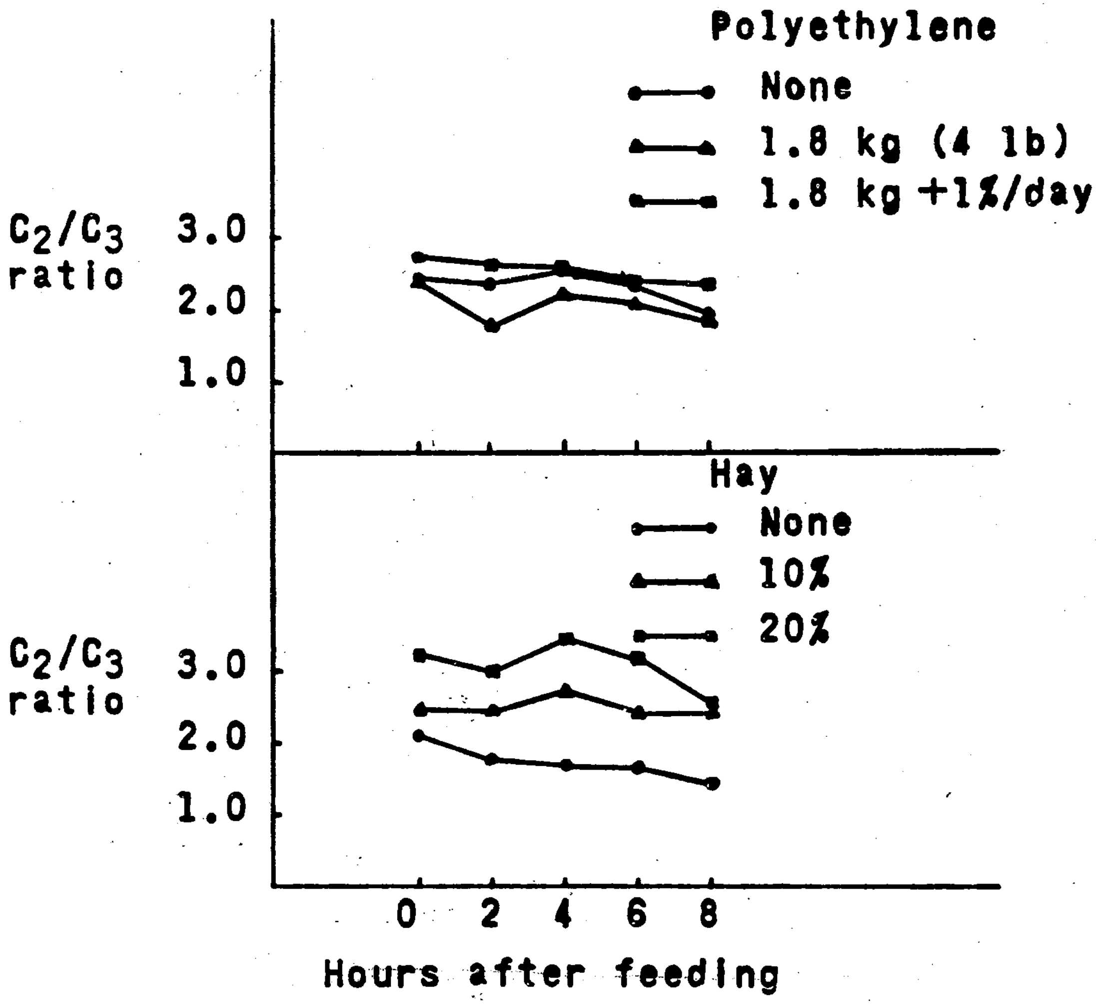

Figure 5. Acetic to Propionic Acid Ratios at Intervals After Feeding During the 2nd Week of Trial I

reach the duodenum with high concentrate rations (20:80 hay:concentrate) that with high roughage rations, and yet it is with very high concentrate rations that severe falls in the amount of fat secreted in the milk of cows may occur. In view of this apparent increase in the amount of long chain fatty acids absorbed from the digestive tract on high concentrate diets, it is unlikely that an absolute shortage of long chain fatty acids precursors would contribute to the reduced milk fat secretion in cows given these rations.

The acetic to propionic ratios seem to be consistent with the decreased milk fat percentage that prevailed during the trial. Thus, the polyethylene did not substitute effectively for roughage in terms of maintaining a normal fermentation pattern in the rumen.

Digestive Disturbances

There was a slightly higher incidence of feed refusals in the group receiving no hay than in the other groups, the incidence being 7, 6, and 5 cases for the 0, 10 and 20% levels of hay, respectively (Table IX)

The inclusion of polyethylene in the ration appeared to reduce the incidence of feed refusals, at least to some extent. There was no difference between the two polyethylene groups in the total number of cases of "off-feed." The highest incidence was during the first two weeks of the trial. During this time these cows were consuming approximately 16.5 kg of feed on the average.

Rumen samples were taken as soon as a cow was reported "off-feed," pH values were recorded and found to range from 6.0 to 6.9. Therefore, there was no evidence that the cows had developed an acidosis condition, which explains why the animals returned to normal feed consumption within two to three days after going off-feed.

TABLE IX

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

Level of polyethylene	Level of hay (% of air-dry ration)		
	0	10	20
None	5	6	1
1.8 kg	2	0	1
1.8 kg + 1%/hay	0	0	3

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

The ratio of acetic to propionic acids found in the rumen samples from cows that were "off-feed" ranged from 1.40 to 2.49. This was considerably lower than the ratio ordinarily found on usual rations, as exemplified by the acetic to propionic ratios found during the pre-trial period when the cows were consuming a 50:50 ratio of grain to hay (Table XVIII).

Trial II

For reasons that are not known several of the rumen samples gave VFA values on analysis which were unreasonable. In some instances only a trace of acetic acid was detected while in other cases values on the order of 3 and 20% were observed. All of the discrepant values were found in the samples taken at four hours after feeding. Samples taken at other times during the pre-trial, second, and fourth weeks of the trial were in the range usually expected. Comparison of the values on the three different treatments give no evidence that the polyethylene had any effect on the proportions of VFA in the rumen (Table X).

Except for the pre-feeding value, the range in pH during the comparison period was from 6.0 to 6.8 (Table XI). The preponderance of the values were within the range of 6.1 to 6.4. There were no appreciable differences among treatments. The pH values of rumen samples taken from the fistulated animals via the fistula opening were more consistent and averaged slightly lower than the rumen samples taken from the cows by stomach tube in trial I. This finding was in agreement with that of Wheaton et al. (1970), and can be attributed to the fact that stomach tube samples may frequently have been obtained from an area of the stomach near the cardia where there was an incomplete mixing of saliva with rumen contents.

The study of the retention of polyethylene in the rumen and its relation to total dry matter of the ingesta is presented in Table XII. Apparently, the polyethylene did not accumulate in the reticulo-rumen area even when the 1% daily level was given; the amount of polyethylene expressed as percentage of the total dry matter decreased from an

TABLE X

AVERAGE VOLATILE FATTY ACID VALUES FOR THE FISTULATED ANIMALS IN TRIAL II

Hours after Feeding	VFA[a]	Levels of polyethylene and week on experiment														
		No polyethylene					1.8 kg initially					1.8 kg initially plus 1% daily				
		0[b]	1	2	3	4	0	1	2	3	4	0	1	2	3	4
0	C_2	66.94		60.30		61.86	61.73		62.10		64.17	67.37		61.80		63.38
	C_3	19.41		24.35		21.98	19.16		20.72		21.03	19.14		25.24		22.44
	C_4	12.09		13.71		14.48	12.26		15.52		13.09	11.86		10.94		12.42
	C_5	1.54		1.62		1.66	6.84		1.63		1,69	1.62		2.00		1.74
2	C_2	69.81		62.70		61.02	65.45		62.30		64.10	66.76		62.54		65.52
	C_3	18.42		22.44		22.63	20.84		19.85		21.31	20.23		25.44		20.68
	C_4	10.07		12.81		14.12	12.02		15.97		12.74	11.72		10.69		11.80
	C_5	1.68		2.02		2.21	1.66		1.86		1.83	1.28		1.31		1.98
4	C_2	66.64	43.95	62.88	60.40	41.50	44.95	58.21	48.13	40.47	63.27	21.66	58.50	62.04	60.59	64.79
	C_3	19.64	29.92	22.56	23.24	31.24	30.47	23.86	23.36	33.36	20.60	42.64	23.37	25.08	23.96	20.53
	C_4	12.00	24.63	12.72	14.60	26.74	22.42	16.38	24.47	25.05	14.26	34.08	16.52	11.08	13.87	13.02
	C_5	1.70	1.48	1.81	1.75	1.50	2.14	1.54	1.02	1.12	1.84	1.59	1.58	1.77	1.58	1.63
6	C_2	68.30		59.83		58.17	67.98		63.22		56.79	67.35		63.16		63.88
	C_3	19.22		24.63		24.64	17.28		18.93		25.89	18.47		24.04		20.80
	C_4	11.39		13.87		15.59	13.29		16.17		15.66	12.60		10.99		13.15
	C_5	1.06		1.64		1.57	1.43		1.66		1.64	1.55		1.80		2.15
8	C_2	72.51		63.41		62.04	69.01		62.03		63.72	68.26		62.87		64.55
	C_3	16.11		20.24		22.34	16.99		19.99		20.95	18.19		25.00		21.14
	C_4	10.17		14.39		13.91	12.59		16.62		13.79	12.12		10.55		13.16
	C_5	1.18		1.94		1.69	1.39		1.35		1.51	1.41		1.56		1.13

VFA[a] determined: C_2 as acetic; C_3 as propionic; C_4 as butyric; C_5 as valeric

[b]Pretrial week

TABLE XI

AVERAGE pH VALUES OF RUMEN FLUID IN TRIAL II

Level of Polyethylene	Week of Periods I, II and III																
	Pre-trial					1	2					3	4				
	Hour After Feeding																
	0	2	4	6	8	4	0	2	4	6	8	4	0	2	4	6	8
None	6.7	6.0	5.9	6.0	6.1	6.0	6.7	6.2	6.1	6.1	6.3	6.1	6.4	6.2	6.3	6.3	6.4
1.8 kg	6.9	6.5	6.3	6.3	6.5	6.1	6.4	6.2	6.2	6.3	6.3	6.2	7.0	6.5	6.5	6.4	6.6
1.8 kg + 1%/day	6.8	6.5	6.5	6.5	6.4	6.1	6.8	6.3	6.2	6.8	6.4	6.2	6.5	6.1	6.2	6.2	6.4

TABLE XII

POLYETHYLENE IN RUMEN OF FISTULATED ANIMALS IN TRIAL II

Treatment		Polyethylene in samples obtained during following weeks on trial				Values for total ingesta removed at end of each period		
Levels of polyethylene	Animal No.	1	2	3	4	Total DM in rumen	Polyethylene Total Amount in rumen	
		(% of total DM)				(kg)	(g)	(% of DM)
None	469	0	0	0	0	3.58	5.4[b]	0.15
	526	0	0	0	0	4.93	0.0	0.00
	333	-[a]	0	0	0	4.12	0.0	0.0
	Avg.		0	0	0	4.22	1.8	0.05
1.8 kg	469	-[a]	19.8	17.7	4.1	3.11	105.8	3.5
	526	29.1	11.5	4.4	4.2	4.17	83.1	2.0
	333	17.9	27.6	14.3	8.1	10.40	845.0	8.8
	Avg.		19.6	12.1	5.1	5.89	344.6	4.8
1.8 kg + 1%/day	469	19.1	7.4	1.0	0.4	3.43	11.0	3.3
	526	-[a]	47.8	22.2	12.6	4.40	493.0	13.4
	333	10.6	16.6	9.6	7.6	4.02	338.0	8.4
	Avg.		23.9	10.9	6.9	3.95	280.7	8.4

[a] No sample taken at this time
[b] Residual polyethylene remaining from previous period

average of 19.6% for the second week to 5.1% at the end of the fourth week when only initial amount of 1.8 kg was fed. When the additional 1% per day was fed, the percentage of polyethylene went from 23.9 to 6.9% at the end of the fourth week of the comparison period. The failure of the polyethylene to accumulate in the rumen of animals fed some of the material on a daily basis may be attributed to removal through the reticulo-omasal orifice, regurgitation and spitting out of the material, and an increasing reluctance to consume the polyethylene. The second of these factors was observed to be especially applicable to one of the animals. There was considerable variation among the animals in regard to readiness with which the polyethylene was consumed, but it did no accumulate even in the animal which was observed to consume all of the daily allowance throughout the period of this treatment.

The polyethylene retained as percentage of the amount fed was higher i.e., 19.1% for the lower level of feeding (1.8 kg initially), as compared to 14.9% for the treatment where a daily amount was given in addition to the initial amount. As a matter of fact, a smaller absolute amount (280.7 vs. 344.6 g) was found in the rumen of the latter group when emptied in the last week of trial.

The average amount taken out by sampling was 30 g in one treatment and 25 g in the other. These quantities were a small proportion of the total polyethylene fed and did not account for the relatively low retention of polyethylene in the rumen. However, it should be noted that these results apply only to the situation where hay comprised 10% of the ration.

CHAPTER V

SUMMARY AND CONCLUSIONS

In conclusion, under the conditions of this experiment, the addition of inert polyethylene material 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 trial.

The proportions of volatile fatty acids present in the rumen of both intact lactating cows and fistulated animals fed polyethylene "squares" at two levels, indicated that this material did not substitute effectively for roughage in terms of maintaining a typical fermentation pattern in the rumen. There was no evidence of accumulation of polyethylene in the rumen-reticulum when fed to fistulated animals at the levels used in this study, at least under conditions where hay comprises 10% of the total ration.

There was some evidence that the inclusion of polyethylene could be expected to decrease the incidence of feed refusals in cows fed little or no hay.

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APPENDIXES

TABLE XIII

AVERAGE DAILY MILK YIELD AND FEED INTAKE (AIR-DRY BASIS)

Treatment: Level of Polyethylene	Level of Hay	Item	Weeks on Experiment (kg/day): Pre-trial	1	2	3	4	5	6	7	8
None	0	Milk Yield	23.1	21.8	21.4	19.6	19.1	18.1	17.8	17.1	15.3
		Feed Intake	19.4	14.4	14.9	14.7	13.7	12.4	12.6	11.8	11.8
	10%	Milk Yield	23.4	22.1	21.0	21.9	21.6	20.6	20.0	20.7	21.1
		Feed Intake	18.9	18.5	16.8	17.2	17.5	14.9	15.2	15.2	15.0
	20%	Milk Yield	21,8	21.9	21.3	20.9	20.3	18.9	18.6	18.3	16.6
		Feed Intake	17.0	17.4	15.6	16.7	16.7	15.2	15.4	15.8	15.4
1.8 kg	0	Milk Yield	22.6	21.7	19.8	18.0	17.5	18.1	16.4	15.4	15.6
		Feed Intake	20.0	16.5	15.3	14.8	15.0	12.7	12.7	12.7	12.7
	10%	Milk Yield	23.5	23.9	22.0	22.7	20.8	18.8	18.9	17.8	19.7
		Feed Intake	19.6	18.7	17.7	18.3	17.3	14.6	15.0	15.5	15.4
	20%	Milk Yield	23.2	21.4	21.4	19.6	19.9	19.0	19.6	19.3	18.6
		Feed Intake	17.8	17.4	17.0	15.5	17.0	15.6	15.8	15.7	15.8
1.8 kg + 1%	0	Milk Yield	26.2	24.7	24.1	23.4	20.1	22.0	21.3	21.3	19.9
		Feed Intake	21.6	17.7	16.8	16.3	15.6	13.8	13.8	13.8	13.8
	10%	Milk Yield	20.4	20.4	20.4	18.8	18.9	18.4	18.1	17.6	17.8
		Feed Intake	18.0	15.1	14.5	14.5	14.5	13.9	13.9	13.9	13.9
	20%	Milk Yield	21.1	20.0	19.5	18.2	18.6	19.2	17.4	16.6	16.2
		Feed Intake	19.4	15.9	15.5	14.2	15.2	14.1	14.2	14.4	15.3

TABLE XIV

AVERAGE WEEKLY MILK COMPOSITION BY TREATMENTS

Treatment: Level of Polyethylene	Treatment: Level of Hay		Week on experiment 1	2	3	4	5	6	7	8
			%							
0	0	Milk fat	3.4	2.8	3.3	2.5	3.2	2.9	2.9	3.3
		Total solids	11.97	11.46	11.96	11.21	11.83	11.78	11.59	11.94
	10%	Milk fat	3.8	2.9	3.3	3.3	4.0	3.8	3.5	3.1
		Total solids	12.93	11.83	12.12	12.33	12.61	12.84	12.66	11.98
	20%	Milk fat	4.4	3.2	3.6	3.5	3.9	3.7	3.7	3.8
		Total solids	12.91	12.07	12.50	12.50	12.72	12.80	12.82	13.00
1.8 kg	0	Milk fat	3.6	3.2	2.9	2.8	2.7	2.8	3.3	3.0
		Total solids	12.12	11.79	11.70	11.64	11.27	11.28	11.88	11.48
	10%	Milk fat	3.8	3.8	3.6	3.4	4.0	4.0	3.4	2.6
		Total solids	12.65	12.80	12.87	12.65	12.98	12.82	11.92	11.56
	20%	Milk fat	3.7	3.5	3.4	3.3	3.4	2.9	3.3	3.4
		Total solids	12.66	12.50	12.53	12.60	12.54	12.14	12.47	12.45
1.8 kg + 1%	0	Milk fat	3.4	2.6	2.7	2.2	2.1	3.1	2.9	3.6
		Total solids	12.33	11.60	11.75	11.32	11.16	11.87	11.63	12.73
	10%	Milk fat	3.5	3.5	3.5	3.5	3.2	3.2	3.2	3.1
		Total solids	12.51	12.52	12.60	12.37	12.12	12.14	11.96	12.10
	20%	Milk fat	3.4	3.1	3.0	2.5	2.6	3.1	3.0	3.1
		Total solids	11.98	11.53	11.77	10.67	11.28	11.20	11.44	11.49

TABLE XV

AVERAGE WEEKLY MOLAR PERCENT OF VOLATILE FATTY ACIDS IN THE NO-HAY RATION

Hour after feeding	VFA[a]	Treatments and Week on Experiment											
		No Polyethylene				1.8 kg				1.8 kg + 1%			
		0	2	4	8	0	2	4	8	0	2	4	8
0	C_2	65.9	59.2			65.3	56.1			64.3	53.8		
	C_3	20.9	28.9			21.4	25.3			26.4	30.4		
	C_4	12.1	9.5			12.3	15.9			8.3	13.0		
	C_5	1.2	2.4			1.0	2.8			1.0	2.8		
2	C_2	73.0	54.6			67.6	50.1			68.3	50.4		
	C_3	16.8	30.8			20.2	29.5			22.2	26.9		
	C_4	9.0	11.6			11.5	17.9			9.3	19.2		
	C_5	1.2	3.0			0.7	2.5			1.2	3.5		
4	C_2	64.7	56.0	54.5	57.4	63.0	50.4	54.7	57.1	66.3	45.6	51.2	56.0
	C_3	21.8	28.0	35.0	26.9	24.2	30.6	27.6	26.4	23.7	31.1	32.4	27.2
	C_4	12.0	13.7	8.1	13.8	11.5	16.5	14.6	14.7	8.6	20.7	11.7	14.8
	C_5	1.5	2.3	2.5	1.9	1.2	2.5	3.1	1.8	1.4	2.6	4.7	1.9
6	C_2	64.5	54.8			64.5	49.5			65.8	44.9		
	C_3	22.9	29.6			20.4	26.7			23.7	33.8		
	C_4	11.2	13.2			13.9	21.0			9.0	17.7		
	C_5	1.5	2.4			1.4	2.9			1.6	3.6		
8	C_2	67.7	49.9			68.4	48.0			64.4	42.5		
	C_3	19.1	35.8			19.2	29.7			25.9	33.5		
	C_4	12.0	12.6			12.0	19.2			8.3	20.5		
	C_5	1.2	1.7			0.9	3.1			1.4	3.4		

[a]VFA- Volatile Fatty Acids: C_2 as Acetic; C_3 as Propionic; C_4 as Butryic; and C_5 as Valeric

TABLE XVI

AVERAGE WEEKLY MOLAR PERCENT OF VOLATILE FATTY ACIDS IN THE 10% HAY RATION

Hour after feeding	VFA	Treatments and Week on Experiment											
		No Polyethylene				1.8 kg				1.8 kg + 1%			
		0	2	4	8	0	2	4	8	0	2	4	8
0	C_2	72.5	56.1			68.6	56.6			69.0	64.1		
	C_3	15.1	26.2			20.9	28.5			20.2	17.2		
	C_4	10.8	15.2			10.2	12.6			9.6	17.1		
	C_5	1.5	1.9			1.2	2.3			1.2	1.6		
2	C_2	69.9	57.4			66.6	56.4			65.5	61.9		
	C_3	18.2	25.5			22.9	24.9			19.4	21.8		
	C_4	10.7	15.0			9.3	16.1			13.8	15.0		
	C_5	1.2	2.2			1.3	2.6			1.4	1.4		
4	C_2	73.3	58.2	53.2	55.3	68.3	58.1	61.7	59.8	62.8	63.2	61.6	61.2
	C_3	14.9	24.0	33.8	26.6	20.1	25.3	22.9	24.1	24.2	17.3	22.6	22.3
	C_4	12.1	14.9	10.9	15.4	10.3	14.2	12.9	12.8	11.7	18.1	14.1	15.4
	C_5	1.4	2.4	2.1	2.7	1.4	2.4	2.6	3.4	1.4	1.4	1.7	1.0
6	C_2	67.7	56.2			68.4	56.2			68.4	62.0		
	C_3	16.7	25.4			20.9	28.2			20.9	19.4		
	C_4	14.3	16.4			9.7	13.2			9.6	17.1		
	C_5	1.2	2.0			1.0	2.4			1.1	1.6		
8	C_2	68.0	56.4			66.4	55.0			66.4	62.3		
	C_3	17.1	24.6			21.0	29.0			19.0	18.9		
	C_4	13.6	16.8			11.2	13.3			13.3	17.4		
	C_5	1.3	2.2			1.3	2.6			1.3	1.5		

[a]VFA-Volatile Fatty Acids: C_2 as Acetic; C_3 as Propionic; C_4 as Butryic; and C_5 as Valeric

TABLE XVII

AVERAGE WEEKLY MOLAR PERCENT OF VOLATILE FATTY ACIDS IN THE 20% HAY RATION

Hour after feeding	VFA	Treatments and Week on Experiment											
		No Polyethylene				1.8 kg				1.8 kg + 1%			
		0	2	4	8	0	2	4	8	0	2	4	8
0	C_2	71.9	66.1			68.9	60.8			67.0	62.5		
	C_3	14.3	18.7			18.0	22.3			17.5	17.6		
	C_4	12.7	13.3			11.5	15.2			13.8	18.1		
	C_5	1.2	1.9			1.6	1.7			1.7	1.9		
2	C_2	68.8	65.7			62.4	47.9			59.4	65.1		
	C_3	15.9	19.4			20.1	30.5			27.7	18.1		
	C_4	14.2	12.9			15.9	19.7			12.3	14.8		
	C_5	1.1	2.0			1.5	2.4			0.6	2.0		
4	C_2	68.8	64.8	64.1	64.2	72.8	61.9	57.8	56.0	64.1	60.8	51.6	56.6
	C_3	13.9	17.9	22.4	20.9	17.2	20.6	25.8	29.4	19.2	17.7	32.0	20.5
	C_4	16.2	16.0	11.9	13.4	9.2	15.5	14.5	12.3	15.2	19.8	13.4	21.5
	C_5	1.1	1.4	1.6	1.5	0.8	2.1	1.9	2.4	1.5	1.7	2.7	1.5
6	C_2	66.8	66.8			67.6	57.7			67.2	64.0		
	C_3	19.0	19.8			17.0	23.0			18.1	17.4		
	C_4	12.5	11.8			14.5	17.9			13.7	16.8		
	C_5	1.7	1.6			0.9	1.4			1.0	1.8		
8	C_2	67.4	59.2			71.5	58.2			63.5	64.2		
	C_3	18.2	23.6			17.4	27.8			20.8	20.1		
	C_4	13.0	15.3			9.4	12.3			14.5	13.8		
	C_5	1.3	1.9			1.7	1.6			1.2	1.8		

[a]VFA-Volatile Fatty Acids: C_2 as Acetic; C_3 as Propionic; C_4 as Butryic; and C_5 as Valeric

TABLE XVIII

ACETIC TO PROPIONIC ACID RATIOS AT INTERVALS AFTER FEEDING IN TRIAL I

	Period of trial and hour after feeding									
	Pre-trial week					Second week				
Ration[a]	0	2	4	6	8	0	2	4	6	8
Polyethylene group										
No polyethylene	4.18	4.16	4.06	3.39	3.74	2.46	2.35	2.56	2.38	1.97
1.8 kg initially	3.36	3.11	3.32	3.45	3.61	2.40	1.82	2.23	2.09	1.86
1.8 kg initially + 1% daily	3.13	2.79	2.88	3.21	2.96	2.76	2.66	2.61	2.42	2.33
Hay group										
No hay	2.85	3.53	2.78	2.91	3.13	2.08	1.77	1.68	1.65	1.42
10% hay	3.74	3.33	3.44	3.50	3.52	2.45	2.44	2.70	2.39	2.40
20% hay	4.17	3.00	4.43	3.50	3.62	3.23	3.00	3.44	3.17	2.54

[a]Polyethylene group (over all hay levels); Hay group (over all polyethylene levels)

TABLE XIX

AVERAGE pH VALUES OF RUMEN FLUID, BY MAIN EFFECTS IN TRIAL I

	Trial Period										4th Week	8th Week
	Pre-trial Week					Second Week						
	Hours after feeding											
	0	2	4	6	8	0	2	4	6	8	4	4
Polyethylene group (over all levels of hay)												
No polyethylene	6.6	6.4	6.3	6.3	6.1	6.3	6.1	5.8	6.2	6.2	6.3	6.3
1.8 kg., initially	6.6	6.7	6.3	6.8	6.4	6.9	6.2	5.9	6.3	6.2	6.2	6.2
1.8 kg. + 1% daily	6.7	6.6	6.3	6.3	6.5	6.6	5.8	5.8	6.0	6.0	6.1	6.3
Hay Group (over all polyethylene levels)												
No hay	6.5	6.6	6.0	6.0	6.4	6.5	5.8	5.6	5.8	5.8	6.1	6.3
10% hay	6.9	6.8	6.5	6.8	6.4	6.9	6.2	5.9	6.5	6.4	6.3	5.9
20% hay	6.6	6.3	6.4	6.6	6.2	6.5	6.1	6.0	6.3	6.2	6.0	6.7

TABLE XX

WEEKLY pH VALUES OF RUMEN FLUID OF INDIVIDUAL FISTULATED ANIMALS

Treatment: Level of Polyethylene	Period	Animal	Week of Period and Hour After Feeding																
			Pre-trial					1	2					3	4				
			0	2	4	6	8	4	0	2	4	6	8	4	0	2	4	6	8
None	I[a]	333	6.7	5.9	5.8	5.9	6.0	5.5	6.7	5.7	5.5	5.4	5.7	5.6	5.5	5.6	5.8	5.8	5.7
	II[b]	469	6.8	6.0	6.0	5.9	6.2	6.2	6.7	6.3	6.4	6.5	6.5	6.3	7.0	6.5	6.6	6.6	6.6
	III[c]	526	6.6	6.0	6.0	6.2	6.1	6.2	6.8	6.7	6.5	6.4	6.7	6.3	6.8	6.5	6.5	6.6	6.9
1.8 kg	I	469	7.0	6.5	6.3	6.3	6.6	6.3	6.8	6.6	6.5	6.8	6.7	6.5	7.0	6.8	6.6	6.5	7.0
	II	526	6.9	6.5	6.3	6.4	6.4	6.5	6.8	6.5	6.5	6.6	6.6	6.5	7.0	6.6	6.6	6.6	6.7
	III	333	6.7	6.4	6.3	6.3	6.4	5.4	5.6	5.6	5.5	5.6	5.5	5.5	6.9	6.0	6.2	6.0	6.0
1.8 kg + 1%	I	526	6.9	6.6	6.7	6.7	6.7	6.4	6.9	6.5	6.4	6.6	6.7	6.4	6.8	6.2	6.4	6.5	6.7
	II	333	6.5	6.3	6.1	6.1	6.1	5.5	6.9	6.2	6.1	6.1	6.3	5.9	6.0	6.1	6.1	6.0	6.1
	III	469	7.0	6.7	6.8	6.7	6.5	6.3	6.7	6.1	6.0	6.1	6.3	6.2	6.7	6.1	6.2	6.2	6.5

I[a] - Period of time from April 19 to May 16.

II[b] - Period of time from May 31 to June 27.

III[c] - Period of time from July 12 to August 8.

VITA

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