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Sodium bentonite in complete rations containing maltlage and the use of maltlage in complete rations for replacement heifers

Clyde P. Cieszynski

To the Graduate Council:

I am submitting herewith a thesis written by Clyde P. Cieszynski entitled "Sodium bentonite in complete rations containing maltlage and the use of maltlage in complete rations for replacement heifers." I have examined the final electronic copy of this thesis for form and content and recommend that it be accepted in partial fulfillment of the requirements for the degree of Master of Science, with a major in Animal Science.

Monty J. Montgomery, Major Professor

We have read this thesis and recommend its acceptance:

D. O. Richardson, C. C. Chamberlain

Accepted for the Council:
Carolyn R. Hodges

Vice Provost and Dean of the Graduate School

(Original signatures are on file with official student records.)

To the Graduate Council:

I am submitting herewith a thesis written by Clyde P. Cieszynski entitled "Sodium Bentonite in Complete Rations Containing Maltlage and the Use of Maltlage in Complete Rations for Replacement Heifers." I recommend that it be accepted in partial fulfillment of the requirements for the degree of Master of Science, with a major in Animal Science.

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We have read this thesis
and recommend its acceptance:

Accepted for the Council:

Vice Chancellor
Graduate Studies and Research

SODIUM BENTONITE IN COMPLETE RATIONS CONTAINING MALTLAGE AND THE USE OF MALTLAGE IN COMPLETE RATIONS FOR REPLACEMENT HEIFERS

A Thesis

Presented for the

Master of Science

Degree

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Clyde P. Cieszynski

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ABSTRACT

Sixteen lactating Holstein cows were randomly assigned to one of two treatments to evaluate sodium bentonite as a milk fat test improver in complete rations containing Maltlage. Treatment I consisted of one part Maltlage and one part corn silage with 1 percent sodium bentonite.

Daily dry matter intake (pounds), daily dry matter intake per hundred pounds body weight (pounds), daily milk production (pounds), daily 4 percent fat-corrected milk, and percent milk fat, for the two treatments were:

I) 19.0, 1.8, 48.8, 37.9, 2.64;

II) 20.3, 1.9, 50.0, 41.0, 2.95.

Rumen pH and molar percent values of acetate, propionate and butyrate in the rumen were 6.3, 55.1, 28.9 and 10.3 for Treatment I and 6.3, 54.6, 26.9 and 12.4 for Treatment II.

Blood serum levels of calcium, magnesium, sodium and phosphorus were 10.69, 2.77, 380.2 and 7.61 mg per 100 ml for Treatment I and 10.70, 2.71, 374.4 and 7.72 mg per 100 ml for Treatment II. Above differences for same variables due to treatment effect, all proved non-significant ($P<.05$).

Data suggests that addition of 1 percent sodium bentonite to

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*Maltlage is a registered trademark of Murphy Products Company, Inc., and denotes a mixture containing wet brewers grains, corn and mineral-vitamin supplement. Average composition of Maltlage used in this study is in Table 1.

complete rations containing a 1:1 ratio (as fed) of Maltlage and corn silage, will improve milk fat test in lactating cows.

Thirty-six Holstein replacement calves were randomly assigned to one of two treatments at birth. Treatment I consisted of one part Maltlage and one part corn silage. Treatment II consisted of chopped mixed grass hay fed *ad libitum* plus Maltlage fed seperately at the following rates:

Week 2-15 - 5.5# Maltlage per 100# body weight
Week 16-20 - 5.0# Maltlage per 100# body weight
Week 21-25 - 4.5# Maltlage per 100# body weight
Week 26-30 - 4.0# Maltlage per 100# body weight.

Calves were weaned at six weeks of age.

Average dry matter intake (pounds), average dry matter intake per hundred pounds body weight (pounds), cumulative average daily gain (pounds), body weight (pounds), length (inches), wither height (inches) and heart girth (inches) for each treatment was:

I) 4.7, 1.98, 0.92, 198, 28.0, 34.6, 39.1;

II) 4.6, 1.99, 0.93, 197, 27.9, 34.6, 39.1.

Differences in growth parameters of calves due to treatment effect were all non-significant (P<.05).

Data suggests that Holstein heifer calves can be raised successfully on a complete ration containing a 1:1 ratio (as fed) of Maltlage and corn silage or when fed Maltlage and chopped mixed grass hay *ad libitum* up to 20 weeks of age.

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INTRODUCTION

A successful dairy enterprise is normally managed to obtain maximum economical returns while controlling costs. Major production expenses on a dairy farm are made up of both feed and labor costs. Feeding systems that emphasize maximum mechanization and minimum labor requirements are of great value. One method of utilizing less expensive forages and reducing labor costs (increase the use of mechanized equipment) is to feed complete rations, where all nutrient ingredients are mixed in quantitative proportions according to the animals' nutritive needs.

Gross income on a dairy enterprise is primarily determined by the sale of milk. Because milk prices are based on milk fat content, dairymen are concerned with not only the amount of milk produced but also the percentage of milk fat it contains. Sodium bentonite, a mineral consisting largely of the clay montmorillonite, has the ability to absorb five times its weight in water and swell twelve to fifteen times its original volume. Sodium bentonite, because of its expanding properties, has been used in dairy rations as a milk fat test improver.

By-products of many industries, which normally would be disposed of, have been fed to livestock as a source of nutrients. A by-product of the brewing industry, in the production of beer and ale, is dried and wet brewers' grains.

The objective of this study was to determine the intake, milk production and fat percentage response of first lactation Holstein cows fed complete rations containing Maltlage and corn silage with and without sodium bentonite and to determine intake and growth measurements of replacement Holstein heifers fed complete rations containing Maltlage with corn silage or chopped mixed grass hay.

CHAPTER II

REVIEW OF LITERATURE

Complete Feeds in Livestock Rations

A successful dairy enterprise is normally managed to obtain maximum economical returns while controlling costs. Since the major production expenses on a dairy farm include both feed and labor cost, a feeding system which utilizes less expensive forages, maximizes mechanization and minimizes labor requirements would be a wise investment. Complete rations, where all nutrient ingredients are mixed in quantitative proportions according to the animals' nutritive needs, is one way of reducing both feed and labor costs.

Coppock (17) and Rakes (81) reviewed the feeding of complete rations and reported several advantages and disadvantages. Among the advantages were:

1. Expression of free choice by individual cows was prevented since each bite is a uniform, nutritionally complete diet.
2. Mineral supplements fed free choice was unnecessary.
3. Complete feeds result in less digestive disturbances early in lactation as the diet is changed from a high forage to a high concentrate diet.
4. By using a specific and obligatory ratio of forage to concentrate, each cow is insured a minimal level of fiber, therefore preventing milk fat depression.
5. The percentage of crude protein in the ration can be controlled.

6. Total diet of the cow can be quantitatively formulated.

Among the disadvantages were:

1. Hay which is stored in the long form or in bales, must be chopped before blending.
2. Mixer wagons are expensive.
3. Complete ration feeding is not economical for small dairy herds and herds on pasture, especially during the pasture season.
4. More calculations are necessary on the farm to implement the use of complete rations.

The optimum protein level in complete feeds has been investigated by several workers. Rakes (81) suggested a 13 to 14 percent crude protein level in complete feeds to support milk production similar to that achieved with conventional rations. Rusoff et al. (89) indicated a slightly higher value of 14 to 16 percent was needed. Hawkins (35) concluded that a complete ration containing approximately 65 percent TDN needed to contain about 14 to 15 percent crude protein to meet the requirements of most cows. Recommendations would vary depending on the ration, individual consumption or a change in protein digestibility. Van Horn et al. (100) reported that both the level and source of protein influences the digestibility of organic matter in the ration.

Adequate growth of young calves fed complete rations containing corn silage has been observed by several workers (9, 37, 67). Goodrich (32) reported that maximum dry matter intake occurred when 40 to 50 percent corn silage dry matter was included in the ration of steer calves.

Schurman and Kesler (90) studied the protein to energy ratios in complete feeds for calves 8 to 18 weeks of age. They recommended protein to energy ratios in grams digestible protein per kilocalories of digestible energy of complete feeds should be less then 1 to 41.1.

Ensiled complete rations have been successfully fed to lactating dairy cattle (22, 61, 59, 74). However, O'Dell and Van Dijk (70) reported decreased intakes and milk production of cows fed ensiled complete rations. Researchers (41, 70) also report that feeding ensiled complete rations may reduce mineral absorbtion and retention. Reduction in production responses could result under long term feeding situations.

<u>Low Milk Fat Producing Rations: High Concentrate to Roughage Ratio</u>

Profits on a dairy enterprise are primarily determined by the sale of milk. Because milk prices are based on milk fat content, dairy farmers are concerned not only with the amount of milk produced, but also the percentage of milk fat it contains.

Feeding high levels of concentrate has been known to cause a depression in milk fat test (5, 6, 46, 48, 50, 58, 72, 86). Bringe and Schultz (12) investigated low milk fat producing rations fed to dairy cattle. A reduction of 50 percent in milk fat was noted when cows which were fed a 1:3 ratio of hay to pelleted grain, were compared to the normal control ration of alfalfa hay fed at a level of 2 kg per 100 kg of body weight and a ground mixture concentrate supplement fed to meet NRC (69) calculated TDN requirements.

Varman and Schultz (103) compared the extent of milk fat depression in different breeds of cows. A normal ration was fed to lactating cows followed by a milk fat depressing ration. The drop in milk fat test of different breeds were as follows: Guernsey 4.9 to 3.7; Holstein 3.3 to 2.2 and; Jersey 5.3 to 4.3. Cows of the three breeds experienced similar declines when fed the milk fat depressing ration, approximately the same extent in terms of unit changes in fat test.

A major goal of dairy researchers has been to find an optimum forage-to-concentrate ratio which will efficiently maximize milk production without depressing milk fat. In general, researchers have recommended that complete rations should contain at least 30 percent forage to prevent milk fat depression and prevent digestive disturbances (61, 64, 71, 81).

Marshall and Voight (61) evaluated forage to concentrate ratios of 40:60, 30:70 and 20:80 (dry matter basis) in complete feeds containing corn silage and concentrate. Percentages of milk fat decreased as the proportion of concentrate in the ration increased, but milk production and body weight gains were increased. MaCleod et al. (58) fed complete rations ad libitum with forage to concentrate ratios of 80:20, 65:35, 50:50 and 35:65 to lactating dairy cattle. Milk fat percentages declined (3.83, 3.72, 3.68 and 3.33) linearly as the amount of concentrate was increased in the ration. Leighton and Helm (55) found evidence that relatively coarse grinding of hay will depress milk fat test and respiration rates in cows fed complete rations containing alfalfa hay and sorghum grain. Nelson et al. (68) noted a highly significant linear decrease in milk fat percentages as the percent concentrate was increased in a ration containing pelleted bermudagrass.

Villavicencio et al. (105) compared roughage sources of alfalfa hay, cottonseed hulls and native grass hay in complete rations containing one percent urea and having a roughage to concentrate ratio of 30:70. There were no significant differences in neither milk production nor milk fat percentage. Johnson et al. (42) compared roughage and protein sources in complete feeds. Roughage sources of haylage and corn silage, and protein sources of SBM and urea had little effect on rumen fatty acid production when incorporated into complete rations for lactating cows. Milk fat, rumen acetate and rumen propionate levels were similar regardless of roughage or protein source.

Bodoh et al. (8) indicate a disadvantage to feeding high concentrate rations throughout a lactation and dry period as measured by a high incidence of cow loss and lowered production yields.

Jorgensen et al. (47) summarized the physiological changes that consistently accompany a depression in milk fat percentage. These changes include:

1. A reduction in rumen acetic acid.
2. An increase in rumen propionic and valeric acids.
3. Decreased blood lipids.
4. A decrease in blood ketone bodies.
5. Blood glucose levels are increased.
6. Body weight gain is increased.
7. Reduced milk production.
8. Milk fat components of short-chain as well as palmitic and stearic acids are decreased.
9. Unsaturated fatty acid components of the milk are increased.

Beitz and Davis (5) observed a significant decrease in acetate and increase in propionate in the rumen of cows fed high concentrate rations. A milk fat decrease in high grain feeding was attributed to the significant changes occurring in rumen fermentation. Chalupa <u>et al</u>. (13) found the rumen liquor of cows with depressed milk fat percentages more acidic and contained decreased molar percentages of acetate and 2-carbon units (acetate + 2x butyrate) with increased molar percentages of propionate and valerate. Shaw <u>et al</u>. (91) fed a high starch bread containing diet to lactating cows. A 30 percent reduction in milk fat test was observed. A positive correlation of +0.64 was found between fat content of the milk and rumen acetic acid. A negative correlation of -0.63 was found between fat content of milk and rumen propionic acid.

Davis and Sachan (21) studied the blood lipid changes in cows fed a high concentrate, low fiber ration. Decreased concentrations of palmitic and stearic acid and increased concentrations of oleic, linoleic and linolenic acids occurred in blood of cows fed high concentrate diets. The fatty acid makeup of milk fat reflected the changes in fatty acid makeup of blood lipids.

Van Soest (101) reviewed the theories used to explain milk fat depression due to the feeding of high levels of concentrate. One theory deals with a decrease in rumen acetic acid. The ruminant mammary gland has been shown to be able to utilize acetate for milk fat synthesis (75). A second theory suggests a decreased blood concentration of betahydroxybutyric acid (BHBA). BHBA has been shown to be utilized by the ruminant mammary gland for synthesis of milk fat (52). A third theory involves the mobilization of fat by endocrine control. Postulated by McClymount and Vallance (63), the theory holds that the glucogenic response during high propionate production suppresses the mobilization of fat from tissues, therefore causing a decrease in blood lipids required for milk fat synthesis.

Jorgensen et al. (47) supported the concept that major factors depressing milk fat on high concentrate rations involve a high level of glucogenic metabolites. These metabolites reduce blood ketone and lipid levels and tend to promote a fattening type of metabolism at the expense of milk fat synthesis.

Sodium Bentonite and its Use in Ruminant Rations

Bentonite, a mineral consisting largely of the clay montmorillonite, has a wide variety of uses. Bentonite is used in sand foundry moldings, decolorizing oils, catalyst manufacture, oil-well drilling muds and animal feeds. Generally, bentonite refers to a highly plastic, colloidal, swelling type of clay originating from volcanic ash.

Knight (51) first applied the term bentonite to a colloidal, highly plastic clay he found in the Cretaceous beds of Wyoming near Fort Benton. Ross and Shannon (87) later redefined the term bentonite restricting its classification to clays produced by the alteration of volcanic ash in situ. Early research by Le Chatelier (54) showed montmorillonite clay to have the general formula $4SiO_2 \cdot Al_2O_3 \cdot H_2O$. Currently, Grim (34) defines montmorillonite as "the name montmorillonite is used currently both as a group name for all clay minerals with an expanding lattice, except vermiculite, and also as a specific mineral name. Specifically it indicates a high-alumia end member of the montmorillonite group with some slight replacement of Al^{+3} by Mg^{++} and substantially no replacement of Si^{4+} by Al^{3+}."

Sodium bentonite will absorb five times its weight in water and swells twelve to fifteen times its original volume. When incorporated into livestock rations, the bulking property of bentonite has the ability to slow the rate of passage of feedstuffs, therefore allowing more time for digestion of available nutrients from the feed and increasing feed efficiency (1, 45, 53, 80, 104).

In aqueous solutions, bentonite is noted for its base exchange properties. Base exchange properties are measured by clay technologists in terms of milliequivalents (meq) per hundred grams, where:

$$1 \text{ meq} = \frac{1 \text{ gram equivalent weight}}{1000} .$$

In this case, an equivalent of an ion is its atomic weight divided by its valence. Sodium bentonite has a cation exchange capacity of 80 to 150 meq per 100g and an anion exchange capacity of 23 meq per 100g (34). Sodium bentonite will release its surface ions of sodium and potassium and exchange them for calcium and magnesium ions. In the rumen, sodium bentonite may enter into base exchange reactions with ammonium ions when the concentration of ammonia is relatively high. Later when the concentration of ammonia declines, the bentonite will release ammonium ions and thus utilize rumen ammonia more efficiently. Cation exchange values for sodium bentonite have been reported as high as 315 meq per 100g (85). The specific ions exchanged in the rumen are still unclear.

Most bentonites carry calcium as the most abundant ion. A few bentonites such as the ones found in Wyoming and in the Black Hills region of the United States, carry sodium as the dominant ion. As an indicator of exceptional swelling properties, the highly colloidal and swelling bentonites usually carry sodium as the major exchange cation.

Volclay* sodium bentonite is a tri-layered, hydrous aluminum silicate with the approximate chemical formula

$$[(Al,Fe)_{1.67}\ Mg_{0.33}]\ Si_4O_{10}\ (OH)_2\ (Na,Ca_{0.33}).$$

Volclay sodium bentonite is made up of 90 percent montmorillonite and 10 percent minute fragments, mostly of feldspar. When dispersed in water, 60 to 70 percent of the particles are separated into very fine particles smaller than 0.5 microns. The sodium, calcium, magnesium and potassium in Volclay sodium bentonite has the base exchange values of 60-65, 5-25, 5-20 and 1-5 meq per 100g, respectively (106).

In dairy rations, sodium bentonite has been used for maintaining or improving milk fat test for lactating dairy cattle low in fiber and high in concentrate. Rindsig, Schultz and Shook (84) fed a milk fat depressing ration to lactating dairy cattle with a concentrate to roughage ratio of three to one. The lactation trial was divided into three periods. The first in which a normal dairy ration was fed. The second period consisted of the milk fat depressing ration. The third period consisted of the milk fat depressing ration itself (control), 5 percent or 10 percent levels of sodium bentonite (80 mesh) added to the pelleted concentrate. Cows had significant increases in milk fat test when fed either level of sodium bentonite, but there were no differences between the two levels. Cows during period three maintained milk fat production of 86, 144, and 144 percent over period two and milk fat production of 60, 87 and 87 percent over period one for the low milk fat ration, 5 percent and 10 percent sodium bentonite treatments, respectively. Milk production was significantly greater for cows fed

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*Volclay is a registered trademark of the American Colloid Company.

sodium bentonite compared to control cows, with milk production being greater for the 5 percent level over the 10 percent level of sodium bentonite in the concentrate. Four percent fat-corrected milk production responses were similar to milk production responses for the respective treatments. Rumen molar percentages of acetate increased, while molar percentages of propionate and valerate decreased in cows fed sodium bentonite compared to controls. No changes in rumen pH were observed throughout the trial.

Benefits of sodium bentonite as a milk fat test improver were also reported by Bringe and Schultz (12). Cows fed a 5 percent level of sodium bentonite in the pelleted concentrate mix maintained a fat test of 2.6 percent while cows not fed any supplementary sodium bentonite maintained only a 1.7 percent milk fat test when fed a 3:1 ratio of pelleted concentrate to hay. Total dry matter intake, when corrected for the weight of sodium bentonite, and milk production responses were non-significant. Significantly higher percentages of rumen acetate (48.6 vs 37.2) and lower percentages of rumen propionate (26.7 vs 38.9) were observed for sodium bentonite fed cows over the controls.

Colling et al. (16) concluded that sodium bentonite (2.5 percent level) had little effect on steers and wether lambs fed high grain diets and was not an effective substitute as a roughage source.

Marshall and Van Horn (60) noticed that lactating cows had higher feed intakes when sodium bentonite was added to rations containing pelleted sugarcane bagasse.

Digestibility studies of lactating cows fed sodium bentonite were investigated by Rindsig and Schultz (85). Cows were fed a low milk fat test producing ration containing 0, 5 and 10 percent levels of sodium bentonite. Though differences were non-significant, mean adjusted dry matter digestibilities were 78.7, 80.8 and 76.5 for the 0, 5 and 10 percent sodium bentonite groups, respectively. The amount of nitrogen retained was 37.2, 79.6 and 53.0g per day while apparent crude protein digestibilities were 79.9, 75.4 and 68.8 percent for the 0, 5 and 10 percent sodium bentonite groups, respectively. In explaining the paradoxical situation of decreased protein digestibility and increased nitrogen retention for sodium bentonite fed cows over the controls, the authors postulated that bentonite may help maintain a more constant rumen ammonium level by holding it in a readily exchangable form. Therefore, the efficiency of nitrogen utilization could be increased even though there was a drop in apparent nitrogen digestibility. The bentonite treated cows had greater fecal nitrogen values, thus showing that bentonite does bind part of the nitrogen. Percent fat in the milk was significantly higher for the sodium bentonite fed cows over the controls with values of 1.47, 2.67 and 2.96 for the 0, 5 and 10 percent sodium bentonite groups, respectively.

Huntington, Emerick and Embry (38) noted a linear decline in nitrogen retention when accompanied by increased levels of sodium bentonite in the diets of lambs. Lambs fed 0, 2, 4, 8 and 12 percent powdered sodium bentonite in the ration had nitrogen retention values of 28.7, 27.2, 21.3, 15.7 and 11.9 g per day, respectively. However, Colling and Britton (15) observed an increase in apparent nitrogen digestibility and retention in sheep fed sodium bentonite.

Sodium bentonite has been used with success in adapting livestock to sudden changes in feeding regimens. Dunn, Emerick and Embry (24) abruptly changed the diets of lambs and steers from a predominately high roughage to a predominately high concentrate ration. Treatments of sodium bentonite, sodium bicarbonate and both bentonite and bicarbonate were fed at 2 percent of the ration for 21 days and 1 percent of the ration from day 22 to day 75 and were compared to a control diet containing no mineral buffers. During the first 21 days of adaptation, lambs fed the combination supplement of sodium bentonite and sodium bicarbonate had an increased feed intake of 19 percent and an increased weight gain of 37 percent over lambs fed the control ration. Steers fed the same supplement had similar increases in feed intake (16 percent) and weight gain (41 percent) over steers fed the control ration. From day 22 to day 75, feed intake and feed efficiency improvements were not sustained. The number of liver abscesses, the incidence of urinary mineral deposits and death losses in steers were 23, 35, 19; 23, 44, 3; 11, 67, 3 and; 6, 56, 0 percent for the control, sodium bentonite, sodium bicarbonate and bentonite-bicarbonate groups respectively. The authors concluded that the increased performance observed in livestock fed sodium bentonite-bicarbonate is restricted to an early adaptation period and not sustained through the remainder of the finishing period. Also, all treatments appeared to offer a high degree of protection from rumen acidosis death due to an abrupt change from high roughage to high concentrate rations.

Huntington, Emerick and Embry (39) noted short term beneficial effects of sodium bentonite fed to lambs at the rate of 2 or 4 percent in a high concentrate diet. For the first 21 days, feed efficiency and ADG of labms were 8.31, 0.10; 4.24, 0.18 and; 8.71, 0.15 for the 0, 2 and 4 percent sodium bentonite groups, respectively. In adjusting lambs to a high concentrate diet, the authors concluded that beneficial results could be obtained by feeding sodium bentonite at the rate of 2 percent of the ration for a 21 day period. If fed for longer duration, adverse effects may result.

Mendel (65) fed a ration supplemented with 2 or 4 percent clay (80 percent montmorillonite with an ion exchange capacity of 83 meg per 100 g) to Hereford-Angus crossbred steers. Empty body weight gains were significantly increased by the addition of 2 or 4 percent clay in isocaloric growing rations. Compared to an isocaloric control, an average of 10 percent less dry matter was required per pound of empty body weight gain when either 2 or 4 percent clay was added in growing rations but not fattening rations.

Prigge (79) simulated acidosis in fistulated steers by force feeding (200 percent voluntary intake) a diet of 85 percent high moisture corn with and without sodium bentonite (2 percent level). Rumen pH levels were 5.2 and 5.3 and peak lactic acid levels at one hour were 15 and 12 mM per liter for the control and sodium bentonite groups, respectively. The amount of HCl required to decrease the pH from 6.5 to 5.5 of 8 hour rumen samples were 65 and 88 meq per liter for the control and sodium benotnite groups, respectively.

Increased incidence of urinary calculi in labms fed sodium bentonite have been reported (24, 39) while others have not confirmed such reports (38).

Mineral balance studies on livestock, fed sodium bentonite, have shown adverse effects due to the addition of the benotnite. Rindsig and Schultz (85) found that the addition of bentonite to the feed made calcium and phosphorus less available to the animal. They suggested that additional calcium and phosphorus be included in bentonite containing rations. Increases in magnesium and potassium retention have been observed in lambs fed a wide range of bentonite levels (38).

Blood serum levels of calcium were significantly decreased and significant increases in blood serum magnesium were noted in lambs fed sodium bentonite (39).

Use of Brewers' By-products in Animal Feeds

By-products of many inductries have been fed to livestock as a source of nutrients. A by-product of the brewing industry, in the production of beer and ale, is dried brewers' grains (DBG), and wet brewers' grains (WBG). DBG according to the American Association of Feed Control Officials, "is the dried extracted residue of barley malt alone or in mixture with other cereal grain or grain products resulting from the manufacture of wort or beer and may contain pulverized spent hops in an amount not to exceed 3 percent, evenly distributed," while WBG "is the extracted residue resulting from the manufacture of wort from barley malt alone or in mixture with other cereal grains or grain products. The guaranteed analysis shall include the maximum moisture" (11).

Early research studies with brewers' by-products were reported by Loosli and Warner (57). Lactating Holstein cows were fed a concentrate mixture containing corn distillers' dried grains (CDDG), DBG or urea as a source of crude protein supplementation. The feeds containing the distillers' or brewers' by-products were superior to a low protein feed (control), in regard to total milk and FCM. CDDG were more valuable than the BDG. Urea was not as effective as the brewers' or distillers' by-products, but was useful as a nitrogen source.

Porter and Conrad (76) studied the relative value of DBG, WBG, dried distillers' grains with solubles (DDGS) and a combination of wheat bran and SBM as supplemental sources for four breeds of dairy cows. By-product protein supplements were added to the ration at the rate of 20 percent of the total dry matter with ground shelled corn making up the remainder of the concentrate. Alfalfa hay or silage and corn silage were used as roughage sources. Feed intake was similar, but cows consumed less dry matter when fed WBG. Cows fed WBG had the highest digestibility. Four percent FCM yields were 21.4, 21.6 21.9 and 21.3 kg per day for the DBG, WBG, DDGS and control groups, respectively.

Porter, Rogers and Conrad (77) compared DBG, rewetted DBG (80 percent water) and WBG. Brewers' grains were fed at the rate of 20 percent of total dry matter intake. Dry matter consumption was less with rewetted DBG (16.7 kg per day) than with DBG (22.4 kg per day) or with WBG (17.9 kg per day). Mean milk productions were similar between treatments within a breed. It was concluded that DBG were used less efficiently than WBG and suggested that the increased in efficiency of WBG may have been induced indirectly by its abnormally high water content, restricting feed intake.

Four experiments with DBG were studied by Rounds and Klopfenstein (88). The first experiemnt showed that the concentration of ammonia released <u>in vitro</u> was less when DBG was used as a source of nitrogen rather than corn gluten meal. A second experiment dealt with rumen protein bypass of DBG using abomasally cannulated sheep. The feeding of DBG resulted in 53.8 percent more total nitrogen reaching the abomasum per day than the feeding of urea. Protein rumen bypass was 60.6 percent for DBG and 30.7 percent for SBM. In the third experiment, steer calves fed corn cob based rations supplemented with DBG gained faster and more efficiently than steers fed the same basal ration supplemented with SBM, urea, or a combination of DBG and urea. Calves fed a combination of DBG and urea gained faster than calves fed urea and only slightly less than calves fed SBM. Feeding the combination of DBG and urea reduced the amount of feed required per kg of gain when compared to the feeding of SBM. Average daily gain (kg per day) and kg feed per kg gain values were 0.93, 7.87; 0.79, 7.86; 0.97, 6.14 and; 0.85, 7.48 for the SBM, urea, DBG and DBG plus urea treatments, respectively. A fourth experiment found that diets containing a combination of DBG and urea resulted in gains equal to SBM containing diets with an increased efficiency over urea containing diets. The authors concluded that feeding a combination of DBG and urea optimizes the use of plant protein and maximizes the use of non-protien nitrogen.

Recently, Merchen, Hanson and Klopfenstein (62) found that protein in DBG is resistant to degradation in the rumen. Abomasally cannulated steers fed DBG or DBG in combination with urea supplements had higher levels of total nitrogen and non-ammonia nitrogen reaching the abomasum than steers fed urea or SBM diets. Rumen bypass of DBG in each of two trials were calculated to be 61 and 48 percent, while SBM bypass in the second trial was calculated to be 24 percent. There were no significant differences between any of the treatments in bacterial nitrogen flow to the lower tract, but the amount of bacterial nitrogen was less in the steers fed supplements containing DBG. Also studied were the amino acids bypassed in the rumen. Feeding either DBG or DBG plus urea diets tended to produce more valine, leucine, phenylalanine and methionine entering the intestinal tract compared to urea or SBM containing diets.

Bravo et al. (10) evaluated three levels of brewers' condensed solubles (BCS) as an energy source for lactating dairy cows and compared them to corn. The control diet fed as a complete feed ad libitum, consisted of corn silage, cottonseed hulls, ground shelled corn, peanut meal and vitamin-mineral premix. BCS was substituted for ground shelled corn on a dry matter basis at the rate of 0.91, 1.59 and 2.27 kg per cow per day. Actual milk yield was statistically higher and milk fat statistically lower for the control cows as compared to the 1.59 BCS cows. No significant differences in body weight change or percent protein in the milk were observed. The data suggested that brewers' condensed solubles can be adequately utilized as an energy source at levels of at least 2.27 kg dry matter per cow per day for lactating Holstein cows.

Johnson and Thompson (43) observed a reduction in liver abscesses in cattle fed diets containing DBG over a 168 day period. Cattle were fed ground shelled corn, minerals and vitamins in combination with 5 percent DBG, 5 percent ground corn cobs or 5 percent ground corn cobs with spent hops. The total number of abscesses observed in each treatment were less and smaller in diameter for cattle fed DBG. The total number of livers condemed due to abscesses were also less from the DBG fed cattle. Backfat thickenss and average daily gain (ADG) was greater ($P<.05$) for non-abscessed cattle compared to abscessed cattle.

Similar to brewers' grains is distillers' grains, a by-product of the distilling industry. Distillers' grains have been fed to lactating dairy cows by several workers with favorable results (56, 73, 108).

Waller _et al_. (107) studied the effective use of distillers' grains in feedlot cattle rations. He compared corn silage supplemented with SBM, corn silage supplemented with distillers' dried grains with solubles (DDGS), and anhydrous ammonia treated corn silage supplemented with DDGS. Cattle fed the non-protein (NPN) treated silage based rations supplemented with DDGS had performance equivalent to rations supplemented with SBM. Corn silage supplemented with DDGS was found to be superior to corn silage supplemented with SBM. Cattle gained 10 percent faster and had more desirable feed efficiencies. The increase in energy supplied by the additional DDGS required to equal SBM on a protein basis was the causative factor for the improved rate of gain. Waller concluded that the addition of DDGS to NPN treated corn silage "optimizes" the value of distillers' grains while making a substantial savings in the cost of protein supplementation for feedlot cattle.

Davis _et al_. (19) suggested some guidelines to follow when feeding brewers' and distillers' grains. These guidelines included:

1. Their use as a protein supplement should be determined based on their relative cost per unit of protein, their availability, and how easily they can be worked into an individual's feeding system.
2. Dried by-products can make up to 25 to 30 percent of the dry matter with satisfactory results.
3. Wet products give best results when added to the ration at approximately 20 percent of total dry matter. Being 80 to

95 percent moisture, products should not be fed to high producing cows because of the strong possibility they will eat less total dry matter. Wet by-products are acceptable feeds for average cows.

4. Brewers' and distillers' grains provide a good source of phosphorus.
5. Storage time is approximately 10 days in winter and 5 days or less in summer. Fly and mold problems can occur in warm weather.

Liquid brewers' yeast has been used with success as a protein supplement in lactating dairy cattle rations (93, 94, 98).

Maltlage Feeding

Maltlage* is a commercial product made up of brewers' pressed grains, brewers' condensed solubles, brewers' yeast, vitamins, minerals and cereal grains. Maltlage is formulated to contain approximately 50-54 percent moisture, 80 percent TDN, 18.5 percent crude protein, 5 percent fat, 10 percent crude fiber, 1.25 percent calcium and 0.87 percent phosphorus (2).

Rakes and Davenport (82) compared production responses of lactating dairy cattle fed a conventional ration of silage, hay and concentrate to rations containing two levels of Maltlage. Three corn silage based rations were fed: I 71.6 percent corn silage, no Maltlage (control); II 53.4 percent corn silage, 39.8 percent Maltlage (medium); III 50 percent corn silage, 50 percent Maltlage (high).

*Maltlage is a registered trademark of Murphy Products Company, Inc.

Alfalfa hay was fed to all treatment groups to adjust the ration crude fiber and protein levels between 14 and 15 percent of the dry matter. Consumption (as fed) of neither the complete feed nor the hay had any significant differences due to ration treatment. Dry matter consumption was lowered by the addition of Maltlage to the ration and may have been attributed to a decrease in dry matter percentage of the Maltlage. Average milk production decreased as Maltlage was added to the ration reflecting a similar trend to that of dry matter intake. Treatment III, in which no grain other than that in Maltlage was fed, may have had a limiting effect on milk production. Average body weight changes were not significantly effected by treatment but Treatment III cows did not maintain their weights as well during the first few weeks of lactation. TDN consumption was lowered as more Maltlage was incorporated into the mixed ration. However, the ratio of FCM produced to TDN consumption was higher for cows fed Maltlage. Conclusions based on this study concerning Maltlage were threefold. A satisfactory level of milk production throughout lactation was maintained by using Maltlage as a partial or complete substitute for a conventional concentrate mixture. The digestible energy in Maltlage was at least as efficiently utilized as that in conventional feeds used in these studies. No reproductive or cow health problems resulted from including Maltlage in the ration.

Jones (44) compared intake and milk production responses of lactating Holstein cows fed a 1:1 blend (as fed) of corn silage and concentrate (18 percent crude protein). In addition, all cows were fed five pounds of alfalfa hay daily in an attempt to prevent milk fat depression and three pounds of 18 percent crude protein concentrate.

Consumption, both on an as fed and dry matter basis, was significantly lower for cows fed Maltlage (2.21 vs 2.70 per hundred pounds of body weight dry matter basis). Though differences were not significant, cows fed Maltlage had smaller milk production yields. However, the Maltlage ration was more efficient in FCM production per unit of net energy intake. Maltlage feeding did not effect either the crude protein nor the total solids content of the milk.

Maltlage was fed to growing Holstein heifer calves from birth to thirty weeks of age by Jones (44). Three complete ration treatments utilizing corn silage were used: I three parts corn silage and one part pelleted dairy concentrate (18 percent crude protein) on an as fed basis; II one part corn silage and one part Maltlage on an as fed basis; III *ad libitum* intake of corn silage plus Maltlage fed separately at the rate of 2 pounds (as fed) per hundred pounds of body weight. Treatment III calves had smaller growth measurements than calves fed Treatment I or II as measured by body weight, length, wither height and paunch circumference. Mean average daily gain (ADG) was significantly greater for calves on Treatment I than calves on both Treatments II or III. Cumulative ADG at 30 weeks of age was smallest for calves in Treatment III. Dry matter consumption was significantly lower for calves on Treatment III compared to Treatments I and II, and crude protein intake of Treatment III heifers was not adequate to maintain an acceptable growth rate. From data and observations of this study, it was concluded that Holstein heifer calves can be raised successfully on complete rations containing a 1:1 ratio (as fed) of corn silage and Maltlage, and that feeding *ad libitum* corn silage plus approximately one percent Maltlage dry matter per 100 pounds of body weight does not provide sufficient protein intake for an acceptable growth rate.

Swanson et al. (97) investigated Maltlage as a concentrate source for growing Holstein heifers. Heifers were above 500 pounds in body weight at the start of the trial and were fed for 42 weeks thereafter. Heifers used in this study had previously been fed Maltlage by Jones (44). Treatment I consisted of 1 part chopped hay and 0.5 part concentrate mix (19 percent crude protein) as fed. Treatment II consisted of 1 part chopped hay and 1.5 parts Maltlage, as fed. Complete rations were fed at the rate to achieve an ADG of 1.54 pounds. Heifers were bred at approximately 16 months of age and the later stages of the trial included both gestation and growth. Treatment I did not support growth at the same rate as Maltlage fed heifers with ADG values of 1.43 and 1.57 for the two treatments, respectively. Heifers appeared to eat Maltlage in preference to chopped hay. The TDN value of Maltlage was calculated at approximately 37 percent as fed, or 80 percent on a dry matter basis. Data from this study showed that Maltlage was just as effective as a dry concentrate mixture when mixed with poor quality grass hay as a feed for growing heifers.

Chase (14) evaluated Maltlage as a concentrate replacement in complete mixed diets for mid-lactation dairy cows. A constant forage to concentrate ratio of 45:55 was maintained on a dry matter basis. The composition of the concentrate portion for the four different treatments consisted of: I cracked corn and commercial pelleted grain; II dried ingredients to simulate the composition of Maltlage; III Maltlage; IV ration II plus water added to make total moisture content equal to Maltlage. Maltlage fed cows consumed less dry matter than cows fed any of the other treatment groups. Dry matter content of the ration alone, could not be used to explain the difference in dry matter intakes. No significant differences in body weight changes, milk production, or 4 percent fat-corrected milk were observed. Pounds of 4 percent fat-corrected milk produced per pound of feed dry matter consumed were 1.13, 1.08, 1.27 and 1.07 for the I through IV treatments, respectively. No significant differences in milk composition were detected. The results of this experiment demonstrated that Maltlage can be used as a satisfactory concentrate replacement in complete mixed rations for mid-lactating dairy cows.

CHAPTER III

EXPERIMENTAL PROCEDURE

Objective

The objective of this study was to determine the intake and milk production response of first lactation Holstein cows fed complete rations containing Maltlage and corn silage with and without sodium bentonite and to determine intake and growth measurements of replacement Holstein heifers fed complete rations containing Maltlage with corn silage or chopped mixed grass hay.

I. Lactation Experiment

Sixteen first lactation Holstein cows were used in a continuous type sixteen week feeding trial to determine the production responses of complete mixed rations containing Maltlage with and without sodium bentonite. Cows were assigned to their respective treatment group at random three days postpartum. Cows used in this study had previously been fed maltlage throughout their entire lifetime by Jones (44) and Swanson *et al*. (97).

Ration Treatments

Treatment I consisted of a complete ration of one part corn silage and one part Maltlage, on an as fed basis. Treatment II consisted of a complete ration of one part corn silage and one part Maltlage with Volclay sodium bentonite (granular size #55) added at the rate of 1 percent, on an as fed basis.

Both complete rations were formulated to contain approximately

14 percent crude protein and 70 percent TDN on a dry matter basis. Complete rations were mixed prior to feeding and were fed fresh, three times daily. No hay or supplemental grain was fed to any of the experimental animals. Complete rations were offered ad libitum to provide approximately 10 percent refusal.

Management of Cows

Cows were housed in the stanchion barn equipped for obtaining individual feed weights at the University of Tennessee-Knoxville dairy farm. All animals were fed individually with care given to notice any abnormalities in feed consumption during early lactation. Cows were allowed exercise twice per day prior to milking at which time they were observed for signs of estrus.

Data Collection

Animals were weighed three days postpartum and at weekly intervals thereafter. Individual consumption data of each cow was determined. Cows were milked twice a day in a standard two-in-line walk-through parlor with daily milk yields recorded with stationary weigh jars. Composite, morning and evening milk samples were collected weekly for analysis of milk fat, total solids, solids-not-fat (SNF) and protein content. Rumen pH and individual volatile fatty acids were collected via stomach tube and measured at monthly intervals. Suction in the collection of rumen samples was provided by a manual syringe. Blood samples were taken at monthly intervals and serum levels of calcium, magnesium, sodium and phosphorus were determined.

Chemical Analyses

Samples of ration ingredients and complete rations were collected weekly and analyzed for dry matter content. Samples were composited by month and analyzed for crude protein, acid-detergent fiber (ADF), acid-insoluble lignin (AIL), calcium, phosphorus and sodium. Fresh feeds or ingredients were dried at 60°C in a drying oven for at least three days to obtain dry matter content. Total dry matter was determined by placing the 60°C dried samples in a 100°C oven overnight and used for calculations of other constituents in order to put them on a 100 percent dry matter basis. Feeds were analyzed for crude protein content by the Kjeldahl method (3). ADF and AIL were determined using modified methods developed by Van Soest (102). Sand was used as a filtrate on all ADF and AIL procedures. Calcium and sodium levels in the feed, and blood serum levels of calcium, sodium and magnesium were determined by the methods of Perkin and Elmer (83). Methods established by Fiske and Subbarow (78) were used for phosphorus determination, both in the feed and blood serum samples. Molar percents of the volatile fatty acids; acetate, propionate, isobutyrate, butyrate, valerate and isovalerate were determined using a Bendix gas chromatograph Model 2600 with procedures developed by Erwin et al. (27). Rumen pH was determined using a Fisher pH meter, Model 600 on fresh rumen samples immediately after they were obtained. Milk fat percentages were determined using a Foss-Milk-O-Tester, Model Mark II.

Statistical Analysis

Programs prepared by Blair et al. (7) were used to analyze the data. Analyses of variance and multivariate analyses were used to determine if differences existed between treatments and between treatments by period (sixteen week trial subdivided into four 4-week periods) for milk production, FCM, milk fat, total solids, SNF, percent crude protein in the milk, dry matter consumption and dry matter consumption per hundred pounds of body weight. Similarly, blood serum levels of calcium, sodium, magnesium and phosphorus and individual rumen volatile fatty acids were tested for differences between treatments by period (sixteen week trial subdivided into three periods). When differences existed ($P < .05$) as indicated by F test, means were separated using Duncan's Multiple Range Test (95), ($P < .05$).

Treatment, week and cow were used as discrete variables in the analysis of variance using the following model:

$$Y_{i\,j\,k} = u + t_i + w_j + c_i + (t * w)_{i\,j} + e_{i\,j\,k}.$$

where: $Y_{i\,j\,k}$ = the estimated value of the dependent production variables: milk production, FCM, milk fat, total solids, SNF, percent crude protein in the milk, dry matter consumption per hundred weight, serum calcium serum sodium, serum magnesium, serum phosphorus and rumen volatile fatty acids.

u = theoretical population mean.

t_i = treatment, i = 1-2.

w_j = week, j = 1-16.

c = cow within treatment.

$e_{i\,j\,k}$ = random error.

The term cow within treatment was used as the error term to test significance for the source treatment.

Dependent production variables milk, FCM, body weight and dry matter consumption were fitted to a non-linear regression on lactation week using the weekly observed values as a polynomial to describe the curve for each cow. The following equation was used:

$$Y_i = a + b_1 \text{ (week)} + b_2 \text{ (week}^2\text{)} + b_3 \text{ (week}^3\text{)}$$

where: Y_i = the estimated value of the dependent production variable for each week.

a = the intercept value for each dependent variable at week 0.

week = week number.

b_1, b_2, b_3 = the regression coefficients for each dependent variable on the independent variable = week, week^2, week^3.

Multivariate analysis of the regression coefficients, b values, which were generated in the previous model for each dependent production variable by cow, was performed using the following model, with treatment as a discrete variable:

$$Y_{i\,j} = u + t_i + e_{i\,j}.$$

where:

$Y_{i\,j}$ = the estimated intercept value and the regression coefficients for each dependent variable on the independent variable week.

u = theoretical population mean.

t_i = treatment, i = 1-2.

$e_{i\,j}$ = random error.

II. Growth Trial

A continuous type feeding trial was conducted beginning with the birth of Holstein female calves. Holsteins were assigned to pens based on birth order within breed and calves were randomly assigned to rations. Thirty-six animals were divided equally between the two ration treatments.

Ration Treatments

Treatment I consisted of a complete ration of one part corn silage and one part Maltlage, on an as fed basis, fed ad libitum.

Treatment II consisted of chopped mixed grass hay fed ad libitum, plus Maltlage fed separately at the following rates:

Week 2-15 - 5.5# Maltlage/100# body weight
Week 16-20 - 5.0# Maltlage/100# body weight
Week 21-25 - 4.5# Maltlage/100# body weight
Week 26-30 - 4.0# Maltlage/100# body weight.

Rates of Maltlage were adjusted biweekly for each calf.

Both complete rations were mixed prior to feeding and fed ad libitum, twice a day to provide approximately 10 percent refusal. Complete rations were formulated to contain approximately 14 percent crude protein and 70 percent TDN on a dry matter basis.

Calf Management

Calves remained with the dam for two to three days after calving. Calves were housed in a calf barn with each calf having its own individual pen. Care was taken to insure that each calf received ample colostrum during the first few hours after birth.

Milk replacer (one pound per nine pounds water) or whole milk (fresh or treated cows) were fed to each calf individually at the rate of 10 percent of body weight for six weeks duration. All calves were weaned at six weeks. Forage feeding (Treatments I and II) were offered to each calf during the second week. Feed consumption data was collected beginning with the third week.

Data Collection

Body weights were measured at birth and at biweekly intervals thereafter for a 30 week period. Beginning at one week of age, wither height, body length and heart girth were recorded at biweekly intervals for a 30 week period. Amounts of individual feed fed and refused, were recorded daily.

Chemical Analyses

Weekly samples of complete rations and ration ingredients were composited and analyzed by month for dry matter content, crude protein, ADF, AIL, calcium and phosphorus as previously described for the lactation experiment.

Statistical Analysis

Programs prepared by Blair et al. (7) were used to analyze the data. Analyses of variance and multivariate analyses were used to determine if differences existed between treatments for body weight, average daily gain, wither height, body length, heart girth and dry matter intake per hundred pounds of body weight. When differences existed ($P < .05$) as indicated by F test, means were separated using Duncan's Multiple Range Test (95), ($P < .05$).

Treatment, week and calf were used as discrete variables in the preliminary analysis of variance using the following model:

$$Y_{ijk} = u + t_i + w_j + c_i + (t * w)_{ij} + e_{ijk}$$

where: Y_{ijk} = the dependent variables: weight, ADG, length, wither height, heart girth, and dry matter intake per hundred pounds body weight.

u = theoretical population mean.

t_i = treatment, i = 1-2.

w_j = week, j = 1-30.

c = calf within treatment.

e_{ijk} = random error.

Dependent variables: weight, length, wither height and heart girth were fitted to a non-linear regression on age using biweekly observed values as a polynomial to describe the response curve for each calf. The following equation was used:

$$Y_i = a + b_1 \text{ (week)} + b_2 \text{ (week}^2) + b_3 \text{ (week}^3).$$

where: Y_i = the estimated value of the dependent variable.

a = the intercept value for each dependent variable at week 0.

week = age of calf in week(s).

b_1, b_2, b_3 = the regression coefficients for each dependent variable = week, week^2, week^3.

Multivariate analysis of the regression coefficients, b values, which were generated in the previous model for each dependent production variable by calf, was performed using the following model, with treatment as a discrete variable:

$$Y_{ij} = u + t_i + e_{ij}$$

where: Y_{ij} = the estimated intercept value and the regression coefficients for each dependent variable on the independent variable week.

u = theoretical population mean.

t_i = treatment, i = 1-2.

e_{ij} = random error.

CHAPTER IV

RESULTS AND DISCUSSION

I. Lactation Experiment

Table 1 contains the chemical compostion of the feeds and feed ingredients. Corn silage had a dry matter content of 31.2 percent and a crude protein content of 8.7 percent. Maltlage dry matter was 48.3 percent and had a crude protein content of 17.4 percent.

Dry matter content was 40.5 and 40.7 for complete rations I and II, respectively. In both complete rations, corn silage provided 39 percent of the total dry matter and Maltlage provided 61 percent of the total dry matter. Crude protein content of complete ration I (13.8 percent) was similar to crude protein content of complete ration II (13.6 percent). Both acid detergent fiber (ADF) and acid insoluble lignin (AIL) were slightly higher on Treatment II (19.6, 2.8) than on Treatment I (17.7, 2.5). Sodium content in complete ration II was slightly higher than that of complete ration I (0.22 vs 0.18 percent) reflecting the addition of sodium bentonite.

Daily feed and dry matter consumption data are reported in Table 2. The amount of dry matter consumed, as measured by both total pounds consumed and by pounds consumed per hundred weight, were slightly higher for cows on Treatment II than for cows on Treatment I, even though differences were not significant. Marshall and Van Horn (60) noted increased intakes of cows fed sodium bentonite in rations containing pelleted sugarcane bagasse. Rindsig and Schultz (85) and Bringe and Schultz (12) found no increases in dry matter intake of cows

TABLE 1

MEANS AND STANDARD DEVIATIONS OF CONSTITUENTS OF COMPLETE FEEDS AND INGREDIENTS OF COMPLETE FEEDS FED TO FIRST LACTATION HOLSTEIN COWS

	Complete ration treatment[a]			
Constituent	I	II	Corn silage	Maltlage
Dry matter (%)	40.5 ± 0.99[b]	40.7 ± 1.21	31.2 ± 1.56	48.3 ± 1.52
Crude protein (%) DMB[c]	13.8 ± 0.91	13.6 ± 0.43	8.7 ± 0.28	17.4 ± 0.69
Acid detergent fiber (%) DMB	17.7 ± 1.68	19.6 ± 1.38	25.9 ± 1.76	12.6 ± 0.91
Acid insoluble lignin (%) DMB	2.5 ± 0.29	2.8 ± 0.23	2.8 ± 0.38	2.4 ± 0.39
Calcium (%) DMB	0.97 ± 0.10	1.00 ± 0.05	0.35± 0.02	1.45 ± 0.09
Phosphorus (%) DMB	0.58 ± 0.04	0.59 ± 0.03	0.23± 0.04	0.82 ± 0.02
Sodium (%) DMB	0.18 ± 0.02	0.22 ± 0.02	0.05± 0.02	0.27 ± 0.03

[a]Treatment I = 1 part corn silage and 1 part maltlage.
Treatment II = 1 part corn silage and 1 part maltlage with 1% sodium bentonite.

[b]Standard deviation.

[c]DMB = Dry matter basis.

TABLE 2

DAILY FEED AND DRY MATTER CONSUMPTION DATA OF FIRST LACTATION HOLSTEIN COWS

Variable, $\bar{x}$	Treatment* I	Treatment* II
Complete Ration Consumed (Lbs)	46.5 ± 10.86[b]	49.7 ± 11.56
% Dry Matter in Ration	40.8[a]	40.9[a]
Dry Matter Consumed (Lbs)	19.0[a] ± 4.54	20.3[a] ± 4.88
Dry Matter Consumed/Cwt (Lbs)	1.8[a] ± 0.39	1.9[a] ± 0.45

*Treatment I = Complete ration consisting of 1 part corn silage and 1 part Maltlage.

Treatment II = Complete ration consisting of 1 part corn silage and 1 part Maltlage with 1% sodium bentonite.

[a]Values in same row with same letter are not significantly different ($P>.05$).

[b]Standard deviation.

due to feeding of sodium bentonite when adjustments were made excluding the bentonite. In contrast, sodium bentonite can be compared to other buffering additives such as sodium bicarbonate and magnesium oxide where a decrease in intake usually occurs (20, 25, 26).

The amount of dry matter consumed as a percent of bodyweight was 1.8 for Treatment I and 1.9 for Treatment II. Since milk production data in this present study was taken during the first 16 weeks of lactation on first lactation cows, dry matter intake was expected to be somewhat low. Low dry matter consumption data have been reported at this location by other researchers (44, 99). Spahr (92) noted that dairy cattle can consume up to 3.5 percent of body weight. Complete rations containing corn silage and Maltlage have been known to cause a decrease in dry matter consumption (14, 44, 82). Rakes and Davenport (82) suggested that low dry matter content of complete rations containing corn silage and Maltlage may be responsible for the low dry matter consumption.

The relationship between dry matter intake and stage of lactation is shown in Figure 1 for each treatment. Treatment I cows reached a peak of voluntary dry matter intake between 8 and 11 weeks postpartum, decreasing thereafter. Voluntary dry matter intake for Treatment II cows leveled off by week 8 but again started to increase on week 14 untill the end of the trial. The relationship between dry matter intake, milk production and body weight to stage of lactation is shown in Figures 2 and 3.

Average period and overall daily production values of milk, FCM and components of milk are shown in Table 3. Overall daily milk production differences between Treatments I and II (48.8 vs 50.0) were

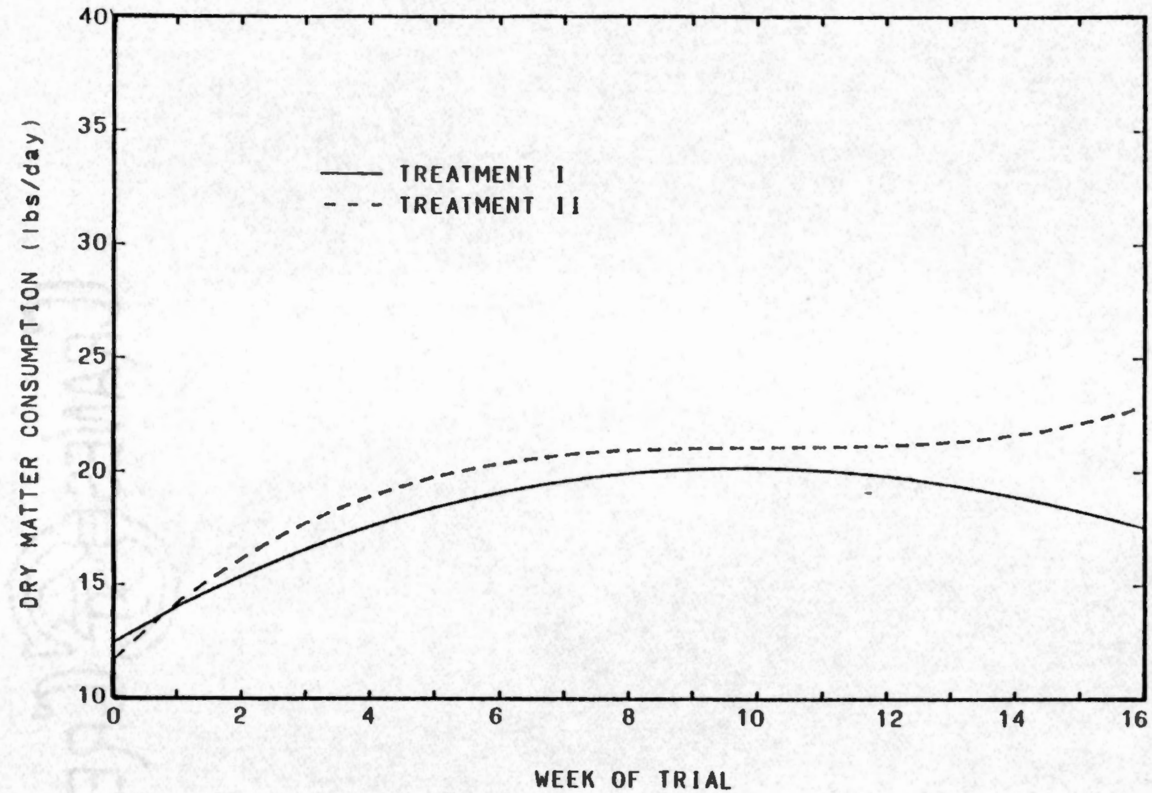

Figure 1. Trinomial regression curves for daily dry matter intake.

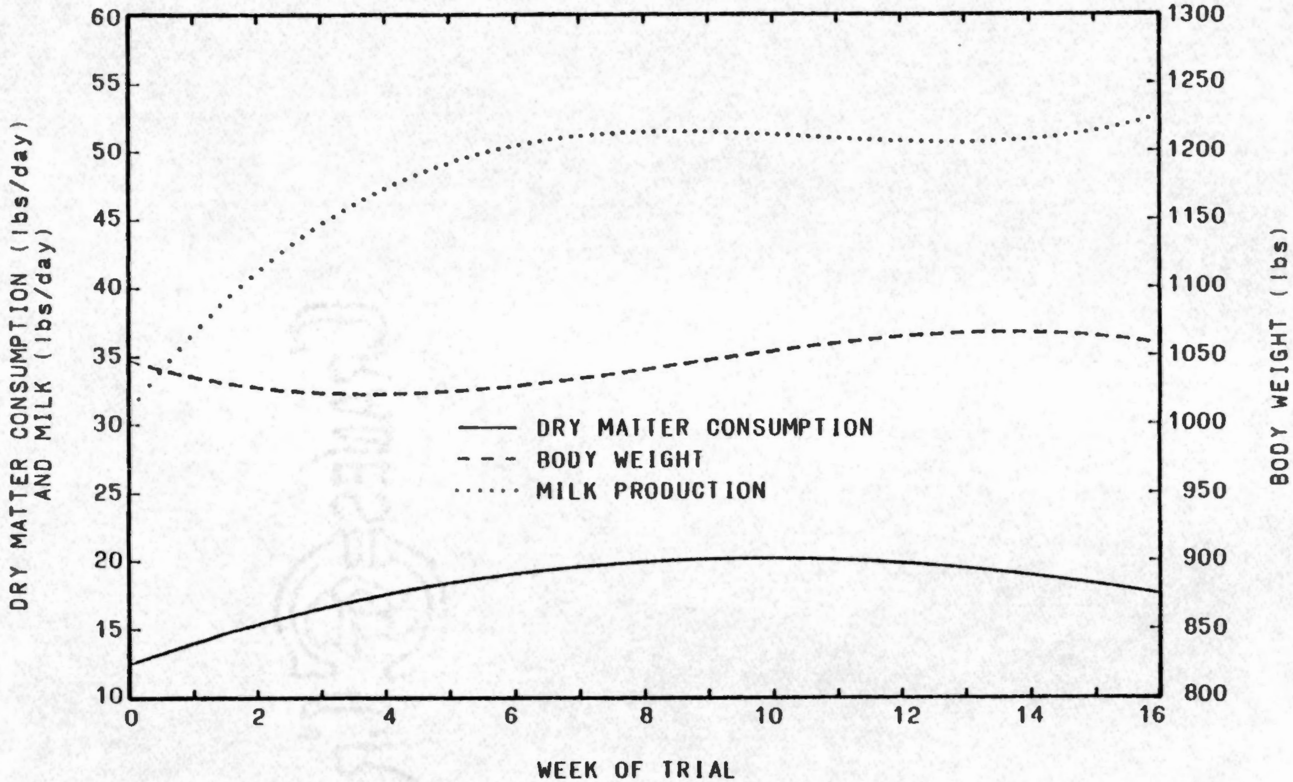

Figure 2. Trinomial regression curves for daily dry matter intake, daily milk production, and body weight for Treatment I cows.

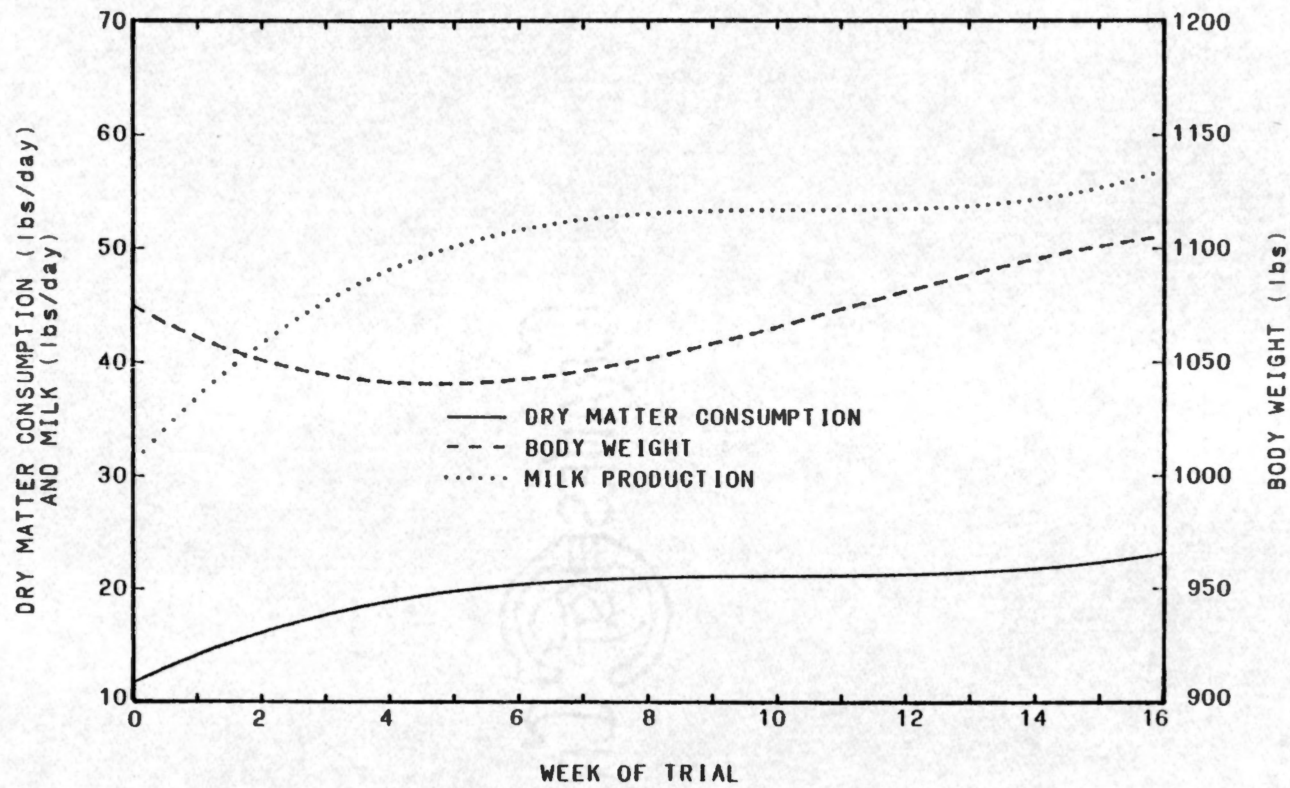

Figure 3. Trinomial regression curves for daily dry matter intake, daily milk production, and body weight for Treatment II cows.

TABLE 3

DAILY PRODUCTION OF FIRST LACTATION HOLSTEIN COWS

Production variable	Treatment[*]	Week 1-4	Week 5-8	Week 9-12	Week 13-16	Overall
Milk production (lbs), $\bar{x}$	I	$42.5^a \pm 10.99^c$	$50.5^a \pm 6.45$	$51.0^a \pm 5.86$	$52.9^a \pm 6.63$	$48.8^a \pm 8.75$
	II	$43.1^a \pm 6.41$	$51.6^a \pm 7.44$	$53.2^a \pm 9.52$	$53.0^a \pm 10.48$	$50.0^a \pm 9.35$
4% fat-corrected milk (lbs), $\bar{x}$	I	$37.5^a \pm 7.42$	$39.4^a \pm 5.72$	$36.8^a \pm 4.09$	$37.9^a \pm 4.42$	$37.9^a \pm 5.7$
	II	$40.4^a \pm 5.14$	$42.5^a \pm 4.75$	$40.7^b \pm 5.53$	$39.9^a \pm 5.64$	$41.0^a \pm 5.3$
Milk composition						
Fat (%), $\bar{x}$	I	$3.46^a \pm 1.39$	$2.58^a \pm 0.79$	$2.19^a \pm 0.72$	$2.16^a \pm 0.62$	$2.64^a \pm 1.09$
	II	$3.71^a \pm 1.19$	$2.91^a \pm 0.86$	$2.55^a \pm 0.87$	$2.48^a \pm 0.91$	$2.95^a \pm 1.08$
Total solids (%), $\bar{x}$	I	$12.38^a \pm 1.74$	$11.80^a \pm 0.83$	$11.59^a \pm 0.71$	$11.77^a \pm 0.60$	$11.89^a \pm 1.14$
	II	$12.67^a \pm 1.07$	$11.85^a \pm 0.48$	$11.62^a \pm 0.65$	$11.74^a \pm 0.95$	$11.98^a \pm 0.91$
Solids-not-fat (%), $\bar{x}$	I	$8.92^a \pm 0.80$	$9.21^a \pm 0.65$	$9.40^a \pm 0.77$	$9.58^a \pm 0.86$	$9.24^a \pm 0.79$
	II	$8.95^a \pm 0.70$	$8.94^a \pm 0.45$	$9.07^a \pm 0.63$	$9.26^a \pm 0.56$	$9.04^a \pm 0.63$
Crude protein (%), $\bar{x}$	I	$3.28^a \pm 0.35$	$3.20^a \pm 0.18$	$3.17^a \pm 0.20$	$3.30^a \pm 0.26$	$3.23^a \pm 0.26$
	II	$3.34^a \pm 0.56$	$2.98^a \pm 0.24$	$3.05^a \pm 0.31$	$3.18^a \pm 0.12$	$3.13^a \pm 0.38$

[*]Treatment I = 1 part corn silage and 1 part maltlage.
Treatment II = 1 part corn silage and 1 part maltlage with 1% sodium bentonite.

[a,b]Treatment means for a production variable in a column with different superscripts differ significantly ($P<.05$).

[c]Standard deviation.

non-significant as was FCM (37.9 vs 41.0). Period differences in daily milk production and FCM were non-significant with the exception of FCM in the period of week 9 through week 12. During weeks 9 through 12, cows on Treatment I produced an average of 36.8 pounds FCM while cows on Treatment II produced an average of 40.7 pounds FCM. Production curves of total milk and FCM are illustrated in Figures 4 and 5.

Rindsig, Schultz and Shook (84) observed significant increases in both milk production and FCM of cows fed sodium bentonite (5 and 10 percent levels included in the pelleted concentrate mix) in complete rations while other workers (12, 85) observed no significant differences in milk production due to sodium bentonite. Rakes and Davenport (82) suggested that cows in their first eight to twelve weeks of lactation fed Maltlage and corn silage without additional concentrate may have limited milk production.

Average milk fat values were 2.64 and 2.95 percent for Treatment I and II, respectively. Though differences were non-significant, they may be meaningful. Researchers have confirmed increases in milk fat percentages in milk of cows fed sodium bentonite (12, 84, 85). Since the cows on either treatment were fed no supplemental hay, a depression in milk fat test was somewhat expected. Methods of handling and storing samples, especially when refrigerated in plastic containers, have been shown to depress milk fat test by as much as 1 percent (23). Differences in milk fat tests between treatments within each period were non-significant, but a consistent trend of increased milk fat percentages of cows on Treatment II over cows on Treatment I followed throughout the trial. Fiber content, as measured by ADF and AIL, was slightly higher for Treatment II (Table 1, page 36). This small

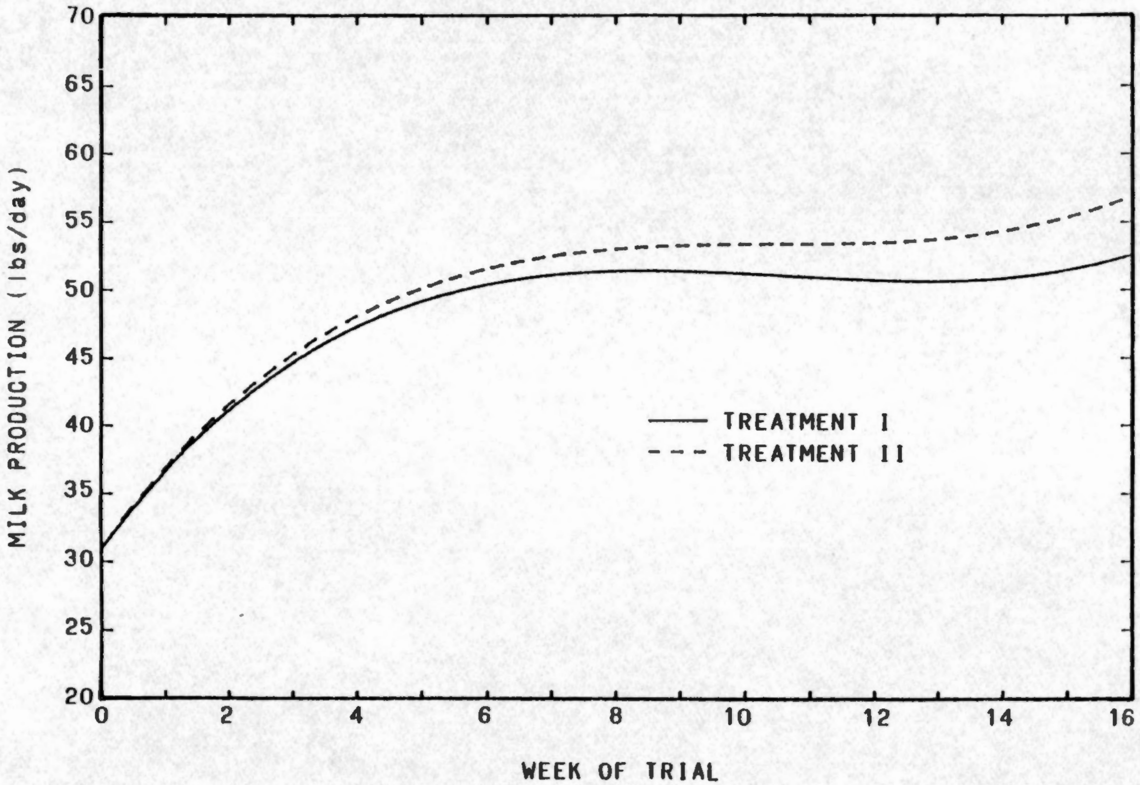

Figure 4. Trinomial regression curves for daily milk production.

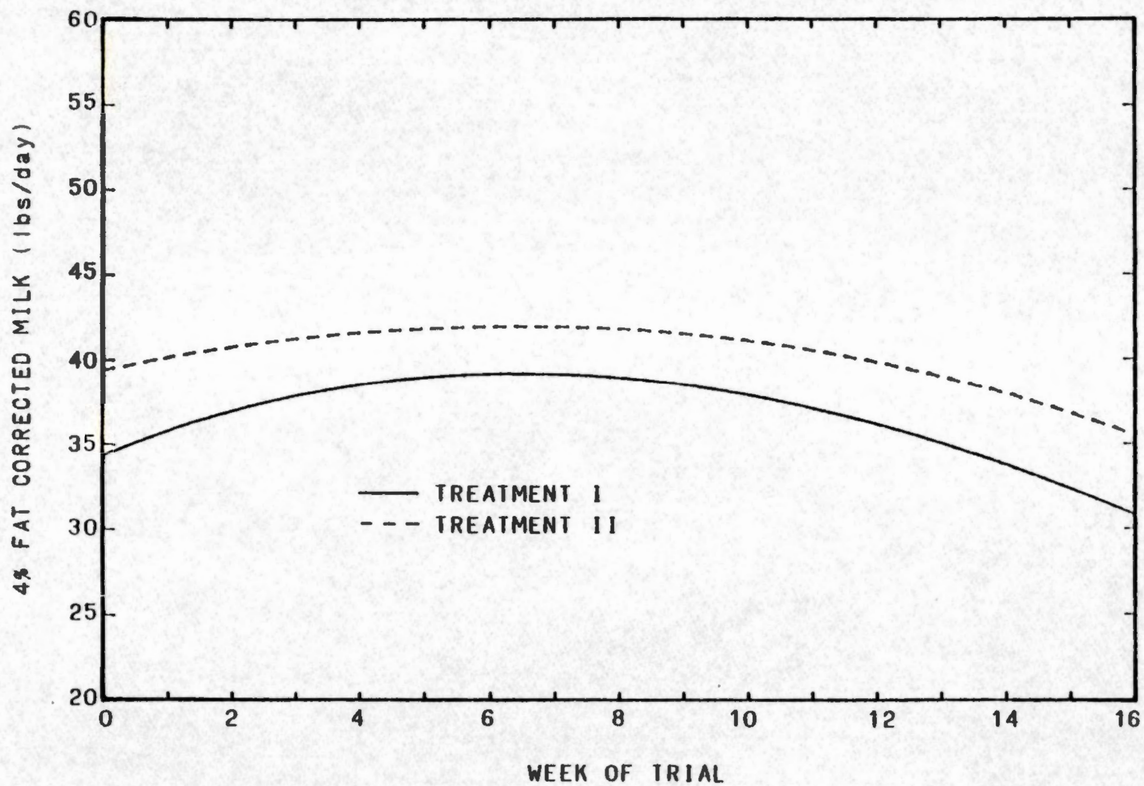

Figure 5. Trinomial regression curves for daily 4% fat-corrected milk production.

increase in fiber level may explain some of the observed differences in milk fat test.

Cows in this study on Treatment II consumed an average of 0.50 pound of sodium bentonite per day (2.46 percent of the total dry matter intake) and produced milk containing 2.95 percent fat compared to controls consuming no bentonite and producing 2.46 percent milk fat. Cows fed 5 percent sodium bentonite in the pelleted concentrate mix by Bringe and Schultz (12), consumed 1.32 pounds of sodium bentonite per day (3.77 percent of total dry matter intake) and produced milk containing 1.7 percent fat. In the same study, cows fed 10 percent levels of sodium bentonite consumed 2.42 pounds of the mineral (7.53 percent of total dry matter intake) and produced milk containing 2.4 percent milk fat. Cows in studies of Rindsig and Schultz (85) consumed 1.21 and 2.44 pounds of sodium bentonite per day (3.67 and 7.35 percent of total dry matter intake) and produced milk containing 2.6 and 2.4 percent fat. Similarily, Rindsig et al. (84) observed cows consume 1.41 and 3.01 pounds of sodium bentonite per day (3.95 and 8.35 percent of total dry matter intake) and produced milk containing 2.6 percent fat compared to controls (no bentonite) producing 1.8 percent milk fat. The amount of sodium bentonite consumed by cows in this present study, as measured by pounds per day and percent of total dry matter intake, was considerably less than that observed by other researchers (12, 84, 85).

Overall values of total solids (TS), solids-not-fat (SNF) and crude protein of milk for Treatment I (11.89, 9.24 and 3.23 percent) were similar to values for Treatment II (11.98, 9.04 and 3.13 percent). Non-significant differences also existed for TS, SNF and crude protein of milk between treatments by period.

Body weights are illustrated in Figure 6. Treatment II cows were slightly heavier than Treatment I cows throughout the trial. However there were no significant differences in body weight due to treatment. Rakes and Davenport (82) and Jones (44) reported greater weight losses (non-significant) of cows consuming a 1:1 ratio of corn silage to Maltlage, probably due to a reduction in dry matter consumption.

Rumen pH and volatile fatty acid (VFA) composition of Holstein cows is shown in Table 4. Rumen pH was 6.3 for both Treatments I and II. Other researchers (12, 84) found no significant differences in rumen pH due to sodium bentonite feeding. Counotte et al. (18) noted that ruminants fed readily fermentable carbohydrates without prior exposure to such diets, may cause a sudden drop in rumen pH from 6.8 to 5.5 or lower. Fulton et al. (31) indicated a possible relationship between lower rumen pH and cessation of voluntary feed intake. Neither was there a drastic change in diet, nor was there a sufficient drop in rumen pH to explain the low dry matter intake observed in this trial.

Differences in VFA composition between treatments for the individual fatty acids were all non-significant. Molar percent values for Treatment I of acetate, propionate and butyrate were 55.1, 28.9 and 10.3 while molar percent values for Treatment II were 54.6, 26.9 and 12.4. Esdale et al. (28) found that a corn silage diet fed to dairy cattle produced rumen molar percent values of 64, 19 and 17, while cows fed a diet of alfalfa hay had rumen molar percent values of 73, 17 and 10 for acetate, propionate and butyrate, respectively. Bauman et al. (4) noted rumen molar percent values of 45, 47 and 8 for acetate, propionate and butyrate in dairy cattle fed a high concentrate low roughage ration.

The smaller molar percentage of acetate (non-significant) and

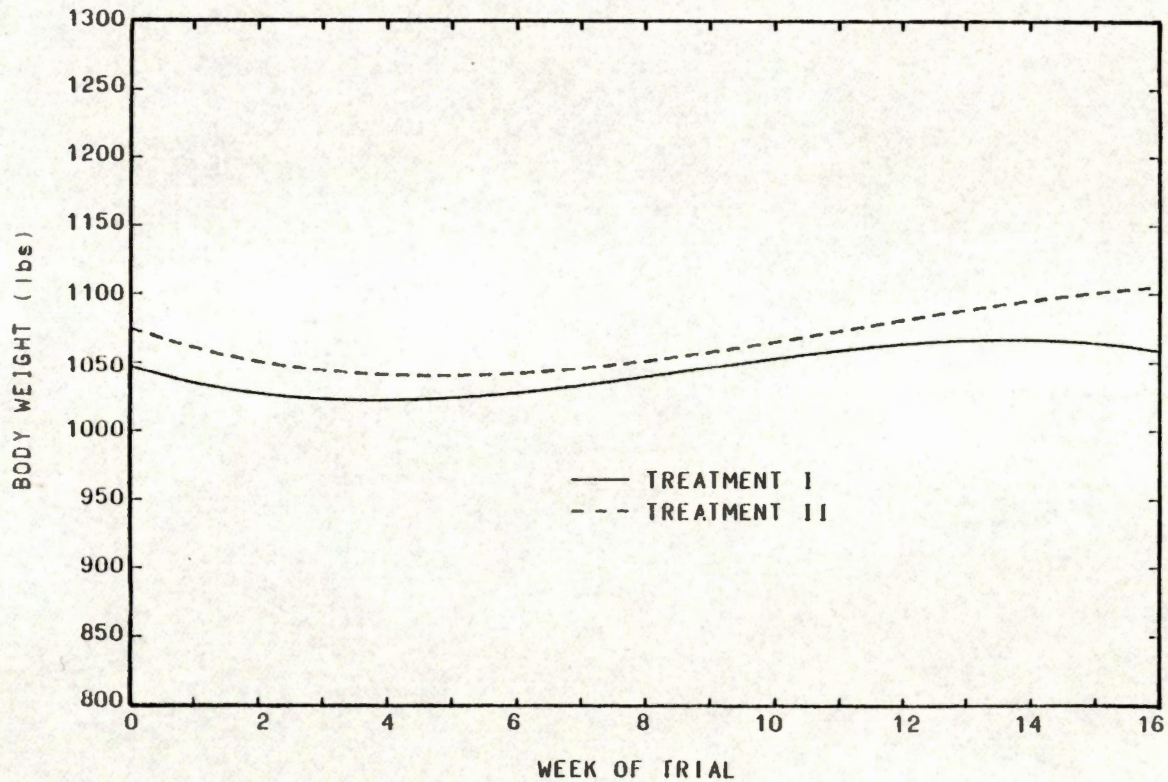

Figure 6. Trinomial regression curves for body weight.

TABLE 4

RUMEN pH AND RUMEN VOLATILE FATTY ACID COMPOSITION OF FIRST LACTATION HOLSTEIN COWS

Variable, $\bar{x}$	Treatment* I	Treatment* II
Rumen pH	6.3[a] $\pm$ 0.32[b]	6.3[a] $\pm$ 0.36
Acetate (molar %)	55.1[a] $\pm$ 5.16	54.6[a] $\pm$ 3.60
Propionate (molar %)	28.9[a] $\pm$ 4.97	26.9[a] $\pm$ 3.35
Butyrate (molar %)	10.3[a] $\pm$ 2.47	12.4[a] $\pm$ 3.24
Isobuytrate (molar %)	1.4[a] $\pm$ 0.79	1.3[a] $\pm$ 0.59
Valerate (molar %)	3.1[a] $\pm$ 1.16	3.1[a] $\pm$ 1.41
Isovalerate (molar %)	1.5[a] $\pm$ 0.59	1.7[a] $\pm$ 0.57
Acetate/Propionate Ratio	2.0[a] $\pm$ 0.57	2.1[a] $\pm$ 0.35

*Treatment I = Complete ration consisting of 1 part corn silage and 1 part Maltlage.

Treatment II = Complete ration consisting of 1 part corn silage and 1 part Maltlage with 1% sodium bentonite.

[a]Values in same row with same letter are not significantly different (P>.05).

[b] = Standard deviation.

corresponding increase in milk fat test (non-significant) of sodium bentonite fed cows in comparison to control cows, does not agree with other workers (12, 13, 47, 84, 91), in which there was a direct relationship between rumen acetate and milk fat percentage. However, rumen propionate did follow an inverse realationship with milk fat test. Acetate to propionate ratios were 2.0 and 2.1 for Treatment I and II, respectively. Others report increased acetate to propionate ratios of cows fed sodium bentonite (12, 84).

Blood serum levels of calcium, magnesium, sodium and phosphorus are shown in Table 5. No significant differences were found between treatments. Average serum values in cows according to Hyde et al. (40) are 11.08, 2.05, 326 and 6.05 mg per 100 ml for calcium, magnesium, sodium and phosphorus, respectively. Fraering et al. (30) found a highly significant effect of season of the year on serum phosphorus levels and stage of pregnancy on serum calcium levels. Forar et al (29) found that inorganic phosphorus in plasma initially decreased with lactation and then increased with time. However, levels of inorganic phosphorus in plasma and milk were more closely related to milk production than stage of lactation.

Regression coefficients for milk, FCM, dry matter consumption and body weight are in Table A1. As measured by multivariate analysis, there were no overall treatment effects on the regression coefficients for milk, FCM, dry matter consumption and body weight curves which are shown in Figures 1, 4, 5 and 6, pages 39, 44, 45 and 48.

Ratios of milk produced to dry matter consumption were 2.57 and 2.46 for Treatments I and II, respectively. Ratios of FCM produced to dry matter consumption were 1.99 and 2.02 for Treatments I and II,

TABLE 5

BLOOD SERUM LEVELS OF CALCIUM, MAGNESIUM, SODIUM AND PHOSPHORUS OF FIRST LACTATION HOLSTEIN COWS

Variable, $\bar{x}$	Treatment* I	Treatment* II
Calcium (mg/100 ml)	10.69[a] ± 0.72[b]	10.70[a] ± 0.86
Magnesium (mg/100 ml)	2.77[a] ± 0.41	2.71[a] ± 0.22
Sodium (mg/100 ml)	380.20[a] ± 29.15	374.40[a] ± 35.40
Phosphorus (mg/100 ml)	7.61[a] ± 1.30	7.72[a] ± 1.56

*Treatment I = Complete ration consisting of 1 part corn silage and 1 part Maltlage.

Treatment II = Complete ration consisting of 1 part corn silage and 1 part Maltlage with 1% sodium bentonite.

[a]Values in the same row with same letter are not significantly different (P>.05).

[b]Standard deviation.

respectively. Jones (44) found that cows consuming a 1:1 ratio (as fed) of corn silage to Maltlage produced more milk and FCM per unit of dry matter intake when compared to cows consuming a 3:1 ratio (as fed) of corn silage to grain. Porter et al. (77) reported that WBG was more efficient than DBG for milk production.

II. Growth Trial

Chemical composition of feed and feed ingredients consumed by replacement heifers are reported in Table 6. Corn silage had a dry matter content of 38.6 percent and a crude protein content of 9.1 percent. Maltlage dry matter was 45.2 percent and crude protein content was 19.8 percent. Mixed chopped grass hay had a dry matter content of 87.7 percent and crude protein content of 8.2 percent. ADF and AIL content for corn silage was 32.3 and 4.4 percent; Maltlage 18.3 and 4.1 percent and; hay 50.7 and 7.9 percent.

Dry matter content for complete ration I was 42.3 percent. In Treatment I, corn silage provided 46 percent of the dry matter and Maltlage provided 54 percent of the dry matter. ADF and AIL content was 25.0 and 4.3 percent for complete ration I. Crude protein content of complete ration I was 14.7 percent. Calcium and phosphorus content in complete ration I was 1.01 and 0.59 percent.

Table 7 contains the daily dry matter consumption and daily dry matter consumption per hundred pounds body weight (cwt). Growing heifers progressively consumed more dry matter as a function of age. Average dry matter intake (pounds) for calves on Treatment I was 4.7 and dry matter intake (pounds) per cwt averaged 1.98. Total dry matter consumption for calves on Treatment II averaged 4.6 pounds with Maltlage

TABLE 6

MEANS AND STANDARD DEVIATIONS OF CONSTITUENTS OF COMPLETE FEEDS AND INGREDIENTS OF COMPLETE FEEDS FED TO REPLACEMENT HOLSTEIN HEIFERS

Constituent	Complete ration 1 part corn silage: 1 part maltlage	Corn silage	Maltlage	Mixed chopped grass hay
Dry matter (%)	42.3 ± 1.44[a]	38.6 ± 2.32	45.2 ± 0.42	87.7 ± 1.94
Crude protein (%) DMB[b]	14.7 ± 0.85	9.1 ± 0.73	19.8 ± 0.41	8.2 ± 1.66
Acid detergent fiber (%) DMB	25.0 ± 3.85	32.3 ± 4.59	18.3 ± 4.65	50.7 ± 7.06
Acid insoluble lignin (%) DMB	4.3 ± 1.28	4.4 ± 1.05	4.1 ± 1.36	7.9 ± 2.07
Calcium (%) DMB	1.01 ± 0.29	0.31 ± 0.08	1.82 ± 0.53	0.54 ± 0.10
Phosphorus (%) DMB	0.59 ± 0.09	0.28 ± 0.03	0.88 ± 0.13	0.26 ± 0.08

[a]Standard deviations.

[b]Dry matter basis.

TABLE 7

DAILY DRY MATTER INTAKE AND DRY MATTER INTAKE/CWT OF REPLACEMENT HOLSTEIN HEIFERS

	Daily Dry Matter Intake (Lbs/Day)			
	Treatment I	Treatment II		
Age (wk)	Corn Silage-Maltlage Mix	Maltlage	Hay	Total DM
5	0.3 ± 0.14[a]	0.3 ± 0.28	0.2 ± 0.12	0.5 ± 0.29
10	2.4 ± 1.23	1.4 ± 1.06	0.6 ± 0.49	2.0 ± 0.79
15	3.9 ± 1.21	3.5 ± 1.13	1.4 ± 0.61	4.9 ± 0.89
20	6.7 ± 1.14	5.2 ± 0.97	1.3 ± 0.38	6.5 ± 1.02
25	7.9 ± 1.37	5.7 ± 0.84	2.9 ± 0.86	8.6 ± 1.51
30	10.7 ± 2.47	5.6 ± 1.02	3.3 ± 0.85	8.9 ± 0.88

	Daily Dry Matter Intake/Hundred Lbs Body Weight (Lbs)	
	Treatment*	
Week	I	II
5	0.3 ± 0.14	0.4 ± 0.25
10	1.7 ± 0.65	1.5 ± 0.55
15	2.4 ± 0.40	2.6 ± 0.18
20	2.8 ± 0.29	2.8 ± 0.29
25	2.6 ± 0.29	2.8 ± 0.17
30	2.8 ± 0.70	2.4 ± 0.11

[a]Standard deviation.

*Treatment I = 1 part corn silage: 1 part Maltlage.
Treatment II = Hay *ad libitum* plus Maltlage fed separately at the following rates:

Week 2-15 - 5.5# Maltlage/100 B.W.
Week 16-20 - 5.0# Maltlage/100 B.W.
Week 21-25 - 4.5# Maltlage/100 B.W.
Week 26-30 - 4.0# Maltlage/100 B.W.

contributing 3.2 pounds and hay contributing 1.4 pounds to the total dry matter intake. Dry matter intake per cwt for calves on Treatment II averaged 1.99. Differences due to treatment of dry matter consumption per cwt were non-significant (P<.05).

Weighbacks of Maltlage calves on Treatment II were initially high at the start of the trial, gradually decreasing until approximately 20 weeks of age, where approximately zero weighback of Maltlage was observed. If feeding of hay and Maltlage to calves was practiced *ad libitum* for reasons of practicality and handling ease, 20 weeks of age would be a reasonable time to start restrictive feeding of Maltlage. At 20 weeks of age, intake could then be restricted to 4.0 to 4.5 pounds Maltlage per hundred pounds body weight while hay is continually fed *ad libitum*.

As previously mentioned, corn silage contributed to 46 percent of the total dry matter in complete ration I. Goodrich (32) observed maximum dry matter intake when 40 to 50 percent corn silage dry matter was included in calf rations. An average dry matter intake per cwt of 2.2 pounds was noted by Jones (44) when he fed a ration of one part corn silage to one part Maltlage to heifer calves 2 to 30 weeks of age. Too low a fiber level in calf starter rations can reduce feed intake.

Miller *et al.* (66) observed increased feed consumption and weight gains in calves fed 10 percent cotton seed hulls in a starter ration as a source of roughage. Since calves were offered their respective ration treatments at two weeks of age, six weeks should be an adequate time for proper development of rumen fermentation. Hibbs *et al.* (36) found that calves by the age of seven weeks had sufficient rumen fermentation to permit all milk and other sources of animal protein to be taken from the ration without decreasing growth. Swanson and Harris (96) indicate that effective rumination is established between two and four weeks of age and that rumination time is positively correlated with dry feed consumption.

Body weight gains of heifers on both treatments increased with age. Cumulative average daily gain (ADG) is in Table 8. Mean ADG was 0.92 and 0.93 for calves on Treatment I and II, respectively. Differences in mean ADG due to treatment effect were shown to be non-significant (P<.05). Hibbs and Conrad (37) found that body weight gains in four to six month old calves fed complete rations of corn silage containing 64 percent concentrate (including corn in corn silage) are similar to gain in calves when good alfalfa hay with 29 percent concentrate is fed.

Listed in Table 9 is the period average daily gain (PADG) of calves. PADG was calculated by taking the difference between two consecutive weeks and dividing by seven. ADG can be determined during an individual seven day weekly period and growth progress of the animal can then be assessed. In all but three weeks, PADG increased with age of calf.

Table 10 lists body weights. Heifers progressively increased in body weight with age. The effect of treatment was non-significant (P<.05) on body weight. Average body weights were 198.3 and 197.6 pounds for Treatment I and II, respectively.

Table A2 lists the regression coefficients for body weight. Multivariate analysis of treatment effect on body weight was non-significant (P<.05). Regression curve plots of body weight are shown in Figure 7.

Length of heifers, from the anterior of the shoulder blade to

TABLE 8

CUMULATIVE AVERAGE DAILY GAIN (ADG) OF REPLACEMENT HOLSTEIN HEIFERS

Age (Week)	Treatment[a] I	Treatment[a] II
	lb	lb
5	0.4 ± 0.21[b]	0.6 ± 0.21
10	0.8 ± 0.30	0.8 ± 0.19
15	0.8 ± 0.27	1.0 ± 0.23
20	1.2 ± 0.34	1.1 ± 0.24
25	1.3 ± 0.21	1.3 ± 0.25
30	1.5 ± 0.28	1.4 ± 0.12

[a]Treatment I = 1 part corn silage: 1 part Maltlage.

Treatment II = Hay *ad libitum* plus Maltlage fed separately at the following rates:

Week 2-15 - 5.5# Maltlage/100 B.W.
Week 16-20 - 5.0# Maltlage/100 B.W.
Week 21-25 - 4.5# Maltlage/100 B.W.
Week 26-30 - 4.0# Maltlage/100 B.W.

[b] = Standard deviation.

TABLE 9

PERIOD AVERAGE DAILY GAIN (PADG) OF REPLACEMENT HOLSTEIN HEIFERS

Age (Week)	Treatment[a] I	Treatment[a] II
	lbs	lbs
5	0.6 ± 0.38[b]	1.0 ± 0.49
10	1.2 ± 0.89	0.9 ± 0.45
15	0.8 ± 0.73	1.3 ± 0.42
20	1.8 ± 0.55	1.7 ± 0.59
25	1.9 ± 0.76	1.7 ± 1.02
30	2.3 ± 0.97	2.2 ± 0.62

[a]Treatment I = 1 part corn silage: 1 part Maltlage.

Treatment II = Hay *ad libitum* plus Maltlage fed separately at the following rates:

Week 2-15 - 5.5# Maltlage/100 B.W.
Week 16-20 - 5.0# Maltlage/100 B.W.
Week 21-25 - 4.5# Maltlage/100 B.W.
Week 26-30 - 4.0# Maltlage/100 B.W.

[b] = Standard deviation.

TABLE 10

BODY WEIGHTS OF REPLACEMENT HEIFERS

Age (Week)	Treatment[a] I	Treatment[a] II
	lb[b]	lb[b]
5	96.00 ± 17.15	105.00 ± 10.76
10	137.18 ± 24.56	133.43 ± 7.98
15	161.00 ± 32.70	186.00 ± 26.07
20	241.55 ± 50.51	236.00 ± 23.94
25	301.00 ± 44.82	304.36 ± 43.02
30	385.00 ± 63.69	364.80 ± 23.06

[a]Treatment I = 1 part corn silage: 1 part Maltlage.

Treatment II = Hay *ad libitum* plus Maltlage fed separately at the following rates:

Week 2-15 5.5# Maltlage/100 B.W.
Week 16-20 5.0# Maltlage/100 B.W.
Week 21-25 4.5# Maltlage/100 B.W.
Week 26-30 4.0# Maltlage/100 B.W.

[b] = Standard deviation.

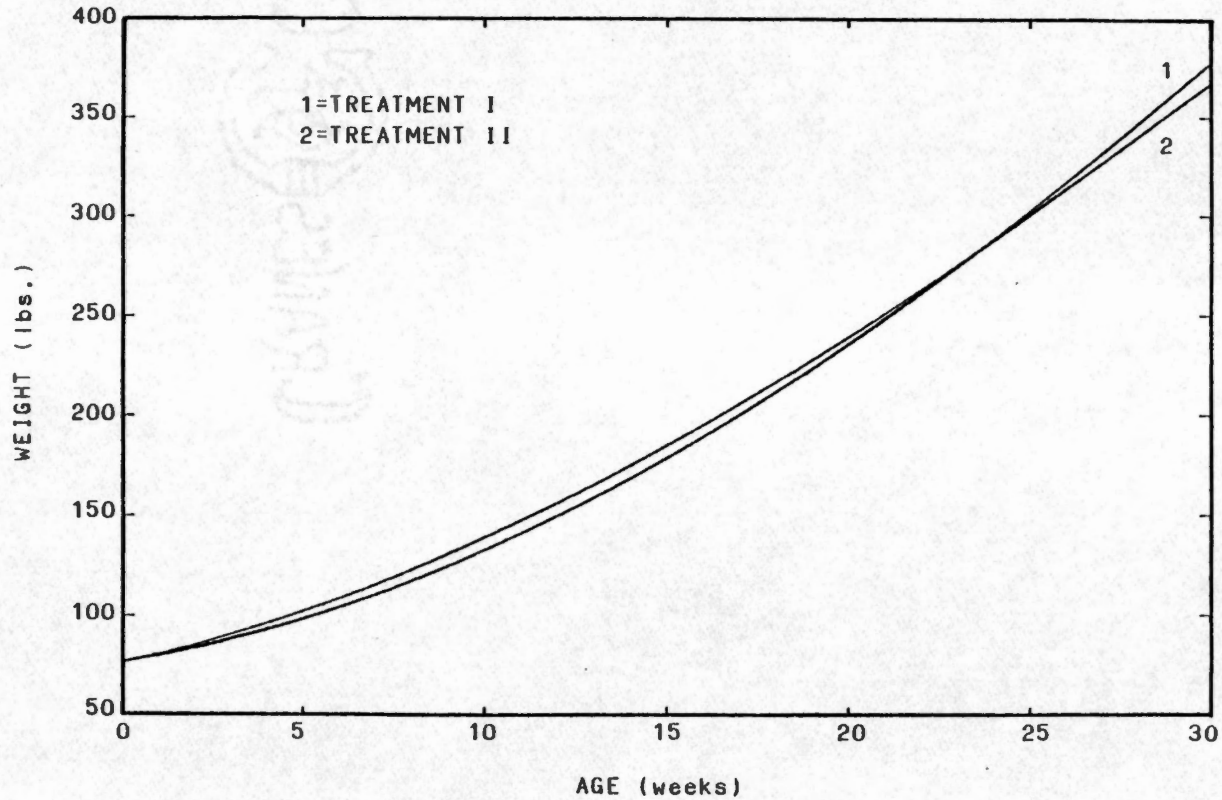

Figure 7. Trinomial regression curves for body weight of Holstein heifers.

the first caudal vertebra along the topline, is shown in Table 11. Length increased with age of calf and the average length for Treatments I and II were 28.0 and 27.9 inches, respectively. Treatment had a non-significant effect on length of calves.

Regression coefficients for length are listed in Table A2. Multivariate analysis of the effect of treatment on regression coefficients for length were non-significant ($P<.05$). Plots of length curves are illustrated in Figure 8.

Wither height measurements are in Table 12. Treatment effect was non-significant ($P<.05$) for wither height. Average wither height was 34.6 inches for both treatments.

Regression coefficients for wither height are listed in Table A2. Multivariate analysis of treatment effects on regression coefficients of wither height were non-significant ($P<.05$). Treatment regression curve plots are shown in Figure 9.

A third measurement, heart girth, is listed in Table 13. Heart girth was measured as the circumference around the calf, just posterior to the front legs. Average heart girth measurements were 39.1 inches for both treatments. Heart girth measurements at 30 weeks of age averaged 49.0 inches for calves on Treatment I and 48.4 inches for calves on Treatment II.

Table A2 lists regression coefficients for heart girth measurements. Multivariate analysis of treatment effect on regression coefficients for heart girth was non-significant ($P<.05$). Heart girth regression curves by treatment are shown in Figure 10.

Jones (44) found no significant differences in body weight, length, wither height and paunch circumference between calves fed a 1:1

TABLE 11

LENGTH OF REPLACEMENT HOLSTEIN HEIFERS

Age (Week)	Treatment[a]	
	I	II
	---in---	
5	23.86 ± 1.65[b]	23.14 ± 0.95
10	25.00 ± 0.97	25.00 ± 0.41
15	26.36 ± 1.65	27.14 ± 1.42
20	30.00 ± 2.17	29.79 ± 1.50
25	33.07 ± 2.67	32.68 ± 1.74
30	36.13 ± 1.46	35.70 ± 0.84

[a]Treatment I = 1 part corn silage: 1 part Maltlage.

Treatment II = Hay *ad libitum* plus Maltlage fed separately at the following rates:

Week 2-15 - 5.5# Maltlage/100 B.W.
Week 16-20 - 5.0# Maltlage/100 B.W.
Week 21-25 - 4.5# Maltlage/100 B.W.
Week 26-30 - 4.0# Maltlage/100 B.W.

[b] = Standard deviation.

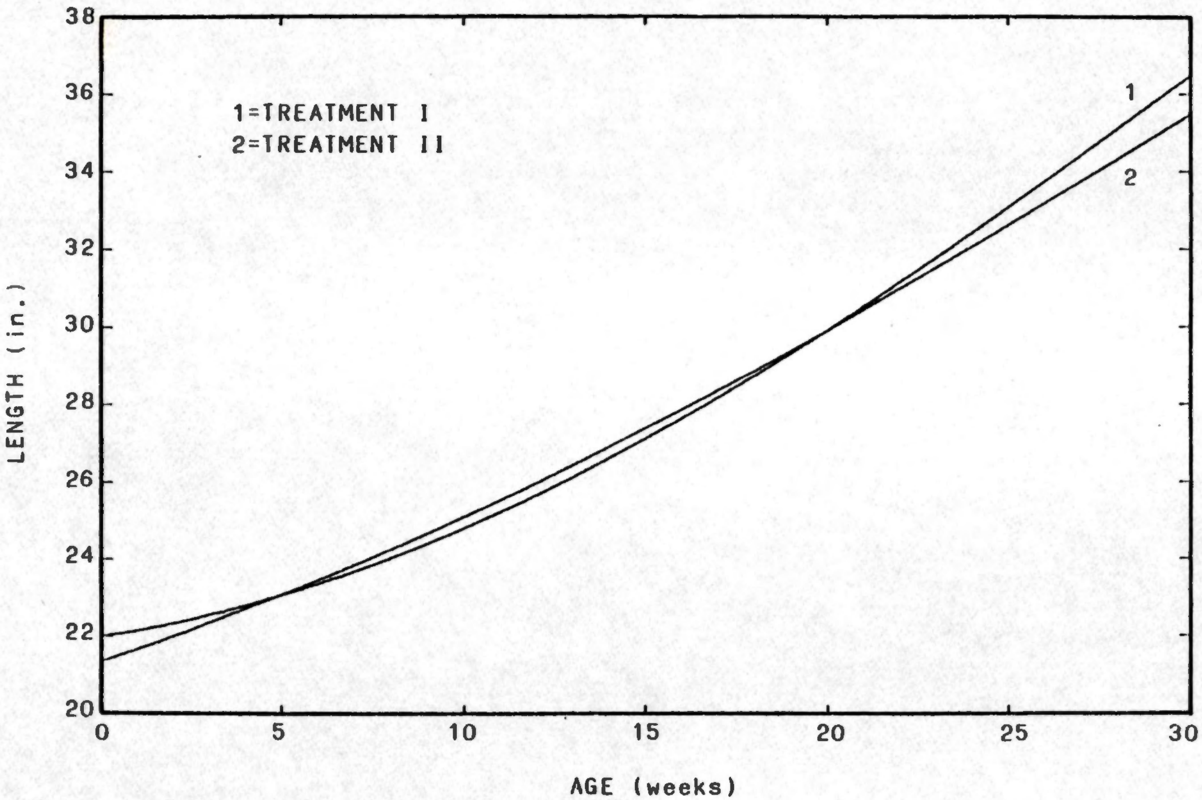

Figure 8. Trinomial regression curves for length of Holstein heifers.

TABLE 12

WITHER HEIGHT OF REPLACEMENT HOLSTEIN HEIFERS

Age (Week)	Treatment[a] I	Treatment[a] II
	---in---	
5	31.07 ± 1.86[b]	31.18 ± 0.98
10	32.23 ± 0.82	32.00 ± 1.44
15	34.07 ± 1.62	34.50 ± 1.53
20	36.32 ± 1.76	35.86 ± 1.31
25	38.14 ± 1.55	38.95 ± 1.93
30	40.25 ± 1.41	40.00 ± 1.54

[a]Treatment I = 1 part corn silage: 1 part Maltlage.
Treatment II = Hay *ad libitum* plus Maltlage fed separately at the following rates:

Week 2-15 - 5.5# Maltlage/100 B.W.
Week 16-20 - 5.0# Maltlage/100 B.W.
Week 21-25 - 4.5# Maltlage/100 B.W.
Week 26-30 - 4.0# Maltlage/100 B.W.

[b] = Standard deviation.

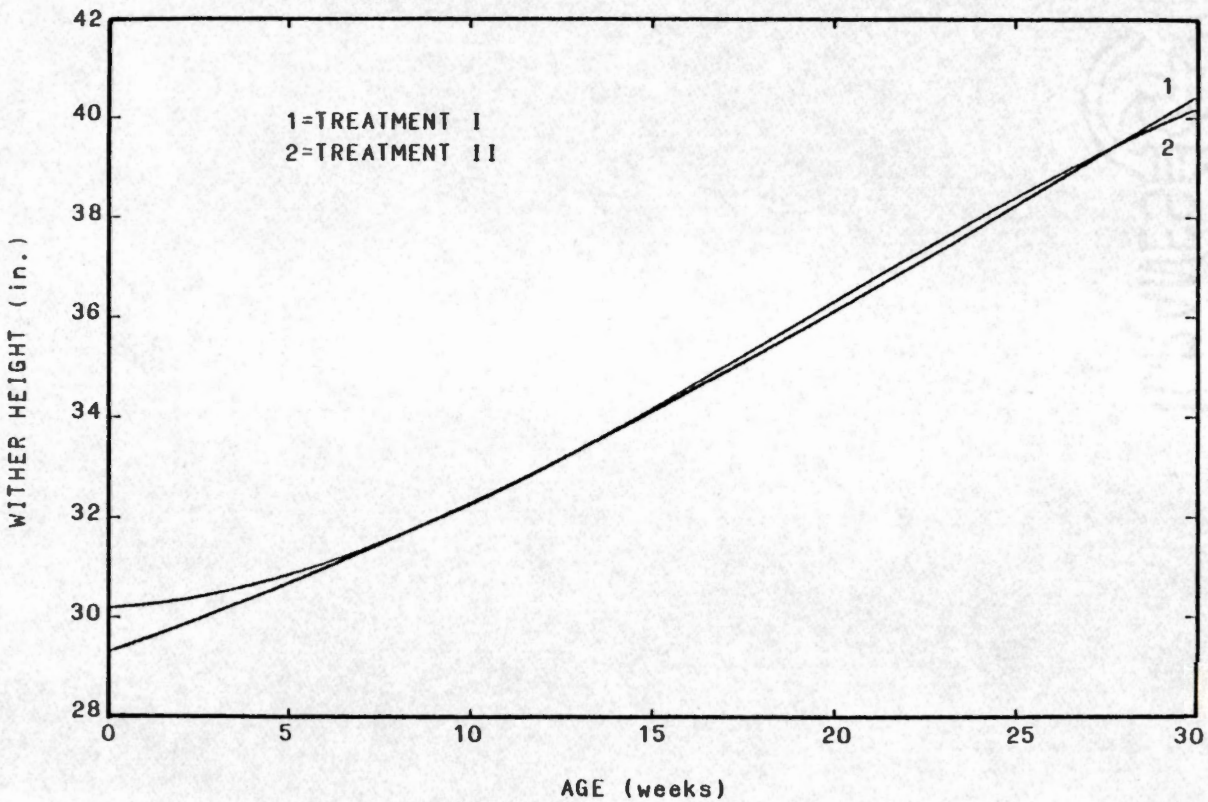

Figure 9. Trinomial regression curves for wither height of Holstein heifers.

TABLE 13

HEART GIRTH OF REPLACEMENT HOLSTEIN HEIFERS

Age (Week)	Treatment[a] I	Treatment[a] II
	---in---	
5	32.29 ± 2.32[b]	33.14 ± 1.31
10	35.73 ± 1.74	35.43 ± 1.21
15	38.07 ± 2.95	39.32 ± 2.03
20	42.00 ± 2.76	41.93 ± 1.34
25	45.29 ± 2.50	45.23 ± 2.60
30	49.00 ± 2.60	48.40 ± 1.08

[a]Treatment I = 1 part corn silage: 1 part Maltlage.

Treatment II = Hay *ad libitum* plus Maltlage fed separately at the following rates:

Week 2-15 - 5.5# Maltlage/100 B.W.
Week 16-20 - 5.0# Maltlage/100 B.W.
Week 21-25 - 4.5# Maltlage/100 B.W.
Week 26-30 - 4.0# Maltlage/100 B.W.

[b] = Standard deviation.

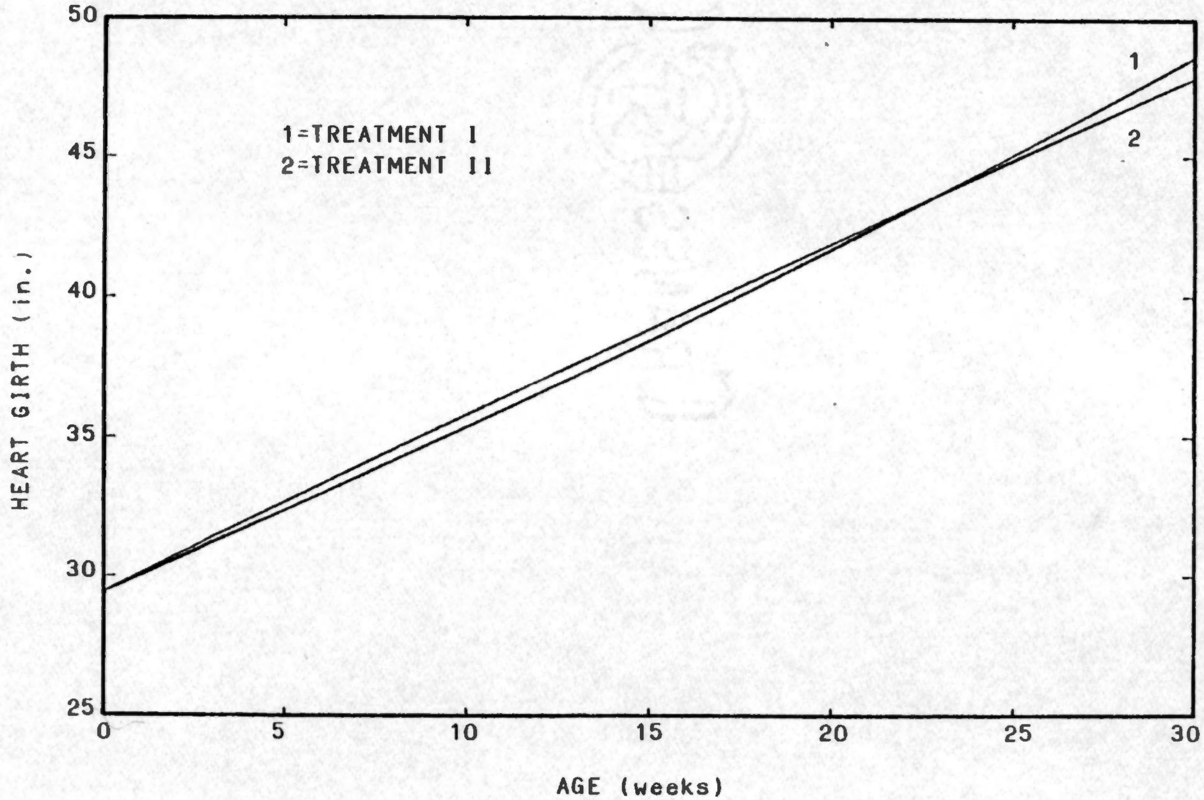

Figure 10. Trinomial regression curves for heart girth of Holstein heifers.

ratio of corn silage to Maltlage and calves fed a 3:1 ratio of corn silage to concentrate plus soybean meal. However, calves fed a ration of corn silage ad libitum plus Maltlage fed separately at the rate of two pounds per 100 pounds body weight, did not grow adequately. Growth of calves used in this current study compared favorably to growth of calves studied by Jones (44). Nease (67) fed replacement heifers complete rations of corn silage-concentrate and hay-concentrate and found no significant effects on body weight, length, height and paunch circumference due to treatment.

Borland and Kesler (9) reported that corn silage can be used as a practicle roughage source when incorporated into complete rations for calves eight to eighteen weeks of age and when care is exercised to prevent spoilage. Kesler et al. (49) found that good quality corn silage is a satisfactory roughage source for young Holstein calves from six to twenty weeks of age. Grieve et al. (33) reported that dairy heifers can be raised successfully to eighteen months of age on corn silage as the only forage as compared to combinations of corn and hay crop silages or corn silage and hay.

Performance of heifers on both rations were similar. Figure 11 shows crude protein intake of heifer calves. In comparison to NRC requirements (69) of crude protein for large breeds gaining 1.6 pounds per day, heifers on both treatments were deficient in crude protein until 16 weeks of age. Calves greater than 16 weeks of age consumed sufficiently enough crude protein to meet their NRC requirements. Therefore, the percent crude protein of both treatment rations should be increased when fed to calves less than 16 weeks of age.

Calves on Treatment I and II at 30 weeks of age weighed 385 and

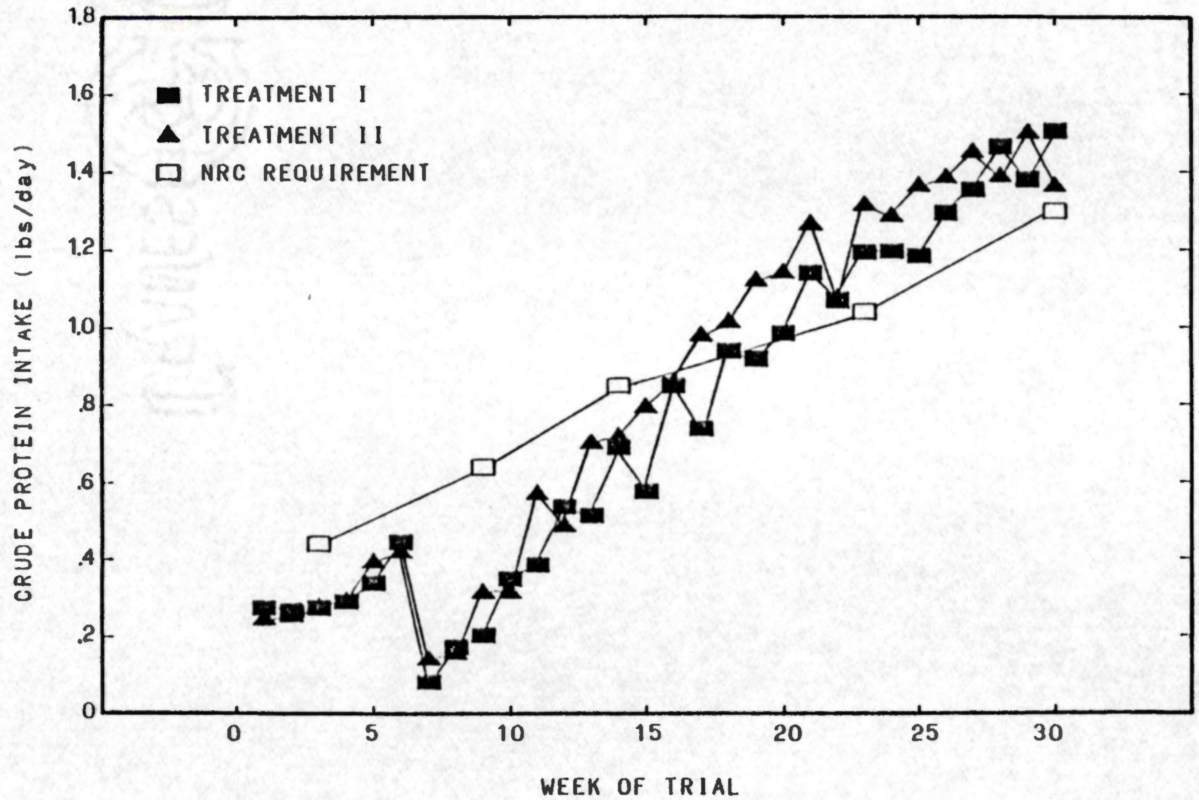

Figure 11. Average daily crude protein intake by treatment versus daily NRC crude protein requirements for Holstein heifers gaining 1.6 pounds per day.

365 pounds, and had a PADG of 2.3 and 2.2 pounds, respectively. Average crude protein intake at 30 weeks of age for calves on Treatment I and II were 1.51 and 1.37 pounds, respectively. Calves in this study compared favorably to NRC requirements (69) of 1.3 pounds crude protein per day for a large breed heifer 32 weeks of age with an ADG of 1.6 pounds and weighing 400 pounds in body weight. Porter et al. (77) found protein in WBG to be utilized with increased efficiency. Increases in protein utilization of brewers' grain may be due to increased rumen bypass of protein. Rumen bypass of protein in DBG has been calculated by Rounds and Klopfenstein (88) at 60.6 percent. Merchen et al. (62) calculated rumen bypass of protein in DBG at 61 and 48 percent.

CHAPTER V

SUMMARY AND CONCLUSIONS

A 16 week continuous type feeding trial was conducted to determine the effect of sodium bentonite as a milk fat test improver in complete rations containing Maltlage (a commercial source of wet brewers' grains). Sixteen lactating Holstein cows were fed one of the following complete rations: I) one part corn silage and one part Maltlage or II) one part corn silage and one part Maltlage with 1 percent sodium bentonite.

Even though differences were non-significant ($P<.05$), cows on Treatment II had a higher percentage of fat in the milk than Treatment I cows. Cows on Treatment II consumed more dry matter and had higher milk and fat corrected milk production than cows on Treatment I, but differences were non-significant ($P<.05$). Cows on both treatments maintained body weight equally well.

Total solids, solids-not-fat and crude protein content of the milk in both treatments were similar.

Differences between Treatments I and II in rumen pH and the volatile fatty acids acetate, propionate, butyrate, isobutyrate, valerate, and isovalerate were found to be non-significant ($P<.05$). Molar percent values for acetate, propionate and butyrate were 55.1, 28.9 and 10.3 for Treatment I, and 54.6, 26.9 and 12.4 for Treatment II.

There were no differences found between treatments in blood serum levels of calcium, magnesium, sodium and phosphorus.

A second trial was conducted to determine the value of Maltlage in complete rations for growing dairy calves. Thirty-six Holstein replacement heifers were fed one of two treatments. Treatment I consisted of one part corn silage and one part Maltlage, Treatment II consisted of chopped mixed grass hay fed ad libitum plus Maltlage fed separately at the following rates:

Week 2-15 - 5.5# Maltlage/100# body weight
Week 16-20 - 5.0# Maltlage/100# body weight
Week 21-25 - 4.5# Maltlage/100# body weight
Week 26-30 - 4.0# Maltlage/100# body weight.

Ration dry matter was adequately consumed by calves on both treatments and differences in dry matter consumption between treatments were non-significant ($P<.05$). Average dry matter intake (pounds per day) and mean average daily gain (pounds) was 4.7 and 0.92 for calves on Treatment I and 4.6 and 0.93 for calves on Treatment II.

Differences in growth parameters of calves due to treatment effect, as measured by body weight, length, wither height and heart girth, were non-significant ($P<.05$).

These data suggest, that the addition of sodium bentonite (one percent) to a complete ration containing a 1:1 ratio (as fed) of Maltlage and corn silage, will improve milk fat test for lactating dairy cattle. Also, that Holstein heifer calves can be raised successfully on a complete ration containing a 1:1 ratio (as fed) of Maltlage and corn silage or when fed Maltlage and chopped mixed grass hay ad libitum up to 20 weeks of age.

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APPENDIX

TABLE A1

INTERCEPT AND REGRESSION COEFFICIENTS FOR MILK PRODUCTION, 4% FAT-CORRECTED MILK DRY MATTER CONSUMPTION AND BODY WEIGHT

Variable	Treatment*	Intercept	B_1	B_2	B_3
Milk Production	I	30.97163750[a]	6.22451831[a]	-0.61248041[a]	0.01924144[a]
	II	31.07775000[a]	6.37641684[a]	-0.60959164[a]	0.01948841[a]
4% FCM	I	34.37458750[a]	1.54834799[a]	-0.13346064[a]	0.00142476[a]
	II	39.38407500[a]	0.78415045[a]	-0.05623920[a]	-0.00048619[a]
Dry Matter Consumption	I	12.43546260[a]	1.65461747[a]	-0.09567013[a]	0.00075943[a]
	II	11.68649642[a]	2.71842059[a]	-0.26408696[a]	0.00861722[a]
Body Weight	I	1047.21275000[a]	-14.33665625[a]	2.41088613[a]	-0.09193437[a]
	II	1075.07875000[a]	-16.00237244[a]	2.14473410[a]	-0.06416627[a]

B_1 = Linear regression coefficient for week.
B_2 = Quadratic regression coefficient for week.
B_3 = Cubic regression coefficient for week.

*Treatment I = 1 part corn silage: 1 part Maltlage.
Treatment II = 1 part corn silage: 1 part Maltlage with 1% sodium bentonite.

[a]Means of variables in a column with different superscripts differ significantly ($P<.05$).

TABLE A2

INTERCEPT AND REGRESSION COEFFICIENTS FOR HOLSTEIN GROWTH CURVES

Variable	Treatment*	Intercept	B_1	B_2	B_3
Weight	I	77.20468889[a]	2.88913646[a]	0.27845080[a]	-0.00133772[a]
	II	76.78243889[a]	3.93630010[a]	0.24429182[a]	-0.00173947[a]
Length	I	22.00964444[a]	0.13347911[a]	0.01598785[a]	-0.00014520[a]
	II	21.36450000[a]	0.30696941[a]	0.00715328[a]	-0.00005714[a]
Height	I	29.32518889[a]	0.24354083[a]	0.00596597[a]	-0.00005782[a]
	II	30.19868889[a]	0.03926898[a]	0.02038164[a]	-0.00035302[a]
Heart Girth	I	29.45395000[a]	0.37858694[a]	0.00096080[a]	0.00003544[a]
	II	29.45356111[a]	0.65551228[a]	-0.00225286[a]	0.00002905[a]

B_1 = Linear regression coefficient for week.
B_2 = Quadratic regression coefficient for week.
B_3 = Cubic regression coefficient for week.

*Treatment I = 1 part corn silage: 1 part Maltlage.
Treatment II = Hay *ad libitum* plus Maltlage fed separately at the following rates:

Week 2-15 - 5.5# Maltlage/100 B.W.
Week 16-20 - 5.0# Maltlage/100 B.W.
Week 21-25 - 4.5# Maltlage/100 B.W.
Week 26-30 - 4.0# Maltlage/100 B.W.

[a]Means of production variables in a column with different superscripts differ significantly (P<.05).

VITA

Clyde P. Cieszynski, son of Theodore and Angeline Cieszynski, was born in Milwaukee, Wisconsin on January 24, 1956. He lived in Cudahy, Wisconsin for the first eighteen years of his life and graduated from Cudahy Senior High in 1974. At the age of twelve, he learned how to play the concertina and later taught music and performed in local polka bands. He entered the University of Wisconsin, River Falls, in September 1974 and received the Bachelor of Science degree in Animal Science in June 1978. He entered graduate school at The University of Tennessee, Knoxville, to study Dairy Nutrition and received the Master of Science degree in Animal Science in August 1980. He will be attending Iowa State University in September 1980 as a Veterinary Medicine student.