To the Graduate Council:

I am submitting herewith a thesis written by Aaron Robert Cole entitled "Comparison of Corn Silage and Cottonseed Hulls as Roughage Sources in Complete Mixed Rations for Calves." I have examined the final 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

Monty J. Montgomery, Major Professor

We have read this thesis
and recommend its appectance:

R. D. Hunt

B. R. Bell

Accepted for the Council:

Lawrence

The Graduate School

COMPARISON OF CORN SILAGE AND COTTONSEED HULLS AS ROUGHAGE SOURCES IN COMPLETE MIXED RATIONS FOR CALVES

A Thesis

Presented for the

Master of Science

Degree

The University of Tennessee, Knoxville

Aaron Robert Cole

December 1984

ACKNOWLEDGEMENTS

The author wishes to express his thanks to all members of the staff of the University of Tennessee Department of Animal Science for their advice, guidance and friendship.

The author wishes to thank Dr. M.J. Montgomery for serving as major professor and for directing the research of this study.

The author wishes to thank Dr. R.N. Heitmann for his friendship, encouragement and advice through the course of this study.

The author wishes to thank Dr. B.R. Bell for serving as a committee member and for reviewing this manuscript.

The author wishes to express his thanks to his fellow graduate students and especially Chris Reynolds for his assistance in helping collect data.

Thanks is given to the staff of the University of Tennessee Knoxville Dairy Farm and especially Mark Lewis for his efforts in making this project run smoothly.

Special thanks is given to the authors parents and in-laws for their support throughout the course of the author's studies. To the authors wife, words cannot express the feeling of deep graditude felt for her support and love throughout the course of these studies.

ABSTRACT

Two continuous feeding trials were conducted during 1982-83 and 1983-84 to compare the effect of complete mixed rations utilizing either corn silage or cottonseed hulls (CSH) as roughage on the performance of dairy heifers. Thirty Holstein heifers in 1982-83, and 25 Holstein heifers in 1983-84 were fed one of two different rations. For the 1982-83 trial, ration 1 consisted of two stages. Stage 1A contained 30 percent CSH, 50 percent corn, and 20 percent soybean meal (SBM) plus vitamines and minerals fed ad libitum until calves reached 18 weeks of age; stage 1B contained 50 percent CSH, 40 percent corn, and 10 percent SBM plus vitamines and minerals fed ad libitum until calves reached 31 weeks of age. Ration 2 consisted of a 3:1 ratio of corn silage plus 16 percent crude protein dairy feed fed ad libitum from two weeks until 31 weeks of age. For the 1983-84 trial, ration 1 consisted of two stages. Stage 1A contained 40 percent CSH, 45 percent corn, and 15 percent SBM plus vitamines and minerals fed ad libitum until 18 weeks of age; stage 1B contained 60 percent CSH, 30 percent corn, and 10 percent SBM plus vitamines and minerals fed ad libitum from 18 until 30 weeks of age. Ration 2 consisted of a 3:1 ratio of corn silage and 16 percent crude protein dairy feed, fed ad libitum from two until 30 weeks of age. Dry matter intake was significantly higher ($P<.05$) for calves fed ration 1 on both trials. Crude protein intake and acid detergent fiber intake were significantly higher ($P<.05$) for calves fed ration 1 on the

1982-83 trial. Calves fed ration 1 on the 1982-83 and the 1983-84 trials had significantly higher body weights during week nine and week eight respectively, and remained significantly higher ($P<.05$) for the remainder of each trial. Paradoxically there were no significant differences in body measurements between rations except for body length for calves fed ration 1 on the 1983-84 trial which was significantly longer ($P<.05$) on week 30. The lack of difference in body measurements suggest that the difference in body weights might be due to fill. For calves on the 1983-84 trial, butyrate (moles/100 moles) was higher ($P<.05$) when heifers were fed corn silage versus CSH. When heifers were fed 60 percent CSH for the final 12 weeks, acetate (moles/100 moles) increased ($P<.05$) and propionate decreased ($P<.05$). Total volatile fatty acid concentration (millimoles/liter) was significantly higher ($P<.05$) for calves fed ration 2. The higher level ($P<.05$) of volatile fatty acid concentration (millimoles/liter) of ration 2 indicates that ration 2 had more fermentable carbohydrates than ration 1. Cottonseed hulls were shown to have 2.16 times the feeding value of corn silage on an as fed basis when fed at the levels reported for ration 1 and 2. These data suggest that Holstein heifers can be successfully raised utilizing complete rations using either CSH or corn silage as roughage sources. This study also suggests that CSH's should only be used when they can be purchased for less than 2.16 times the cost of the same unit of corn silage.

TABLE OF CONTENTS

CHAPTER		PAGE
I.	INTRODUCTION	1
II.	REVIEW OF LITERATURE	2
	Growth Rates of Holstein Heifers	2
	Use of Complete Mixed Rations	3
	Cottonseed Hulls in Complete Mixed Rations	6
	Use of Corn Silage in Calf Rations	8
	Volatile Fatty Acids in Heifers	9
III.	MATERIALS AND METHODS	11
	Experimental Animals	11
	Rations	11
	Housing	13
	Calf Management	14
	Data Collection	14
	Volatile Fatty Acid Analysis	15
	Chemical Analysis	16
	Statistical Analysis	16
IV.	RESULTS AND DISCUSSION	19
	Chemical Composition of Feed Ingredients	19
	Dry Matter Intake	21
	Crude Protein Intake	24
	Acid Detergent Fiber Intake	26
	Body Weight Gains	26
	Body Measurements	32

CHAPTER PAGE

IV. (Continued)

Volatile Fatty Acid Concentration of Calves on 1983-84 Trial 39

Economic Aspects of Cottonseed Hulls Versus Corn Silage 43

V. SUMMARY AND CONCLUSIONS 45

LIST OF REFERENCE 48

APPENDIXES 54

APPENDIX A. SETTINGS FOR VFA ANALYSIS ON BENDEX 2600 GAS CHROMATOGRAPH 55

APPENDIX B. TABLE 1-A. INTERCEPT AND REGRESSION COEFFICIENTS FOR GROWTH CURVES AND DRY MATTER INTAKE OF REPLACEMENT HEIFERS ON 1983-84 TRIAL 56

VITA 57

LIST OF TABLES

TABLE		PAGE
1.	Feed Constituents of Rations Fed to Holstein Replacement Heifers	12
2.	Mean and Standard Deviation of Constituents of Complete Feeds and Feeds Fed to Replacment Heifers on 1983-84 Trial	20
3.	Mean and Standard Deviation of Daily Dry Matter Intake (Kilograms) of Replacement Heifers	22
4.	Mean and Standard Deviation of Daily Crude Protein Intake (Kilograms) of Replacement Heifers on 1983-84 Trial	25
5.	Mean and Standard Deviation of Daily Acid Detergent Fiber Intake (Kilograms) of Replacement Heifers on 1983-84 Trial	27
6.	Mean and Standard Deviation of Body Weight (Kilograms) of Replacement Heifers.	28
7.	Mean and Standard Deviation of Cumulative Average Daily Gain (Kilograms) of Replacement Heifers	29
8.	Mean and Standard Deviation of Body Length (Centimeters) of Replacement Heifers.	33
9.	Mean and Standard Deviation of Body Height (Centimeters) of Replacement Heifers.	34
10.	Mean and Standard Deviation of Heart Girth (Centimeters) of Replacement Heifers.	35
11.	Mean and Standard Deviation of Volatile Fatty Acid Concentration (Moles/100 Moles) of Replacement Heifers on 1983-84 Trial	40
12.	Mean and Standard Deviation of Volatile Fatty Acid Concentration (Millimoles/liter) of Replacement Heifers on 1983-84 Trial	42

LIST OF FIGURES

FIGURE		PAGE
I.	Dry Matter Intake of Replacement Heifers on 1983-84 Trial	23
II.	Body Weight of Replacement Heifers on 1983-84 Trial	29
III.	Body Length of Replacement Heifers on 1983-84 Trial	36
IV.	Heart Girth of Replacement Heifers on 1983-84 Trial	37
V.	Body Height of Replacement Heifers on 1983-84 Trial	38

CHAPTER I

INTRODUCTION

There are many factors that contribute to the success of a dairy operation. One of these factors is a successful and economical heifer raising program. Feed costs represent a major portion of the expense that goes into raising replacement heifers. Many dairy operators have looked at using more economical feeds for their heifer raising programs. Byproduct feeds have proven to be an economical substitute for some of the more expensive conventional feedstuffs used in heifer raising programs.

Cottonseed hulls have been shown to be an acceptable substitute for hay in rations (29,35). However the low palatibility of cottonseed hulls makes it necessary to include them with more palatable feedstuffs in a complete mixed ration to achieve desired intake.

The use of corn silage as a feedstuff in the dairy industry is based on its favorable yields and high nutritional quality. However there is a limited amount of data on its use in rations for replacement heifers.

The objectives of this experiment were to compare intake, rate of growth, body measurements, and rumen volatile fatty acids (VFA's) of calves fed a complete rations based on cottonseed hulls or corn silage. Also comparisons of growth rates of calves on this trial were made with calves on previous growth trials using complete rations based on cottonseed hulls or corn silage at this university (32).

CHAPTER II

REVIEW OF LITERATURE

Growth Rates of Holstein Heifers

The optimum growth rate of a dairy animal is that which allows an animal to develop its full lactation potential at a desirable age and at a minimum of expense (47). Swanson (48) conducted experiments on identical twins to determine the effect different growth rates had on lactation. In a summary of 3 experiments using twins raised on a high plane of nutrition or a normal plane of nutrition, those animals raised on the high plane gained 71 kilograms more than their mates raised on a normal program over 26 months. The heifers raised on the high level of nutrition produced 220 kilograms less milk during their first lactation, and 130 kilograms less milk during their seconds lactation than did their twins raised on a normal feeding program. This was probably due to fat deposit in the udder causing less secretory tissue to form. Results of other experiments where twins were used to study normal nutrition or low nutrition showed heifers raised on subnormal rations gained only 70 percent as much weight as their twins on a normal feeding program. These heifers on the subnormal plane of nutrition produced only 87.1 percent of the milk than their twins produced on a normal nutritional program (46).

Achieving growth rates that will result in heifers large enough

to breed at 14 to 17 months of age without overconditioning is the goal of most dairymen. In the Holstein, average daily gains of .64 kilograms to .68 kilograms per day over the first 14 months is necessary to produce an animal of breeding size at 14 months of age (14).

Body measurements such as height, length, and heart girth can be a useful tool in determining proper growth rates in heifers. In a survey conducted by Heinricks and Rugaber (20) in Pennsylvaina, 80 percent of the heifers observed were not ready to breed at 15 months of age and suggested that the use of a tape to take body measurements and compare to breed standards might be a way to detect weaknesses in a heifer raising program.

Use of Complete Mixed Rations

Complete mixed rations are totally blended rations containing all ingredients in the desired proportions (42). These rations are advantageous in that they can be fed ad libitum using self feeders. By using complete mixed rations, the dairyman is assured that the animals receive a balance of nutrients instead of being able to select either concentrate or forage.

Putman and Davis (41) showed no significant difference in production levels of lactating cows fed either a complete pelleted ration or a ration of concentrate and forage. Rakes (42) reported the milk production and feed intake of cows fed blended feeds have generally been comparable to that of those fed the roughage and concentrate portions of the ration separately. Similar results have been observed by others (36,41,53,54).

Rakes (42) noted that complete mixed feeds seem to be particularly notorious for their adverse effect on butterfat percentage. Leighton and Helm (27) reported decreased butterfat percentage when complete rations were ground to a small particle size. The formulation of complete rations for high producing cows usually contains low levels of roughage. The inclusion of a minimum of 30 percent roughage in a complete mixed feed seems to be the level below which a definite drop in the butterfat percent can be expected (42). Ronning and Laben (44) reported that a 60:40 ratio of roughage to grain produced best results for lactating dairy cows.

The use of roughage in complete mixed rations is also important as a regulator of intake (39). The use of CSH in ruminant diets has been shown to increase feed intake (26,31,49). This increase in intake may be related to the small particle size of the hulls. Hogan and Weston (22) found forage retention time and digestion decreased with a reduction of particle size. Conrad et al. (9) found that intake of low digestible feeds was influenced by roughage capacity, rate of passage, and dry matter digestibility while high digestible feed intake was influenced by metabolic size, production, and digestibility. Owens et al. (40) found that rumen turnover rate increased as steers were fed CSH at either 5 or 30 percent of the diet. A decrease in dry matter digestibility was noted also. If the particle size of CSH does increase rumen turnover, the benefical effects of using CSH as bulk to limit intake may not be achieved.

With ad libitum feeding, complete rations which are low in roughage may be overeaten resulting in overconditioning of the cattle. However the nutritional requirements of a high producing cow in the first few months of lactation are difficult to meet, even with relatively low levels of roughage in the diet. Dairymen that use a complete mixed ration formulated for high producing cows must either control the amount consumed by the lower producing cows, or tolerate some fattening by these lower producers.

The use of complete mixed rations for calves has some of the same advantages as with producing cows. Hibbs and Conrad (21) reported that calves fed a pelleted complete ration resulted in earlier dry feed intake, earlier rumen function, and more rapid growth than calves fed the grain and roughage portion of the ration separately. The use of self feeders help cut labor costs and cut down competition for feed among heifers to insure that each individual in a group gets adequate intake. In addition, formulation problems are fewer with complete mixed rations for heifers due to the fact that high production demands of milking are not involved during this growing period. Rations are generally formulated to produce a steady growth rate over the period from weaning until first calving.

Clifton and Fowler (6) reported Holsteins gaining .99 kilograms per day and Jerseys gaining .68 kilograms per day on complete mixed rations as opposed to .81 kilograms per day for Holsteins and .46 kilograms per day for Jerseys fed concentrate and hay separately. Several other researchers have reported satisfactory growth rates using complete mixed rations to raise heifers (5,24,36).

Cottonseed Hulls in Complete Mixed Rations

Cottonseed hulls (Gossypium sp.), a byproduct of the cotton industry, have been shown to be an acceptable substitute for roughages in ruminant diets. Reports of the use of CSH can be found as far back as 1891 (12). Cottonseed hulls have an average chemical composition of 90.2 percent dry matter, 2.6 percent ash, 40.6 percent crude fiber and 4 percent crude protein (10). The feeding value of CSH often varies due to the amount of cellulose fiber left on the hull after processing. Cottonseed hulls alone are unpalatable and are usually mixed with more palatable feeds to induce their consumption. Due to the low nutritive value of CSH, they are used primarily as a source of bulk in a ration. When available and economically feasible, CSH can be used as a bulk source in starter and complete mixed rations for calves (30,38).

One physical problem with using CSH in a feeding program is the bulk of the hulls. Storage and transportation of the hulls is inconvenient due to the bulk. One answer to this problem is to pellet the CSH. Pelleting of CSH can reduce the bulk to less than 40 percent of the normal hull size (4).

In research conducted by Brown et al. (4) milk production, milk fat, protein, solids not-fat, and fatty acids in milk were compared between cows receiving bulk CSH or pelleted CSH at various levels of diet. No difference was found for milk production, fat percent, protein, solids not-fat, or fatty acids between cows fed bulk or pelleted CSH when compared at each level.

Montgomery et al. (33) compared milk production of cows fed pelleted and unpelleted CSH in a complete ration. There was no difference in milk production between cows fed 15 percent pelleted or unpelleted CSH plus a 20 percent crude protein concentrate. Cows consuming either form of CSH consumed more dry matter than other cows on the project which were fed either hay or silage as roughage sources. Cows fed pelleted CSH did had similar butterfat percentage than other cows on the experiment.

Verland et al. (52) conducted experiments feeding different forms of CSH to dairy cows to determine their effect on milk production. Cottonseed hulls were either regular CSH, pelleted CSH, delinted CSH, or pelleted delinted CSH fed at a level of 30 percent of the diet. Cows fed pelleted CSH had increased milk yield but showed a decrease in butterfat percentage. Cows fed pelleted delinted CSH had higher butterfat percent than cows fed regular pelleted CSH.

Rakes and Davenport (43) reported average daily gain of 1 kilogram for Holstein heifers fed from two to six months of age on complete rations using CSH to make up 30 percent of the total ration. Clifton and Fowler (7) reported similar rates of gain for Holsteins fed complete rations containing 24 percent CSH over the same age range. Rakes (42) reported that Holstein heifers over six months of age had average daily gains of .68 kilograms per day when fed complete rations containing 78.5 and 82.5 percent CSH, and 1 kilogram per day average gain when fed complete rations containing 41.5 percent CSH.

In work conducted by Migioia (30) Holstein heifers gained an average of .86 kilograms per day when fed a two-stage diet containing 20 percent CSH until the animals reached 136 kilogram body weight, and 43 percent CSH from 136 kilogram body weight up to 273 kilogram body weight. Similar results were reported by Oller (38) using the same two-stage ration utilizing CSH as the roughage source.

Use of Corn Silage in Calf Rations

The use of corn silage in feeding programs is related to the high yield of the crop, and to its nutritional quality as a feed. Corn silage has been shown to be an acceptable source of fiber for raising calves (36,38). The use of corn silage in a complete ration for calves has also shown satisfactory results (36). One drawback to using corn silage in complete rations is that it must be fed fresh daily to prevent spoilage. This requirement for fresh feeding prevents the use of self feeders which is a popular method of feeding other complete feeds.

Gardner (16) reported average daily gains of .60 kilograms for heifers fed corn silage based complete diets over the first 16 weeks of age. This growth rate was not significantly different from growth rates of other heifers fed alfalfa hay or alfalfa silage based rations. Nease (36) reported no significant differences for height, length, and girth for heifers fed isonitrogenous rations of hay and a 16 percent crude protein grain mix, or corn silage, grain mix, and SBM. Grieve et al. (17) found that Holstein heifers fed

corn silage as the sole roughage from birth until breeding gained 115 percent of the Morrison standard (34), and 102 percent of the height or the Morrison standard. In additional work, Grieve et al. (18) fed corn silage to heifers from weaning through three lactations as the sole roughage without adversely affecting health or reproduction. Jones (24) reported cumulative average daily gains of .74 kilogram per day for Holstein heifers fed a ration of three parts corn silage plus one part 18 crude protein concentrate from birth until 30 weeks of age. Oller (38) reported similar cumulative average daily gains for Holstein heifers fed a three to one mix of corn silage and 18 percent crude protein concentrate. Nease (36) reported cumulative average daily gains of .83 kilograms and .74 kilograms for Holstein heifers fed a two to one mix of corn silage plus protein supplement. In addition, Nease (36) reported .79 kilograms and .70 kilograms cumulative average daily gain for Holstein heifers fed a four to one mix of corn silage plus protein supplement from birth to 29 weeks of age in two growth trials.

Volatile Fatty Acids in Heifers

Volatile fatty acids are end products of rumen fermentation of carbohydrates. They supply between 60 and 80 percent of the energy of the ruminant (2). The three major VFA's are acetate, propionate, and butyrate. Lengemen and Allen (29) reported that calves produced VFA's at adult levels at eight weeks of age when given high concentrate diets. Conrad and Hibbs (8) showed that

calves fed high roughage diets reached maximum VFA production at six weeks of age. Rumsey et al. (45) reported pelleting or grinding of roughage tended to increase the microbial population, thus increasing the amount of VFA's produced.

Halevi et al. (19) showed that the production of acetate increased as the amount of fiber in the diet increased and that reduced fiber levels in the diet favored propionate production. Murdock and Wallenius (35) demonstrated no significant difference in VFA's produced from calves fed diets containing alfalfa hay, CSH or alfalfa plus beet pulp as fiber sources. Migioia (30) reported the level of acetate to be significantly higher between calves fed rations using either CSH or alfalfa hay as fiber sources, and the level of propionate to be significantly lower for those same calves when fed a higher level of fiber when more CSH were added to the diet.

CHAPTER III

MATERIALS AND METHODS

Experimental Animals

Thirty Holstein heifers in 1982-83, and 25 Holstein heifers in 1983-84, from the University of Tennessee, Knoxville dairy herd were used in two continuous feeding trials. Calves were assigned to ration treatments according to order of birth. Calves were assigned to either indoor or outdoor housing according to order of birth.

Rations

Ration composition and feeds used for the 1982-83 and the 1983-84 trial are listed in Table 1. For the 1982-83 trial ration 1 consisted of a two stage complete ration. Stage A consisted of a ration mixture of 30 percent CSH, 50 percent corn, 20 percent SBM, plus vitamines and minerals. Ration 1A was fed from two week until 18 weeks of age. Stage B consisted of a ration mixture of 50 percent CSH, 40 percent corn, 10 percent SBM, plus vitamines and minerals. Ration 1B was fed from 18 until 31 weeks of age. Ration 1 was mixed at the dairy by placing all ingredients into a portable grinder mixer, and mixing for 20 minutes. Ration 1 was stored in metal barrels to prevent rodent contamination.

Ration 2 for the 1982-83 trial was a complete mixed ration of corn silage and 16 percent commercial dairy ration mixed in a ratio

TABLE 1. FEED CONSTITUENTS OF RATIONS FED TO HOLSTEIN REPLACEMENT HEIFERS

Year	1982-83			1983-84		
Ration	1A[a]	1B[b]	2[c]	1A[a]	1B[b]	2[c]
Constituents						
Corn	50%	40%		45%	30%	
Cottonseed Hulls	30%	50%		40%	60%	
Soybean Meal	20%	10%		15%	10%	
16% Dairy Feed			25%			25%
Corn Silage			75%			75%

[a]Ration 1A was fed ad libitum from two weeks until 18 weeks of age.

[b]Ration 1B was fed ad libitum from 18 until 31 weeks of age on the 1982-83 trial, and 30 weeks on the 1983-84 trial.

[c]Ration 2 was fed ad libitum from two weeks until 31 weeks of age for calves on the 1982-83 trial, and from two weeks until 30 weeks of age for calves on the 1983-84 trial.

of three parts corn silage to one part dairy feed. Ration 2 was mixed on the premises before the a.m. and p.m. feedings each day.

For the 1983-84 trial ration 1 consisted of two stage. Stage A consisted of a ration mixture of 40 percent CSH, 45 percent corn, 15 percent SBM, plus vitamines and minerals. Ration 1A was fed from two until 18 weeks of age. Stage B consisted of 60 percent CSH, 30 percent corn, 10 percent SBM, plus vitamines and minerals. Ration 1B was fed from 18 weeks until 30 weeks of age.

Ration 2 for the 1983-84 trial consisted of a complete mixed ration of corn silage and 16 percent commercial dairy ration mixed in a ratio of three parts silage to one part dairy feed. Ration 2 was mixed on the premises before the a.m. and p.m. feeding each day.

All rations were fed twice daily. Refusals were taken at the p.m. feeding. Rations were fed ad libitum so as to assure a 10 percent refusal rate.

Housing

Calves on the 1982-83 trial were randomly assigned to either indoor housing, in a ventilated calf barn, or outdoor housing using calf hutches. Calves on the 1983-84 trial were assigned to indoor housing or outdoor housing according to order of birth. Stalls in the calf barn were bedded with sawdust. Hutches were bedded with a small amount of straw.

Calf Management

Calves were weighed at birth. Each calf received colostrum during the first few hours postpartum. Calves were ear tagged and assigned to their respective treatment group and housing facilities. A commerical milk replacer, or whole milk from treated or fresh cows, was offered to each calf at a rate of 10 percent of body weight, in two 5 percent aliquots at 7:00 a.m. and 5:00 p.m. Fluid feed was offered for the first six weeks. Calves were checked daily for incidence of scours and respiratory problems. Calves with any illness were treated in accordance with recommendations by the veterinary staff of the University of Tennessee. Calves were dehorned at approximately 20 weeks of age.

Data Collection

Data collection started with the birth of Holstein heifers assigned to the two trials. Body weight, heart girth, height and length were recorded at birth for calves on both trials. Every 14 days thereafter body weights were recorded. Every 28 days thereafter all body measurements were recorded. Calves were weighed and measured until they reached 31 weeks of age on the 1982-83 trial, and 30 weeks of age for the 1983-84 trial. Daily feed records were kept on the amount of feed offered and refused by each calf. Any sign of calves being scoured or having respiratory problems was recorded.

Volatile Fatty Acid Analysis

Raw rumen fluid samples were collected from calves on the 1983-84 trial for VFA analysis. Rumen fluid samples were analysed by methods described by Erwin et al. (13). Four samples were taken from each calf starting at eight weeks and then once monthly thereafter. Samples were collected by using a stomach tube equipped with a steel strainer. A speculum was used to pass the tube so as to prevent the calves from chewing the tube. Raw samples were collected by aspiration with a 60 milliliter syringe attached to the end of the stomach tube and then frozen until being processed.

The raw samples were processed for analysis by allowing them to thaw to room temperature and then centrifuging for 5 minutes at 5140 x G in a Sorvall Superspeed RC2-B automatic refrigerated centrifuge. Two 5 milliliter aliquotes of supernatant were removed from each sample and placed in labelled centrifuge tubes. The 5 milliliter samples were acidified with 1 milliliter of 25 percent meta-phosphoric acid. The samples were allowed to stand for 30 minutes in a cooler to acidify. The samples were centrifuged again at 20,400 x G for 10 minutes in the Sorvall centrifuge. The supernatant was then removed and stored in vials. The samples were refrozen until analysis was performed on a gas chromatograph.

Prepared samples were analyzed using a Bendix 2600 gas chromatograph. A Hamilton syringe was used to inject 0.5 microliter of sample into the gas chromatograph to determine concentration of VFA's

against a known standard sample. Calculations were performed to determine total VFA's in the sample, acetate:propionate ratio, and moles/100 moles of each acid. Machine settings and column packing are listed in the Appendix.

Chemical Analysis

Feed samples from the 1983-84 trial were collected weekly for dry matter determination. Samples were dried for 72 hours in a 60^{o}C drying oven. Total dry matter was determined placing a portion of each sample in a 100^{o}C drying oven for 24 hours. Samples were composited by month and analyzed for crude protein, acid detergent fiber, acid insoluble lignin, calcium, and phosphorus. Crude protein content was determined by the Kjeldahl method (1).

Acid detergent fiber, and acid insoluble lignin were determined by the methods of Van Soest (51). Calcium levels in the samples were determined by atomic absorption - atomic emission spectrophotometry. Phosphorus levels in the samples were determined by methods established by Fishe and Subbarow (15).

Statistical Analysis

Statistical analysis were performed on the SAS system using programs prepared by Blair et al. (3). Univariate and multivariate techniques were used to determine if treatment affected body weight, average daily gain, height, length, girth, dry matter intake, and rumen VFA's. The F test was used to determine significant differences.

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

$$Y_{ijk} = U + T_i + W_j + C_k + (TxW)_{ij} + E_{ijk}$$

where Y_{ijk} = the dependant variables: weight, average daily gain, length, height, heart girth, dry matter intake, and rumen VFA's.

U = intercept.

T_i = treatment, i = 1 or 2

W_j = week j = 1 to 31 for 1982-83

1 to 30 for 1983-84

C_k = calf within treatment.

Eijk = random error.

A second model was used to determine at what week significant differences could be detected.

A regression analysis was performed on the dependent variables in a nonlinear regression on age. Observed values for the dependent variables were used to describe the response curve for each calf. The following equation was used:

$$Y_i = a + b_1 (week) + b_2 (week)^2 + b_3 (week)^3$$

where Yi = the estimated value of the dependent variable.

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

week = age of calf in weeks.

The regression coefficients for each dependent variable b_1, b_2, and b_3 were tested for differences using the F test.
The following model was used:

$$Y_{ij} = Trt_i + E_{ij}$$

where $Y_{ij} = b_1$, b_2, and b_3 for each dependent variable.

Trt_i = treatment i = 1 or 2.

E_{ij} = random error.

Multivariate analysis was used to determine if the regression of the dependent variables (body weight, length, height, heart girth, and dry matter intake) over time were affected by treatment. The following model was used:

$$Y_{ijk} = Trt_i + Week_j + E_{ijk}$$

where Y_{ijk} = the dependent variables.

Trt_i = treatments i = 1 or 2.

$Week_j$ = j = 1 to 30.

E_{ijk} = random error.

CHAPTER IV

RESULTS AND DISCUSSION

Chemical Composition of Feed Ingredients

The feed ingredients fed to the Holstein heifers on both trials are listed in Table 1 (page 12). No feed samples were collected during the 1982-83 trial therefore, chemical analysis was not possible. Dry matter percentage for feeds fed during the 1982-83 trial were estimated by using dry matters of similar rations fed during the 1983-84 trial. The chemical composition of feeds, and the feed ingredients fed to the Holstein heifers during the 1983-84 trial are listed in Table 2. Dry matter percentage of ration 1, both A and B was higher than that of ration 2. The difference in dry matters was undoubtly due to CSH being approximately 90 percent dry matter and corn silage being approximately 28 percent dry matter. Crude protein levels of ration 1A and ration 2 were similar. Ration 1B had the lowest crude protein level which was probably due to the fact that CSH has only 4 percent crude protein. Acid detergent fiber level was lowest for ration 2, 20 percent, intermediate for ration 1A, 27.61 percent, and highest for ration 1B, 40.25 percent. Acid insoluble lignin followed the same pattern with ration 2 being lowest, ration 1A being intermediate, and ration 1B being highest. Calcium and phosphorus levels were similar between all rations.

TABLE 2. MEAN AND STANDARD DEVIATION OF CONSTITUENTS OF COMPLETE FEEDS AND FEEDS FED TO REPLACEMENT HEIFERS ON 1983-84 TRIAL

Constituents	Ration 1[a]		Ration 2[b]
	A	B	
Dry matter (%)	90.60 ± .32	90.80 ± .31	45.25 ± .79
Crude protein[c]	14.00 ± .29	11.50 ± .52	13.49 ± .54
Acid detergent fiber[c]	27.61 ± 2.57	40.25 ± 2.97	20.00 ± 1.20
Acid insoluble lignin[c]	9.20 ± 1.18	12.28 ± 1.20	4.37 ± .49
Calcium[c]	.63 ± .14	.74 ± .10	.76 ± .16
Phosphorus[c]	.30 ± .05	.23 ± .05	.55 ± .05

[a]Ration 1 = (A and B): A = 40 percent cottonseed hulls, 45 percent corn, 15 percent soybean meal plus vitamins, salt and minerals fed ad libitum up to 18 weeks of age. B = 60 percent cottonseed hulls, 30 percent corn, 10 percent soybean meal plus vitamines, salt and minerals fed ad libitum from 18 to 30 weeks.

[b]Ration 2 = 3 parts corn silage: 1 part concentrate (16 percent dairy feed) fed ad libitum up to 30 weeks.

[c]Percent dry matter basis.

Dry Matter Intake

Table 3 presents dry matter intake at various ages for heifers on both trials. Figure I present dry matter intake at various ages for heifers on the 1983-84 trial. Daily dry matter intake was significantly higher ($P<.05$) for calves fed ration 1 than calves fed ration 2 on both trials. The higher dry matter percentage of ration 1 (90.70 percent) as opposed to ration 2 (45.25 percent) explains a large portion of the difference in dry matter intake between the two rations. Dry matter intake of both rations increased as age of the heifers increased. Dry matter intake of both rations was similar to that reported by Oller (38). Dry matter intake of ration 1 was similar to that reported by Migioia (30). Dry matter intake of ration 2 was similar to that reported by Jones (24) and Nease (36).

Jahn et al. (23) reported that dry matter intake increased as fiber levels in the diets of calves increased up to a maximum intake at 23 percent acid detergent fiber. Above 23 percent acid detergent fiber intake decreased. In this study no decrease in dry matter intake was observed. Calves continually increased dry matter intake as age increased, even when calves were switched from ration 1A with 26.74 percent acid detergent fiber to ration 1B with 43.45 percent acid detergent fiber.

Appendix Table 1-A lists regression coefficients for dry matter of calves on the 1983-84 trial. Treatment had a significant effect ($P<.05$) on intercept and the regression coefficient for week in the

TABLE 3. MEAN AND STANDARD DEVIATION OF DAILY DRY MATTER INTAKE (KILOGRAMS) OF REPLACEMENT HEIFERS

Age (Weeks)	Ration 1[a] 1982-83[b]	Ration 1[a] 1983-84	Ration 2[a] 1982-83[b]	Ration 2[a] 1983-84
6		.46 ± .24		.24 ± .18
7	1.57 ± .35		.73 ± .24	
10		2.71 ± .48		1.49 ± .25
11	3.20 ± .38		1.85 ± .35	
14		4.07 ± .57		2.38 ± .43
15	4.31 ± .57		2.67 ± .47	
18		4.70 ± .65		3.04 ± .27
19	5.24 ± .92		3.34 ± .41	
22		6.01 ± .84		3.58 ± .38
23	6.19 ± 1.01		3.48 ± .53	
26		7.01 ± .97		4.17 ± .52
27	7.63 ± .97		3.96 ± .68	
30		8.04 ± .93		4.65 ± .69
31	8.21 ± .98		4.85 ± .78	

[a]Rations 1 and 2 refers to Table 1 for description of ration composition.

[b]Dry matter percent of feeds fed on the 1982-83 trial were estimated using the dry matter percents of feeds fed on the 1983-84 trial.

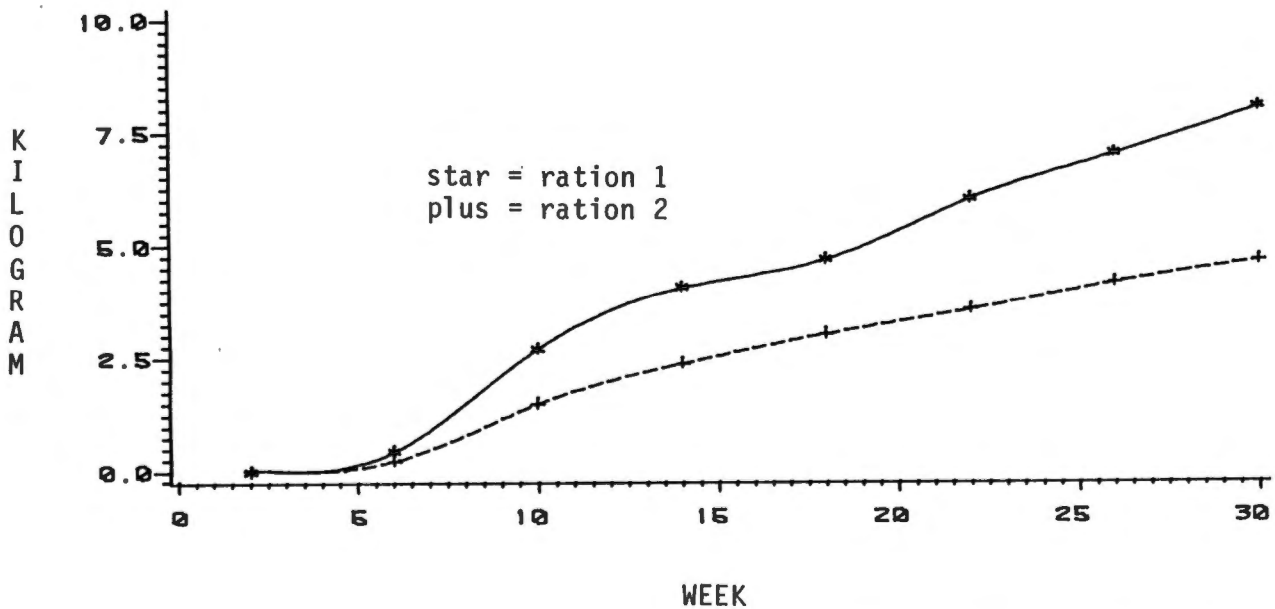


FIGURE I. DRY MATTER INTAKE OF REPLACEMENT HEIFERS ON 1983-84 TRIAL

trinomial regression of dry matter intake. The regression coefficients for week in the quadratic and cubic forms were not significant different between treatments. The multiple regression for dry matter intakes were significantly different ($P<.01$) between treatments.

Crude Protein Intake

Crude protein intake for heifers on the 1983-84 trial, at various ages is listed in Table 4. All heifers increased protein intake as their age increased. Crude protein intake was significantly higher ($P<.05$) for calves fed ration 1 as compared to ration 2. Higher crude protein intake of heifers fed ration 1 as compared to heifers fed ration 2 is related to the greater dry matter intake of ration 1 as compared to ration 2. Oller (38) reported a slightly higher level of crude protein intake for heifers fed CSH based diets. This higher level of crude protein intake was due to the the use of a lower level of CSH and a higher level of SBM in his mixed diet. Crude protein intake of heifers fed ration 2 was similar to that reported by Oller (38) for heifers fed a corn silage based mixed ration.

When compared to recommendations for crude protein intake for large breed dairy heifers as set by the National Research Council (37) heifers on ration 1 consumed slightly more than the recommended levels throughout the 30 weeks. Heifers on ration 2 were below recommended levels of intake until the week 18, at which point they consumed slightly more than the recommended levels. Heifers on ration 2 were probably deficient over the first 18 weeks due to the low dry matter intake of the corn silage ration.

TABLE 4. MEAN AND STANDARD DEVIATION OF DAILY CRUDE PROTEIN INTAKE (KILOGRAMS) OF REPLACEMENT HEIFERS ON 1983-84 TRIAL

Age (Weeks)	Ration 1[a]	Ration 2[a]	NRC Recommendation Total Protein Intake[b]
6	.06 ± .01	.03 ± .01	.18
10	.38 ± .02	.20 ± .01	.33
14	.57 ± .07	.32 ± .05	.36
18	.66 ± .11	.41 ± .09	.39
22	.69 ± .09	.48 ± .11	.42
26	.81 ± .13	.56 ± .10	.45
30	.92 ± .17	.63 ± .14	.47

[a]Rations 1 and 2 refers to Table 1 for description of ration composition.

[b]National Research Council (37).

Acid Detergent Fiber Intake

Acid detergent fiber intake for heifers on the 1983-84 trial at various ages is listed in Table 5. Acid detergent fiber intake was significantly higher ($P<.05$) for calves fed ration 1 than that of calves fed ration 2. The fact that ration 1, both A and B, had higher acid detergent fiber levels, and ration 1 was consumed in larger quantities (dry matter basis) accounts for the higher acid detergent fiber intake by calves fed ration 1. Oller (38) reported lower levels of acid detergent fiber intake for calves fed CSH based diets. This was due to the fact that Ollers rations contained lower levels of CSH. Oller (38) reported similar acid detergent fiber intake for heifers fed corn silage based mixed rations.

Body Weight Gains

Body weight gains of heifers both trials are shown in Table 6. Body weight gains of heifers on the 1983-84 trial was shown in Figure II. Differences in body weight gains for heifers fed ration 1 and 2 on the 1982-83 and the 1983-84 trials were not significantly different until week nine and eight, respectively. At nine weeks of age for calves on the 1982-83 trial, and eight weeks of age for calves on the 1983-84 trial, body weights were significantly higher ($P<.05$) for calves fed ration 1, and remained significantly higher ($P<.05$) throughout the trial.

Cumulative average daily gains for heifers on both trials

TABLE 5. MEAN AND STANDARD DEVIATION OF DAILY ACID DETERGENT FIBER INTAKE (KILOGRAMS) OF REPLACEMENT HEIFERS ON 1983-84 TRIAL

Age (Weeks)	Ration 1	Ration 2
6	.13 ± .06	.05 ± .01
10	.75 ± .12	.30 ± .08
14	1.13 ± .28	.48 ± .09
18	1.30 ± .51	.61 ± .12
22	2.42 ± .48	.72 ± .11
26	2.82 ± .71	.83 ± .09
30	3.24 ± .68	.93 ± .15

TABLE 6. MEAN AND STANDARD DEVIATION OF BODY WEIGHT (KILOGRAMS) OF REPLACEMENT HEIFERS

(Weeks)	Ration 1[a] 1982-83	Ration 1[a] 1983-84	Ration 2[a] 1982-83	Ration 2[a] 1983-84	NRC[b] Recommendations
6		54.32 ± 4.32		51.70 ± 5.51	59
7	55.65 ± 5.01		62.61 ± 6.98		
10		76.36 ± 6.75		64.62 ± 9.70	75
11	87.45 ± 4.95		71.98 ± 7.80		
14		102.41 ± 5.23		81.63 ± 8.56	95
15	113.61 ± 6.35		92.66 ± 7.01		
18		127.5 ± 3.75		106.70 ± 6.35	116.5
19	143.27 ± 8.01		117.24 ± 9.20		
22		156.26 ± 7.55		127.16 ± 11.16	139
23	166.59 ± 6.87		139.02 ± 7.89		
26		182.8 ± 7.86		156.21 ± 13.18	160
27	191.40 ± 9.11		161.61 ± 10.02		
30		201.57 ± 11.96		183.71 ± 11.45	180
31	225.59 ± 12.01		186.31 ± 11.90		

[a]Ration 1 and 2 refers to Table 1 for description of ration composition.

[b]National Research Council (37).

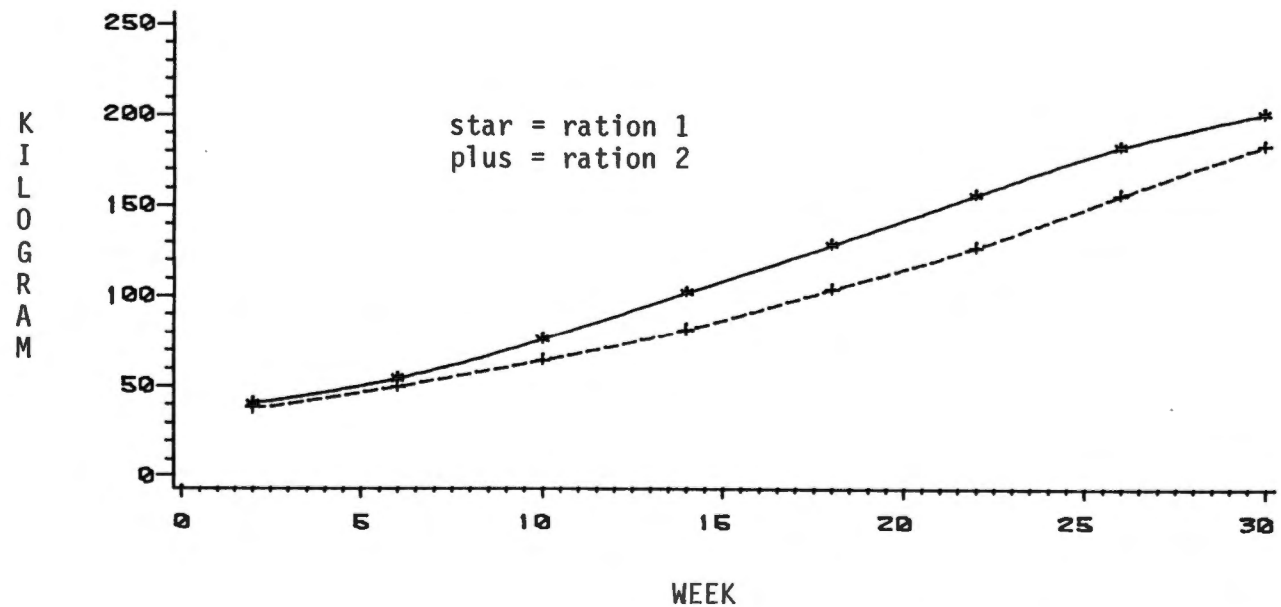


FIGURE II. BODY WEIGHT OF REPLACEMENT HEIFERS ON 1983-84 TRIAL

are presented in Table 7. Calves fed ration 1 had average daily gains slightly below that recommended by the National Research Council (37) until 17 weeks of age for calves on the 1982-83 trial, and 22 weeks for calves on the 1983-84 trial. Cumulative average daily gain for calves fed ration 1 was slightly above National Research Council (37) recommendations for the reminder of each trial. Cumulative average daily gains for calves fed ration 2, on both trials, was slightly below that of the National Research Council (37) recommendations throughout the trials.

In the trial conducted by Oller (38) similar body weight gains were reported for calves fed CSH based diets, also he reported similar gains in body weight for calves fed corn silage based mixed rations. Migioia (30) reported similar body weight gains for calves fed CSH based complete rations. Nease (36) reported similar body weights for calves fed corn silage based diets using either a 2 to 1 or 4 to 1 ratio of corn silage to concentrate. Jones (24) reported similar body weights for heifers fed a three to one mix of corn silage plus 18 percent crude protein concentrate.

Appendix Table 1-A lists regression coefficients for body weight gains of Holstein heifers on the two treatments. Intercept and the regression coefficient for week, in the trinomial regression curves were not significantly different between treatment. Regression coefficients for the terms week in the quadratic and cubic forms in the trinomial regression were significantly different ($P<.05$)

TABLE 7. MEAN AND STANDARD DEVIATION OF CUMULATIVE AVERAGE DAILY GAIN (KILOGRAMS) OF REPLACEMENT HEIFERS

(Weeks)	Ration 1[a] 1982-83	Ration 1[a] 1983-84	Ration 2[a] 1982-83	Ration 2[a] 1983-84	NRC[b] Recommendations
6		.35 ± .10		.29 ± .09	.47
7	.51 ± .11		.36 ± .11		
10		.52 ± .15		.38 ± .11	.75
11	.65 ± .16		.44 ± .11		
14		.64 ± .15		.45 ± .12	.75
15	.72 ± .18		.52 ± .14		
18		.70 ± .20		.53 ± .13	.75
19	.79 ± .19		.60 ± .16		
22		.75 ± .20		.58 ± .12	.75
23	.80 ± .22		.63 ± .15		
26		.79 ± .21		.65 ± .15	.75
27	.81 ± .19		.65 ± .17		
30		.76 ± .19		.70 ± .16	.75
31	.87 ± .23		.70 ± .16		

[a]Rations 1 and 2 refers to Table 1 for description of ration composition.

[b]National Research Council (37).

between treatments. The trinomial regression lines for body weights were significantly different ($P<.01$) between treatments.

Body Measurements

Body measurements of calves on both trials are listed in Tables 8, 9, and 10. Body measurements of calves on the 1983-84 trial are shown in Figures III, IV and V. All body measurements for both trials were slightly higher for calves fed ration 1, however, no statistical difference was detected using univariate analysis except for body length on the 1983-84 trial at 30 weeks of age. Using multivariate analysis, showed that all regression lines for body measurements were significantly different ($P<.01$) between treatment. Even though the total regression lines for body measurements were significantly different ($P<.01$) the individual components (b values) were not significantly different. All body measurements were slightly higher than those reported by Oller (38). Body measurements were similar to those reported by Migioia (30), Jones (24) and Nease (36) for calves fed similar diets.

Jahn et al. (23) reported that fill (contents of the retulorumen, omasum and abomasum) increased linearly with increased dietary fiber level, thus resulting in a smaller proportion of live weight gain attributed to true tissue gain. In addition, they reported maximum tissue gains were obtained when a ration containing 12 percent acid detergent fiber was fed, and that tissue gains decreased as the fiber was increased from 12 percent to 34 percent acid detergent fiber.

TABLE 8. MEAN AND STANDARD DEVIATION OF BODY LENGTH (CENTIMETERS) OF REPLACEMENT HEIFERS

Age (Weeks)	Ration 1[a] 1982-83	Ration 1[a] 1983-84	Ration 2[a] 1982-83	Ration 2[a] 1983-84
6		66.74 ± 1.68		65.84 ± 1.69
7	65.96 ± 1.75		66.14 ± 2.01	
10		73.08 ± 9.02		66.93 ± 3.33
11	72.87 ± 2.53		70.76 ± 2.25	
14		78.26 ± 3.07		72.64 ± 2.51
15	85.01 ± 3.03		80.01 ± 2.81	
18		86.68 ± 2.99		80.65 ± 2.54
19	94.54 ± 3.27		87.53 ± 2.75	
22		91.31 ± 2.87		85.98 ± 3.33
23	102.57 ± 2.89		97.31 ± 3.50	
26		98.02 ± 2.97		91.19 ± 3.20
27	107.37 ± 3.05		102.99 ± 3.98	
30		103.25 ± 3.15		98.76 ± 4.29
31	109.22 ± 2.99		105.41 ± 4.40	

[a]Rations 1 and 2 refers to Table 1 for description of ration composition.

TABLE 9. MEAN AND STANDARD DEVIATION OF BODY HEIGHT (CENTIMETERS) OF REPLACEMENT HEIFERS

Age (Weeks)	Ration 1[a] 1982-83	Ration 1[a] 1983-84	Ration 2[a] 1982-83	Ration 2[a] 1983-84
6		82.55 ± 2.61		81.08 ± 2.69
7	83.33 ± 2.37		81.28 ± 2.67	
10		87.15 ± 3.01		83.57 ± 2.67
11	88.90 ± 2.41		84.99 ± 2.72	
14		92.23 ± 2.56		87.50 ± 3.01
15	90.72 ± 2.74		87.73 ± 2.86	
18		96.52 ± 3.21		93.35 ± 2.76
19	94.84 ± 3.08		91.62 ± 2.64	
22		102.39 ± 2.34		98.30 ± 4.00
23	96.59 ± 2.83		91.92 ± 3.05	
26		105.28 ± 4.29		102.50 ± 2.31
27	99.64 ± 3.41		93.62 ± 2.88	
30		108.43 ± 3.38		106.36 ± 3.18
31	104.14 ± 3.29		98.73 ± 2.99	

[a]Rations 1 and 2 refers to Table 1 for description of ration composition.

TABLE 10. MEAN AND STANDARD DEVIATION OF HEART GIRTH (CENTIMETERS) OF REPLACEMENT HEIFERS

Age (Weeks)	Ration 1[a] 1982-83	Ration 1[a] 1983-84	Ration 2[a] 1982-83	Ration 2[a] 1983-84
6		91.12 ± 3.42		88.70 ± 3.21
7	90.50 ± 4.00		87.91 ±	
10		98.25 ± 4.55		94.49 ± 3.63
11	101.52 ± 3.91		96.42 ±	
14		108.28 ± 3.81		101.47 ± 2.90
15	111.68 ± 4.02		105.23 ±	
18		115.57 ± 4.21		111.13 ± 3.72
19	120.42 ± 4.19		113.84 ±	
22		121.44 ± 4.87		116.84 ± 3.58
23	125.48 ± 4.77		120.65 ±	
26		129.41 ± 5.08		124.33 ± 3.89
27	132.54 ± 5.58		127.23 ±	
30		134.92 ± 6.22		132.94 ± 3.99
31	139.88 ± 6.01		132.08 ±	

[a]Rations 1 and 2 refers to Table 1 for description of ration composition.

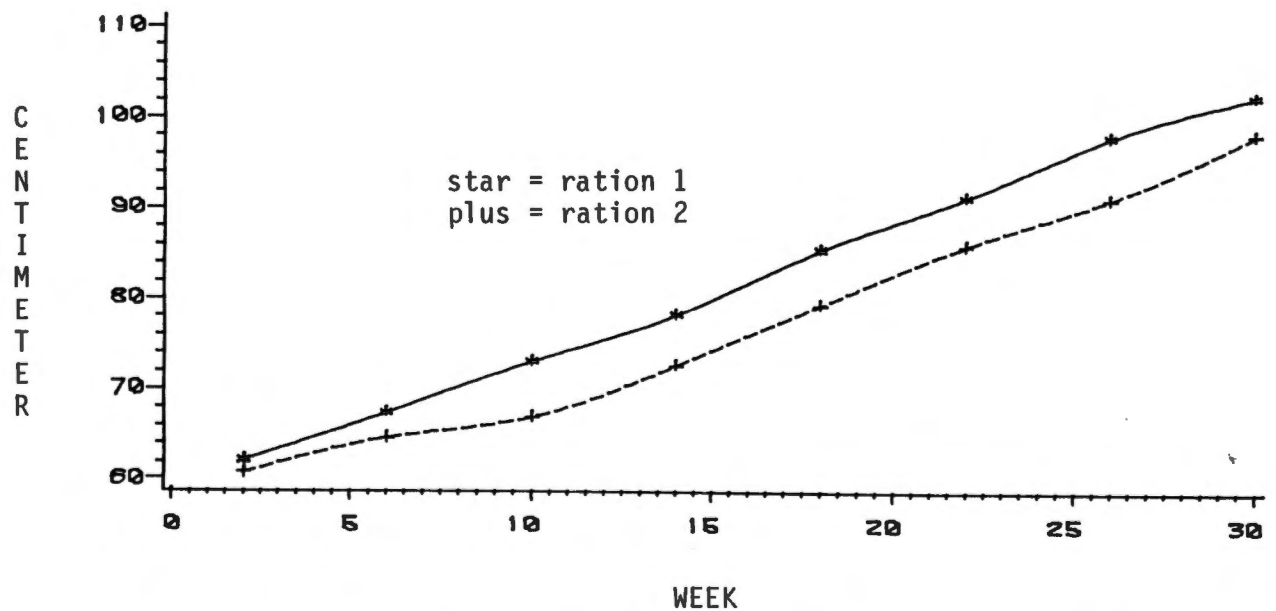


FIGURE III. BODY LENGTH OF REPLACEMENT HEIFERS ON 1983-84 TRIAL

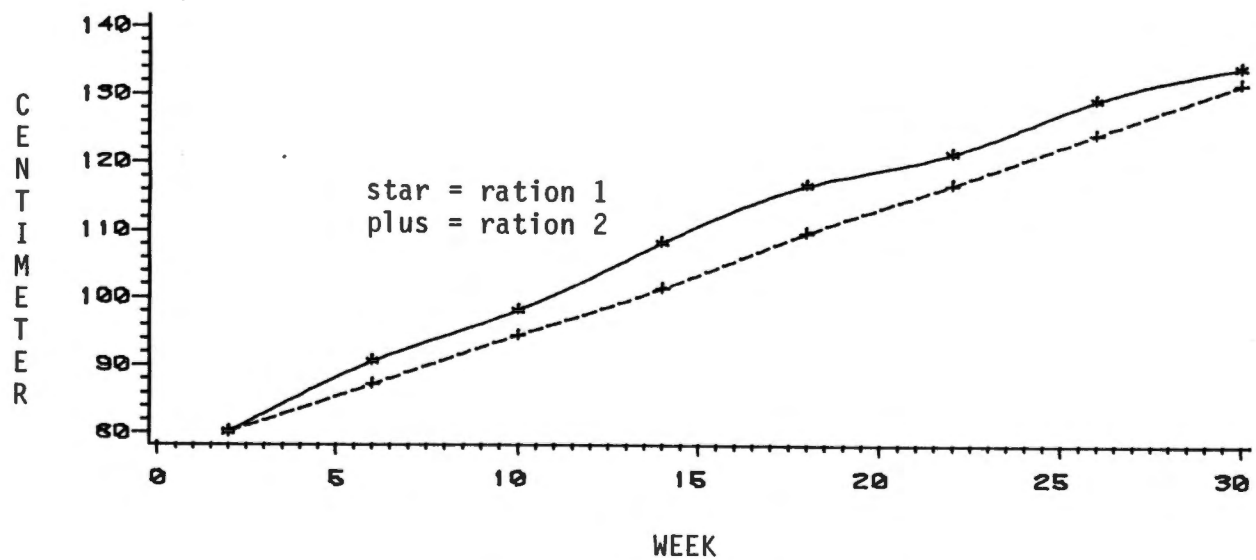


FIGURE IV. HEART GIRTH OF REPLACEMENT HEIFERS ON 1983-84 TRIAL

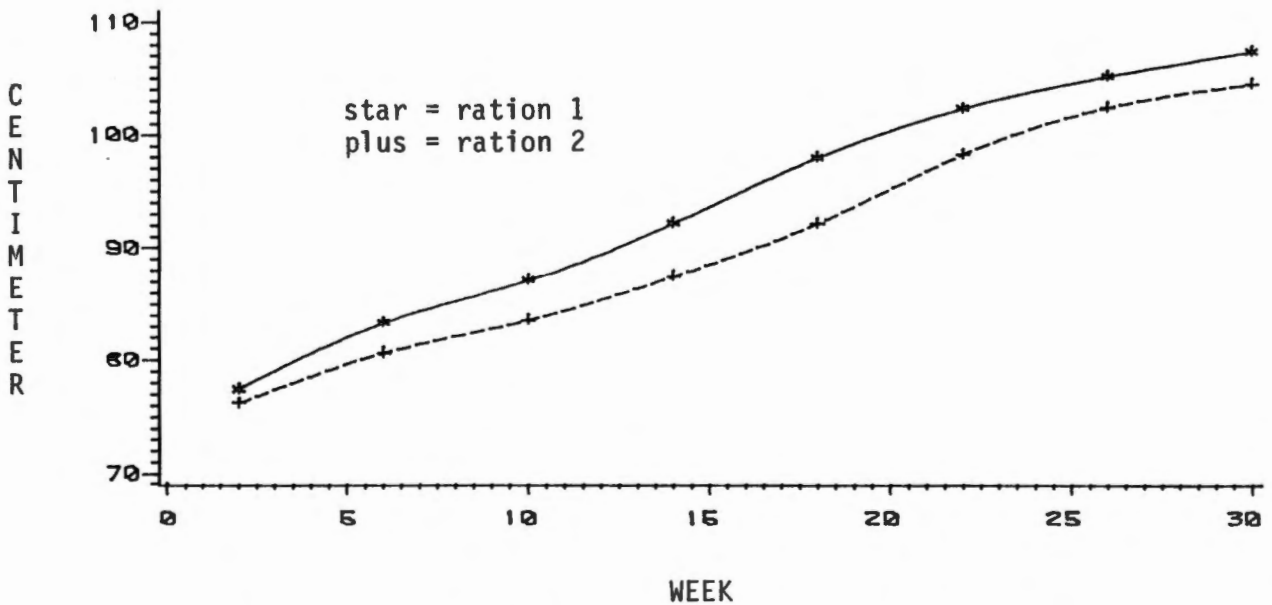


FIGURE V. BODY HEIGHT OF REPLACEMENT HEIFERS ON 1983-84 TRIAL

Although rations had a significant effect on body weight of calves in this study, no attempt was made to determine the true tissue gain between rations. The lack of difference for heart girth and body height for calves in this study suggest the difference in body weight might be due to fill, rather than tissue gain.

Volatile Fatty Acid Concentration Of Calves On 1983-84 Trial

Moles per 100 moles of VFA's are presented in Table 11. Acetate level was not significantly different between ration 1A and ration 2, but was significantly higher ($P<.05$) for ration 1B than either ration 1A or 2. This finding agrees with that of Halevi et al. (17) who found that as dietary fiber increases, moles per 100 moles of acetate increases.

Propionate level was not significantly different between ration 1A and 2, but, opposite to that of acetate, was significantly lower for ration 1B than either 1A or 2. This finding is also in agreement with Halevi et al. (17) who found the increased levels of fiber reduced the level of propionate concentration in relation to acetate concentration. Due to these concomitant changes of acetate and propionate with ration 1B, there was significant ($P<.05$) increase in acetate/propionate ratio.

Butyrate levels were not significantly different between ration 1A and 1B. However, butyrate level of ration 2 was significantly higher ($P<.01$) than that of ration 1A or 1B. This higher level of butyrate was not observed in previous studies using corn silage based diets (30,38). Shifts in the balance in rumen acids may be associated

TABLE 11. MEAN AND STANDARD DEVIATION OF VOLATILE FATTY ACID CONCENTRATION (MOLES/100 MOLES) OF REPLACEMENT HEIFERS ON 1983-84 TRIAL

VFA'S	Ration 1A[a]	Ration 1B[a]	Ration 2[a]
Acetate	64.89 ± 3.46	72.96 ± 3.41	62.94 ± 4.10
Propionate	21.76 ± 4.54	19.31 ± 2.61	19.08 ± 2.73
Butyrate	9.27 ± 2.69	8.91 ± 1.54	14.11 ± 2.90
Isobutyrate	1.09 ± .42	.52 ± .16	.84 ± .32
Valerate	2.00 ± .78	1.73 ± .49	2.07 ± 1.05
Isovalerate	.99 ± .42	1.58 ± .99	.96 ± .39
Acetate: propionate ratio	3.15 ± .81	5.34 ± .88	3.41 ± .65

[a]Refer to Table 1, page , for description of ration composition.

with the protozoal population as well as the methane bacteria (50). Jorgenson and Schultz (25) observed high butyrate production when cows were fed high grain pelleted rations. Eadie and Mann (11) have shown that ciliate protozoa are associated with butyrate production. Leng (28) proposed that the interconversion of butyrate from acetate may serve the purpose of oxidizing reduced co-factors in the cells to allow further fermentation to proceed. In this way the energy cost of activating two acetate molecules to give rise to one butyrate may be overcome, since for every unit of butyrate produced 2 units of reduced co-factors are oxidized. These oxidized co-factors can then be used for the fermentation of more hexose molecules to VFA.

Table 12 reports VFA concentration (millimoles/liter) of Holstein heifers on the 1983-84 project. Acetate concentration was significantly higher ($P<.05$) for calves fed ration 2 than for calves fed either ration 1A or 1B. Propionate concentration was similar between calves fed ration 1A or ration 2, but was significantly lower for calves fed ration 1B. Butyrate concentration was significantly higher ($P<.05$) for calves fed ration 2 than calves fed either ration 1A or 1B. Total VFA concentration was significantly higher ($P<.05$) for calves fed ration 2 than for calves fed either ration 1A or 1B.

Volatile fatty acids are the end products of rumen fermentation of carbohydrates. The fact that calves fed ration 2 had significantly higher ($P<.05$) concentration of VFA's than calves fed either ration 1A or 1B, indicates that ration 2 had a higher level of fermentable carbohydrates than either ration 1A or 1B.

TABLE 12. MEAN AND STANDARD DEVIATION OF VOLATILE FATTY ACID CONCENTRATION (MILLIMOLES/LITER) OF REPLACEMENT HEIFERS ON 1983-84 TRIAL

	Ration 1A[a]	Ration 1B[a]	Ration 2[a]
Acetate	106.94 ± 36.34[ac]	107.20 ± 27.20[a]	135.27 ± 36.01[b]
Propionate	35.84 ± 14.78[a]	21.79 ± 9.54[b]	42.53 ± 13.78[a]
Isobutyrate	1.81 ± .90[a]	.81 ± .36[b]	1.88 ± .90[a]
Butyrate	15.38 ± 7.32[a]	13.36 ± 4.78[a]	31.52 ± 11.41[b]
Isovalerate	1.53 ± .65[a]	2.43 ± 1.95[b]	2.02 ± 1.20[a]
Valerate	3.26 ± .95[a]	2.60 ± 1.1 [a]	4.85 ± 3.00[b]
Total VFA'S	164.73 ± 55.31[a]	148.08 ± 42.00[a]	218 ± 60.06[b]

[a]Rations 1 and 2 refers to Table 1 for ration composition.

[b]VFA concentrations with different postscripts are significantly different (P<.05).

[c]Intercept and regression coefficient for variables with different postscripts are significanly different (P<.05).

Economic Aspects of Cottonseed Hulls Versus Corn Silage

In any feeding program used in a production situation, the economic aspects of that feeding program must be determined. With this in mind, an economic evaluation of CSH as compared to corn silage in mixed rations was performed.

The amount of feed (as fed basis) to produce 1 kilogram of body weight gain was determined for each ration. No gains prior to six weeks of age were used in this determination due to the fact that calves were receiving milk diets at this time. It was determined that from six weeks of age to 18 weeks of age it took 6.75 kilogram of the CSH ration (ration 1A), of which 2.7 kilogram was CSH, to produce 1 kilogram of body weight gain. From 18 weeks until 30 weeks it took 10.08 kilogram of the CSH ration (ration 1B), of which 6.05 kilogram was CSH, to produce 1 kilogram of body weight gain. It was the determined that from six until 30 weeks of age 4.38 kilogram of CSH were needed in the ration to produce 1 kilogram of body weight gain. For the corn silage mixed ration (ration 2) 12.58 kilogram of feed, of which 9.44 kilogram was corn silage, produced 1 kilogram of body weight gain. To produce the same gain as 4.38 kilogram of CSH in a mixed diet would produce, 9.44 kilogram of corn silage was needed in a mixed diet. It took 2.16 times as much corn silage to produce 1 kilogram of gain as it did of CSH when fed in mixed rations. It is therefore reasonable to suggest that producers can pay as much as 2.16 times the cost of producing corn silage for the same amount of CSH. However, it should be noted that this relationship of corn silage to CSH may change if different levels of the two are fed.

This calculated relationship of CSH to corn silage is in close agreement to the standard values for total digestible nutrients between the two. When comparing standard values of total digestible nutrients for corn silage and CSH on an as fed basis, it was determined that CSH has 1.98 times as much total digestible nutrients as does corn silage.

Due to the fact that corn silage diets must be fed fresh daily and CSH diets can be fed using self feeders, it is obvious some labor can be saved if CSH diets are fed by using self feeders. The amount of labor that may be saved if self feeders are used will influence what a producer can pay for CSH as compared to corn silage, but this determination can only be made on an individual basis.

CHAPTER V

SUMMARY AND CONCLUSIONS

The effect of two complete mixed rations, utilizing either CSH or corn silage as roughage, on animal performance was evaluated in two continuous trials.

Thirty Holstein heifers in 1982-83, and 25 Holstein heifers in 1983-84, were fed one of two different rations. For the 1982-83 trial ration 1 consisted of two stages. Stage 1A contained 30 percent CSH, 50 percent corn, and 20 percent SBM, plus vitamines and minerals fed ad libitum from two until 18 weeks of age. Stage 1B contained 50 percent CSH, 40 percent corn, and 10 percent SBM, plus vitamines and minerals fed ad libitum from 18 until 31 weeks of age. Ration 2 consisted of a 3:1 ratio of corn silage and 16 percent crude protein dairy feed fed ad libitum throughout the study. Ration 1 for the 1983-84 trial consisted of two stages. Stage 1A contained 40 percent CSH, 45 percent corn, and 15 percent SBM, plus vitamines and minerals fed ad libitum from two until 18 weeks of age. Stage 1B contained 60 percent CSH, 30 percent corn, and 10 percent SBM, plus vitamines and minerals fed ad libitum from 18 until 30 weeks of age. Ration 2 consisted of a 3:1 ratio of corn silage and 16 percent crude protein dairy feed, fed ad libitum throughout the study.

Calves fed ration 1, on both trials had significantly higher ($P<.05$) dry matter intake. The higher level of dry matter intake was due to the higher dry matter percentage of ration 1, and also to

the smaller particle size of ration 1. Calves on the 1983-84 trial had significantly higher ($P<.05$) crude protein and acid detergent fiber intake for calves fed ration 1.

On both trials, calves fed ration 1 had significantly higher ($P<.05$) body weights than those calves fed ration 2. Cumulative average daily gains on both trials were significantly higher ($P<.05$) for calves fed ration 1.

On both trials, body measurements were not significantly different between rations with the exception of body length on week 30 of the 1983-84 trial which was significantly longer ($P<.05$) for calves on ration 1. The lack of difference in body measurements suggest that the difference in body weights may be due to fill, rather than tissue gain.

For calves on the 1983-84 trial, moles per 100 moles of VFA's were similar between ration 1A and ration 2 with the exception of butyrate which was significantly higher ($P<.05$) on ration 2. Ration 1B produced significantly higher ($P<.05$) levels of acetate, and significantly lower ($P<.05$) levels of propionate than either rations 1A or 2. Volatile fatty acid concentration (millimoles/liter) was significantly higher ($P<.05$) for ration 2 with the exception of propionate production which was similar between ration 2 and 1A but significantly higher ($P<.05$) than of ration 1B. This higher level of VFA concentration by ration 2 indicates that ration 2 contained more fermentable carbohydrates than either rations 1A or 1B.

CSH were shown to have 2.16 times the feeding value of corn

silage (as fed basis) when used in the mixed feeds in the 1983-84 trial.

This study suggests that both CSH and corn silage can be used in complete mixed rations for dairy heifers, and that acceptable rates of growth can be achieved with either forage. However, this study suggest that CSH's should only be used when they can be purchased for less than 2.16 times as much as the cost of the same unit of corn silage.

LIST OF REFERENCES

LIST OF REFERENCES

1. A.O.A.C. Official Methods of Analysis. 1965. (19th Edition) Association of Official Agricultural Chemists, Washington, D.C.

2. Bergman, E. N., R. S. Reid, M. G. Murray, J. M. Brockuay, and F. G. Whitelaw. 1965. Interconversions and production of volatile fatty acids in the sheep rumen. Biochem. J. 97:53.

3. Blair, W. H., R. L. Cross, D. D. Ingold, C. P. Witman, J. H. Goodnight, J. R. Sall, L. B. Hasell, O. M. Delong, W. S. Sarle, H. J. Kirk, M. B. Hichols, J. Z. Helwig, K. A. Council, and P. S. Reinhardt. SAS User's Guide, 1979 Edition. SAS Institute, Inc.

4. Brown, W. H., F. M. Whiting, B. S. Daboll, R. J. Turner, and J. D. Schuh. 1977. Pelleted and nonpelleted cottonseed hulls for lactating dairy cows. J. Dairy Sci. 60:919.

5. Ciesyznski, C. P. 1980. Sodium bentonite in complete rations containing maltlage and the use of maltage in complete rations for replacement heifers. M.S. Thesis. The University of Tennessee.

6. Clifton, C. M., and P. R. Fowler. 1972. All-in-one rations for young replacement heifers, utilizing various roughage sources. J. Dairy Sci. 55:693 (Abstr.).

7. Clifton, C. M., and P. R. Fowler. 1973. All-in-one rations, self-fed, versus coastal bermuda grass hay and limited grain for young dairy heifers. J. Dairy Sci. 56:648 (Abstr.).

8. Conrad, H. R., and J. W. Hibbs. 1958. High roughage systems for raising calves based on the development of early rumen function. Effect of rumen inoculations and Chlortetracycline on rumen function of calves fed high roughage pellets. J. Dairy Sci. 41:1248.

9. Conrad, H. R., A. D. Pratt, and J. W. Hibbs. 1964. Regulation of feed intake in dairy cows. I. Change in importance of physical and physiological factors with increasing digestibility. J. Dairy Sci. 47:54.

10. Cullison, A. E. 1975. Feeds and Feeding. Reston Publishing Company Inc., Reston Virgina. 426.

11. Eadie, J. M., and S. O. Mann. 1970. In: Physiology of Digestion and Metabolism in the Ruminant. A. T. Phillipson, Edition Oriel Press. Newcastle Upon Zyne, England. 335.

12. Emery, F. E., and B. W. Kilgore. 1891. Digestion experiments. I. Digestibility of cottonseed hulls. North Carolina Agr. Exp. Sta. Bull. 80c.

13. Erwin, E. S., G. J. Marco, and E. M. Emery. 1961. Volatile fatty acid analysis of blood and rumen fluid by gas chromatography. J. Dairy Sci. 44:1768.

14. Etgen, W. M., and P. M. Reaves. 1978. Dairy Cattle Feeding and Management. 6th Edition. John Wiley and Sons, New York, New York. 334.

15. Fiske, C. H., and J. Subbarow. 1966. The colorimetric determination of phosphorus. J. Biol. Chem. 66:375.

16. Gardner, R. W., and M. Akbar. 1970. Effect of pelleting calf rations on minimum protein requirements. J. Dairy Sci. 53:18.

17. Grieve, D. G., J. B. Stone, G. K. Maclead, and R. A. Curtis. 1976. All silage forage programs for dairy cattle. I. Heifer performance from birth to eighteen months of age. J. Dairy Sci. 59:912.

18. Grieve, D. G., R. A. Curtis, J. B. Stone, and G. K. Maclead. 1980. All silage forage programs for dairy cattle. III. Health, survival and reproduction. J. Dairy Sci. 63:601.

19. Halevi, A., H. Newmark, and S. Amir. 1973. Straw in different proportions as sole roughage in diets for cows in mid lactation. J. Dairy Sci. 56:1242.

20. Heinricks, A. J., and R. J. Rugaber. 1984. How good are you raising heifers? Hoards Dairyman.

21. Hibbs, J. W., W. D. Conrad, and N. Frank. 1956. A high roughage system for raising calves based on the early development of rumen function. VI. Influence of hay-to-grain ratio of calf performance, rumen development, and certain blood changes. J. Dairy Sci. 41:1230.

22. Hogan, J. P., and R. H. Weston. 1967. The digestion of chopped and ground roughage of sheep. II. The digestion of nitrogen and some carbohydrate fractions in the stomach and intestines. Aust. J. Agric. Res. 18:803.

23. Jahn, E., P. T. Chandler, and C. E. Polan. 1970. Effect of fiber and ratio of starch to sugar on performance of ruminating calves. J. Dairy Sci. 53:964 (Abstr.).

24. Jones, B. E. 1978. Utilization of maltlage in complete rations for lactating cows and replacement dairy heifers. M.S. Thesis. The University of Tennessee.

25. Jorgenson, N. A., and L. H. Schultz. 1965. Ration effects on rumen acids, ketogenesis, and milk composition. II. Restricted roughage feeding. J. Dairy Sci. 48:1040.

26. Lee, D. D., Z. Storm, and G. C. McCoy. 1973. Milling by-products as sources of crude fiber in rations fed to young dairy calves. J. Dairy Sci. 56:682 (Abstr.).

27. Leighton, R. E., and R. E. Helm. 1967. Ad libitum feeding of complete rations to dairy cows. J. Dairy Sci. 50:617.

28. Leng, R. A. 1969. In: Physiology of Digestion and Metabolism in Ruminants. A. T. Phillipson, Edition, Oriel Press, Newcastle Upon Zyne, England. 411.

29. Lengemann, F. W., and N. W. Allen. 1955. The development of rumen function in the dairy calf. I. Some characteristic's of the rumen contents of cattle of various ages. J. Dairy Sci. 38:651.

30. Migioia, S. N. 1982. Comparison of a conventional feeding program with a two-stage complete ration program utilizing cottonseed hulls as the fiber source for replacement heifers. M.S. Thesis. The University of Tennessee.

31. Miller, W. J., Y. G. Mortin, and P. R. Fowler. 1969. Effects of addition of fiber to simplified and to complex starter fed to young dairy calves. J. Dairy Sci. 52:677.

32. Montgomery, M. J. Unpublished Data.

33. Montgomery, M. J., E. W. Culvahouse, and H. Henderson. 1979. Comparison of unpelleted and pelleted cottonseed hulls as a replacement for hay for lactating cows. 1978-79 Animal Science Res. Progress Report. Animal Sci. Dept. The University of Tennessee.

34. Morrison, F. B. 1956. Feeds and Feeding. 22nd Edition. The Morrison Publishing Co., Ithaca, New York.

35. Murdock, F. R., and R. W. Vallenius. 1980. Fiber sources for complete calf starter rations. J. Dairy Sci. 63:1869.

36. Nease, R. R. 1977. Complete rations utilizing hay or corn silage for dairy calves. M.S. Thesis. The University of Tennessee.

37. Nutrient Requirements of Dairy Cattle. 1978. 5th Edition. National Academy of Sciences, Washington, D.C.

38. Oller, P. C. 1982. Comparison of corn silage and cottonseed hulls in complete rations for calves in confinement housing and outdoor calf hutches. M.S. Thesis. The University of Tennessee.

39. Olson, H. H. 1965. What do we know about complete feeds for dairy cattle? Proc. Cornell Nutrition Conf. 80.

40. Owens, F. A., B. J. Shockley, R. W. Fent, and R. G. Teeter. 1978. Cottonseed hulls for ruminants. J. Animal Sci. 47 (Suppl. 1):121 (Abstr.).

41. Putman, P. A., and R. E. Davis. 1961. Effect of feeding complete rations to lactating cows. J. Dairy Sci. 44:1465.

42. Rakes, A. H. 1969. Complete rations for dairy cattle. J. Dairy Sci. 52:870.

43. Rakes, A. H., and D. G. Davenport. 1973. Cottonseed hulls and hydrolyzed feather meal in complete rations for herd replacements. J. Dairy Sci. 56:648 (Atstr.).

44. Ronning, M., and R. C. Laben. 1966. Response of lactating cows to free-choice feeding of milled diets containing from 10 to 100 percent concentrates. J. Dairy Sci. 49:1080.

45. Rumsey, Z. S., P. A. Putnam, J. Bond, and R. R. Oltjen. 1970. Influence of level and type of diet on ruminal pH and VFA, respiratory rate and EKG patterns of steers. J. Animal Sci. 31:608.

46. Swanson, E. W., and J. D. Harris, Jr. 1958. Development of rumination in the young calf. J. Dairy Sci. 41:1768.

47. Swanson, E. W. 1967. Optimum growth patterns for dairy cattle. J. Dairy Sci. 50:244.

48. Swanson, e. W. 1978. Heifer Performance Standards: Relation of Rearing Systems to Lactation. Large Dairy Herd Management. University Presses of Florida. Garnsville, Flordia.

49. Van Horn, H. H., M. B. Olayiwole, G. J. Wilcox, B. Harris, Jr., and J. M. Wing. 1976. Effects of housing. Milk feeding management and ration formulation on calf growth and feed intake. J. Dairy Sci. 59:924.

50. Van Soest, P. J. 1982. Nutritional Ecology of the Ruminant. O and B Books, Inc. Corvallis, Oregon.

51. Van Soest, P. J. 1963. The use of detergents in the analysis of fiborus feeds. II. A rapid method for the determination of fiber and lignin. J. Assn. Official Agr. Chemists. 46:829.

52. Verland, S. D., B. Harris, Jr., H. H. Van Horn, and C. J. Wilcox. 1980. Effect of masonex and forms of cottonseed hulls on dairy cows. J. Dairy Sci. 50:937.

53. Villavincencio, E., L. L. Rusoff, R. E. Girouard, and W. H. Waters. 1968a. Effect of long term feeding of complete feeds to high producing cows. J. Dairy Sci. 51:623.

54. Villavincencio, E., L. L. Rusoff, R. E. Girouard, and W. H. Waters. 1968b. Comparison of complete feed rations to concentional rations for lactating cow. J. Dairy Sci. 51:1633.

APPENDIXES

APPENDIX A

SETTINGS FOR VFA ANALYSIS ON BENDEX 2600 GAS CHROMATOGRAPH

Running temperature 130 C

Multiplier = x4

Rate C per minute = 10

Fuction isothermal

Flow rates

H_2 = 3

Air = 3

N = 2.5

Integrater

16 seconds

High noise

x1

.1 minute

Recorder attenuotor = 500

Lo.

Column

6 foot U shaped 2 mm diameter

Packing material = 5P1200

APPENDIX B

Table 1-A. INTERCEPT AND REGRESSION COEFFICIENTS FOR GROWTH CURVES AND DRY MATTER INTAKE OF REPLACEMENT HEIFERS ON 1983-84 TRIAL

Variable	Treatment[a]	Intercept	B_1[b]	B_2[b]	B_3[b]
Weight	1	35.709A[c]	1.8304A	.27898A	-.0050734A
	2	34.227A	1.7964A	.12503B	-.0006699B
Length	1	60.242A	.95143A	.036863A	-.0007179A
	2	61.206A	.09781A	.068489A	-.0010243A
Height	1	75.959A	.94096A	.033456A	-.00099182A
	2	75.731A	.52458A	.037294A	-.00070258A
Heart Girth	1	77.048A	2.6734A	-.017549A	-.0001685A
	2	74.364A	1.6830B	.013136A	-.00028459A
Dry Matter Intake	1	-1.4869A	.42903A	-.0043887A	.000024032A
	2	- . 987B	.18800B	.0027424A	-.0001086A

[a]Refer to Table 1, page for ration composition.

[b]B_1 = linear regression coefficient for week B_2 = quadratic regression coefficient for week B_3 = cubic regression coefficient for week.

[c]Intercept and regression coefficient for variables with different postscripts are significantly different ($P<.05$).

VITA

Aaron R. Cole son of Mr. and Mrs. Robert M. Cole, was born in Detroit, Michigan on September 26, 1956. He moved with his family to Sparta, Tennessee in 1965 where he grew up and graduated from White County High School in 1975. He entered Tennessee Technological University in 1975 where he studied animal science. In 1979, he received a B.S. degree in Animal Science. In 1981, he entered graduate school at The University of Tennessee to study Dairy Nutrition and received the Master of Science degree in 1984.

He is married to Kathy S. Johnson of Sparta, Tennessee.