# INFLUENCE OF DIFFERENT LEVELS OF WHEAT IN CONCENTRATE MIXTURE ON RESPONSES OF LACTATING DAIRY COWS

By

MARTIN ALLEN FALDET

Bachelor of Science

Iowa State University

Ames, Iowa

1984

Submitted to the Faculty of the Graduate College
of the Oklahoma State University
in partial fulfillment of the requirements
for the Degree of
MASTER OF SCIENCE
December, 1986

INFLUENCE OF DIFFERENT LEVELS OF WHEAT
IN CONCENTRATE MIXTURE ON RESPONSES
OF LACTATING DAIRY COWS

Thesis Approved:

L. J. Bush
Thesis Advisor

Charles A. Hibberd

Earl P. Aalseth

Norman N. Durham
Dean of Graduate College

ACKNOWLEDGEMENTS

I wish to express my sincere appreciation to my major advisor, Dr. Linville J. Bush, for his guidance, assistance, and encouragement during the course of this study and preparation of this manuscript. Appreciation is also extended to Dr. C.A. Hibberd and Dr. E.P. Aalseth, members of my graduate committee, for their evaluations and suggestions in the preparation of this manuscript.

Special thanks go to Mr. Glenden Adams, Thor Nalsen and employees of the Dairy Cattle Center for their care of the experimental animals and aid in conducting the trials, and to Jane Wells and Belen Lester for their assistance in lab work.

I would like to express my sincere gratitude to all the people who assisted me in this study and during my stay at Oklahoma State University.

Finally, I wish to extend a very special thanks to my parents, Merlin and Suzanne Faldet, and to my brother and sisters for their love and constant support during my entire education.

TABLE OF CONTENTS

LIST OF TABLES

# CHAPTER I

## INTRODUCTION

A dairy cow today produces significantly more milk than cows in the past and requires a high level of energy to meet the demands of milk production. This energy demand is furnished primarily by cereal grains, most of which are not wheat. Therefore, there is a great potential existing for increased use of wheat in feeding programs for dairy cattle.

In Oklahoma, surpluses of hard red winter wheat have increased 32 percent from January of 1985 to January of 1986. In the United States, an 18 percent increase in stocks of hard wheat was noted. These surpluses mainly reflect decreased exports and have decreased the price of wheat to a level that it is competitive with other feed grains. When this is the situation, wheat can be used to advantage in formulating high energy rations for lactating dairy cows.

In most of the earlier experiments on feeding wheat to dairy cows, milk production was low and total intake of wheat was minimal in many cases. In a few cases, intake of wheat reached 9 to 15 pounds per day (Monroe and Hayden, 1933 and 1934; Bateman, 1942; Hewitt and Turner, 1944), which is still low in comparison to amounts of grain commonly fed to dairy cows today (i.e., 25 to 30 lb/cow/day).

More recently, McPherson and Waldern (1969) found that cows fed alfalfa hay plus concentrate mixtures containing from 20 to 93% Gaines soft white wheat had no problems with "off-feed" and no significant differences in milk production attributable to amount of wheat in the ration. In contrast, Cunningham et al. (1970) observed lower milk yield by cows fed a concentrate mix containing 66.7% ground soft red winter wheat than by cows fed a mix with 33.3% wheat.

Tommervik and Waldern (1969) observed Gaines soft white wheat to be comparable in its nutritive value to that of corn, oats, barley and milo with respect to palatability and milk production and composition. Cunningham et al. (1970) suggested soft red winter wheat fed as high as 67% in the concentrate mix to dairy cows may lower milk fat content and 4% fat-corrected-milk production. In their trial, wheat replaced corn and soybean meal.

One of the main concerns about feeding wheat to cows is the possibility of developing an "off-feed" or acidosis condition. The starch portion of wheat is readily fermentable in the rumen (Waldo, 1973) and may have detrimental effects on milk fat content by altering the volatile fatty acid production in the rumen in favor of propionate. Fitch and Cave (1932) reported a tendency for some cows to go "off-feed" when wheat comprised 57% of a concentrate mix. Bailey (1965) also observed cows fed high levels of wheat to go "off-feed" and drop in milk yield. However, Waldern (1970) did not encounter these problems in his studies, possibly because an adequate amount of dry roughage was fed.

Another concern with respect to feeding dairy cows is that of providing an adequate supply of amino acids for milk synthesis. Amino acid requirements for lactation are relatively high and in order to meet these requirements it may be beneficial to maximize the supply of amino acids at the site of absorption by allowing a substantial portion of high quality dietary protein to escape the rumen without degradation. When feeding wheat, duodenal amino acid supply may be deficient or unbalanced for high producing dairy cows, since ruminal degradation of wheat protein has been estimated to be higher than that of other cereal grains (Mertens, 1977; Madsen and Huelplund, 1985; Commonwealth Agricultural Bureaux, 1984). This may be the factor responsible for decreased milk production observed in certain studies.

Differences in responses of dairy cows fed wheat may be attributed to a difference in milk production by the animals, type of forage utilized, variety or type of wheat, amount of wheat intake, or method of grain processing. Therefore, the objectives of this research were to:

a) Compare the performance of lactating cows fed concentrate mixtures containing different amounts of ground hard red winter wheat in a complete ration with sorghum silage as the only forage.

b) To study the influence of different levels of ground hard red winter wheat in the concentrate mixture on production responses of lactating dairy cows fed alfalfa hay as the only forage.

c) Evaluate the effect of different amounts of wheat in the ration on concentration of volatile fatty acids and ammonia in rumen fluid and urea in blood plasma of cows.

d) Evaluate the effect of different amounts of wheat in the ration when alfalfa hay is the sole roughage source on digestibility of dry matter and crude protein of rations.

## CHAPTER II

## LITERATURE REVIEW

Wheat is primarily noted for its use as a food commodity rather than as animal feed. However, when wheat is abundant and comparable in cost to other cereal grains used as energy sources for domesticated animals, it may be used in specific feeding regimes.

Wheat occupies a major position as an agricultural commodity in the Great Plains areas of the United States. It is also prominent in the corresponding Prairie provinces of Canada, as well as in the white and soft red wheat growing areas scattered throughout North America. In Oklahoma, an abundant supply of wheat is generally available for livestock feeding. According to the February, 1985 bimonthly issue of the Oklahoma Farm Statistics, wheat stocks (includes stocks at mills, elevators, warehouses, terminals and processors) totaled a record 195 million bushels, which was up 33 percent from the previous year and 8 percent above the previous record high in 1983. Stocks of wheat in the United States were up 18%. This increase in stock piles is attributed to much lower U.S. export sales.

With increasing surpluses, a price depression normally occurs. The seasonal average price received for winter wheat was 3.51, 3.36 and 3.20 dollars per bushel for 1983, 1984 and 1985, respectively. The price has reached as low as $2.77/bu (August, 1985) for winter wheat, according to the Oklahoma Crop and Livestock Reporting Service. These relatively low prices occasionally make wheat competitive with other feed grains used as an energy source in dairy rations. However, many dairymen are unfamiliar with utilizing wheat in dairy rations, and are therefore reluctant to use it. There is also a shortage of data as to the relative nutritive value and acceptability of wheat for dairy cows. In this chapter, an effort has been made to review the available literature on feeding wheat to dairy cows.

## Nutrient Composition of Wheat

The type or variety of wheat, climatic conditions, soil fertility, and geographical area considerably influence the nutritive value of wheat, with crude protein and amino acid composition being more variable than other nutritive components (Sullivan, 1970). Waldern (1970) reported ranges of variability of 12-19%, 10-15% and 8-12% of crude protein content for hard red spring wheats, hard red winter wheats, and soft wheats, respectively. In general, hard red spring wheat has the highest crude protein value followed by red winter wheat and then soft red and white winter wheat. In dairy rations, it has been suggested that lysine and/or methionine are the limiting amino acids for milk protein synthesis or milk production (Broderick et al., 1974; Chandler and Polan, 1972; Schwab et al., 1976). Therefore, a high protein, hybrid wheat with a higher lysine and/or methionine content would be most beneficial in significantly influencing the role of wheat usage in dairy feeding programs as well as other livestock programs.

Wheat can be used effectively in formulating high energy rations for lactating dairy cows. The energy content among different types of wheat is less variable than that of protein (Waldern, 1970; NRC, 1982). Morrison (1956) gives digestibility coefficients for an average of all types of wheat for protein, fat, fiber, and nitrogen free extract of 84, 81, 70, and 91, respectively.

Wheat is a good source of certain water soluble vitamins (B vitamins, niacin) compared to other small grains (Sullivan, 1970). Wheat is also a rich source of vitamin E, although a poor source of vitamins A and D. Different types of wheat appear to be variable in the trace mineral contents which is probably due to variations in soil and climatic conditions (Sullivan, 1970). In general, wheat is adequate in phosphorus but deficient in calcium and magnesium (Waldern, 1970). The most recent nutritive composition for wheat types are found in the United States-Canadian Table of Feed Composition, 1982 (Table 1). Wheat is also favorable in nutritive aspects when compared to other cereal grains which are used as energy sources for dairy cattle diets (Table 2).

## Amounts of Wheat in the Concentrate Mixtures

Even when wheat is competitive to other feed grains, farmers hesitate to feed wheat because they are either not accustomed to doing so or do not appreciate its high feeding value. One major concern by dairymen when using wheat in dairy rations is how much wheat can be included in the concentrate mix. This concern relates to the effect

TABLE I

NUTRIENT COMPOSITION OF DIFFERENT TYPES OF WHEAT[a].

| | Hard | | Soft | | |
|---|---|---|---|---|---|
| Item | Red spring | Red winter | Red winter | White winter | White winter PC |
| | (% or Mcal/kg, as fed basis) | | | | |
| Dry matter | 88.0 | 88.0 | 88.0 | 89.0 | 89.0 |
| Crude protein | 15.1 | 12.7 | 11.5 | 10.1 | 10.0 |
| $NE_1$ | 1.81 | 1.80 | 1.82 | 1.84 | 1.82 |
| Crude fiber | 2.5 | 2.5 | 2.2 | 2.3 | 2.5 |
| Ash | 1.6 | 1.7 | 1.8 | 1.6 | 1.9 |
| Calcium | .03 | .04 | .04 | .06 | .09 |
| Phosphorus | .38 | .38 | .38 | .32 | .30 |
| Amino acids | | | | | |
| Lysine | .35 | .36 | .36 | .31 | .30 |
| Isoleucine | .54 | .51 | .45 | .41 | .40 |
| Leucine | .88 | .89 | .90 | .71 | .75 |
| Methionine | .19 | .21 | .22 | .15 | .14 |
| Phenylalanine | .66 | .63 | .64 | .47 | .48 |
| Threonine | .36 | .37 | .39 | .32 | .31 |
| Valine | .59 | .59 | .58 | .46 | .46 |
| Tryptophan | .14 | .17 | .27 | .12 | .12 |
| Arginine | .59 | .64 | .65 | .46 | .45 |
| Histidine | .24 | .30 | .32 | .22 | .20 |

[a]United States - Canadian Tables of Feed Composition, 1982 (Third Revision)

TABLE II

COMPARATIVE NUTRITIVE VALUE OF GRAINS[a]

| Item | Corn | Barley | Sorghum | Oats | Wheat |
|---|---|---|---|---|---|
| | (% or Mcal/kg, as fed basis) | | | | |
| Dry matter | 89.0 | 88.0 | 90.0 | 89.0 | 89.0 |
| Crude protein | 9.6 | 11.9 | 11.1 | 11.8 | 14.2 |
| NE | 1.78 | 1.71 | 1.78 | 1.57 | 1.81 |
| Crude fiber | 2.6 | 5.0 | 2.4 | 10.8 | 2.6 |
| Ash | 1.3 | 2.3 | 1.8 | 3.1 | 1.7 |
| Calcium | .03 | .04 | .03 | .07 | .04 |
| Phosphorus | .26 | .34 | .29 | .33 | .37 |
| Amino acids | | | | | |
| Lysine | .25 | .39 | .25 | .39 | .37 |
| Isoleucine | .35 | .45 | .45 | .43 | .47 |
| Leucine | 1.21 | .75 | 1.44 | .81 | .87 |
| Methionine | .17 | .15 | .13 | .17 | .18 |
| Phenylalanine | .48 | .58 | .56 | .52 | .61 |
| Threonine | .35 | .37 | .36 | .36 | .38 |
| Valine | .44 | .57 | .52 | .56 | .57 |
| Tryptophan | .08 | .15 | .11 | .15 | .15 |
| Arginine | .43 | .51 | .39 | .70 | .59 |
| Histidine | .26 | .24 | .23 | .18 | .29 |

[a]United States - Canadian Tables of Feed Composition, 1982 (Third Revision).

that the level of wheat in the concentrate mix has on acceptability of the ration by cows and, therefore, milk production (Waldern, 1970).

The earliest research was conducted by the Ontario Agricultural College, Guelph in 1893, cited by Waldern (1970), on feeding either a 50 or 100% wheat concentrate to four lactating dairy cows for 3 to 4 weeks. They concluded that wheat rations provided favorable results in production responses but a combination of wheat and bran was more economical to feed.

In 1931, Jacobs of the Oklahoma Panhandle Station reported that at least two-thirds of the daily grain ration for dairy cows may be comprised of wheat and would not cause a decrease in milk flow.

Hayden and Monroe (1931) showed that wheat is satisfactory at levels of 40 and 50% of the concentrate portion for a dairy ration. In 1932, dairymen still claimed wheat to be unpalatable and would cause digestive disturbances. This led Monroe and Hayden (Ohio Bull. 532) to conduct an experiment feeding two Jersey cows a grain mixture of coarse ground wheat with 2% steam bone meal for a complete lactation. Alfalfa hay was fed as the sole roughage source. One cow produced over 9,800 pounds of milk and 474 pounds of butterfat while consuming two tons of wheat in 365-day lactation. It appeared this cow had an average wheat intake per day of 11 pounds and probably much more during the peak of lactation. No off-feed or digestive disturbances were noted for either cow.

Fitch and Cave (1932) reported that wheat could be included in the concentrate mix as high as 57%; however they did observe a slight tendency for cows to go off feed. Other researchers around 1930 found wheat to be suitable only at a level no higher than one-third of the concentrate portion of a dairy ration (Kentucky Experimental Station, 1931; Ontario Dept. Agric., 1932). Dice, in 1932, reported no palatability problems when using ground durum wheat at a level of 66% of the concentrate mix. Similarly, Bateman in 1933 concluded that wheat is a safe and palatable feed for dairy cows when properly fed. The experiment by Bateman at the Utah Exp. Station (1942) consisted of feeding four cows chopped wheat according to production as the only grain in combination with alfalfa hay for a complete lactation period. One cow was considered a high producer at that time; her production record consisted of 14,031 pounds of milk containing 430 pounds of butterfat. Total wheat consumption was 2,892 pounds during her lactation period with an average of 14 pounds of chopped wheat per day during the month of highest butterfat production. Summarizing earlier work, Morrison (1956) reported ground wheat should probably not exceed one-third to one-half of the concentrate mix for dairy rations to obtain best results. However, he did point out ground wheat has successfully been fed as the only grain in the concentrate portion, with plenty of legume hay for roughage.

The experiments cited above were conducted using cows producing considerably less milk and fed much less concentrates than is common in the industry today. Wheat intake was minimal, not exceeding 4 to 7 pounds of wheat per day in many cases. It was only in a few cases (Monroe and Hayden, 1933 and 1934; Bateman, 1942; Hewitt and Turner, 1944), that intake of wheat reached 8 to 14 pounds per day, which is still low in comparison to amounts of grain commonly fed to dairy cows today, which could be as high as 15-22 pounds of wheat daily. Also, much of the older literature did not report what type of wheat or what roughage source was utilized during the experiments. This may have an important impact on the results observed.

High prices and low surpluses of wheat from 1940 through 1960 temporarily stopped extensive research on wheat feeding to dairy cows. It was not until growing surpluses of wheat caused decreased wheat prices that were competitive with other grains that interest in wheat research was renewed. Most information on the nutritive value of wheat for dairy cattle came from studies in 1969 at Washington State University, Pullman and in 1970 at Purdue University. McPherson and Waldern (1969) compared pelleted grain rations containing six different levels (93, 83, 73, 63, 53 and 20%) of steam-rolled soft white wheat in acceptability and lactation trials. Alfalfa hay was used as the sole source of roughage in double-reversal trials. As the amount of wheat was increased above 20% of the concentrate mixture, it replaced barley, oats and cottonseed meal. In the acceptability trial, hay was restricted to 1% of body weight and concentrates were offered for ad libitum consumption. Cows in the acceptability trial had an average daily concentrate dry matter intake of 25.8 pounds over all treatments, with a sustained consumption of 25.4 pounds of wheat per day by cows fed the concentrate with the highest percentage of wheat. Palatability was slightly lower for the 93 and 83% wheat level; however, cows became accustomed to the higher wheat rations within a short time. Overall, no problems with "off-feed" or digestive disturbances were noted. Total milk production ranged from 55.3 to 62.4 pounds per cow per day and was similar for all levels of wheat. Crude fiber intake levels ranged from 10 to 13% of the total dry matter which was not high enough to maintain normal milk fat content; however, milk fat content was similar for all treatments, with an overall average of 2.6%. Average 4% fat-corrected-milk (FCM), non-fat solids (NFS), milk protein production and body weight gain per day were similar for all levels of wheat. Body weight gains were very high ranging from 1.8 to 2.9 pounds per day and were attributed to the high concentrate (65%) to low roughage (35%) diet. This diet resulted in higher propionic acid levels relative to acetic acid in the rumen fluid, which might divert nutrients for fat synthesis from the mammary gland, resulting in high weight gains and low milk fat content that was observed. In the lactation trial, concentrate intake averaged 45.3% of the total dry matter intake, ranging from 15.4 to 17.4 pounds per cow per day for the entire trial. Many of the cows consumed over 24 pounds of concentrate, including 22 pounds of wheat per day in early lactation without indications of cows going "off-feed" or having any digestive disturbances. Average daily milk production over all levels was 51.4 pounds with no significant differences among treatments. Milk protein content and NFS were similar for all treatments. Also, 4% FCM was similar for all treatments; however, milk fat content was higher for the 73% wheat mix (3.9%) than for the 63 or 20% wheat mix. Ration fiber or intake was not related to fat test. The increase in milk fat content may have been simply a reflection of the decrease in milk production which was observed for the 73% wheat mix.

The results of the experiments by McPherson and Waldern (1969) discussed above are not consistent with those obtained by Cunningham et al. (1970). The latter group fed lactating cows concentrate mixtures containing either 33.3 or 66.7% of two varieties of ground soft red winter wheat as a partial replacement for corn and soybean meal. The two varieties of wheat had a 18 and 14% protein content. A combination of alfalfa hay and corn silage (approximately 1 to 2.8 on a dry basis) comprised the forage component of the ration. For cows fed either the low or high protein variety of wheat, milk yield was significantly lower ($P<.05$) when wheat comprised 66.7% of the concentrate than when half as much wheat was used (59.4 vs 62.0 and 56.5 vs 60.1 pounds per day). Also, milk fat content and therefore 4% FCM was significantly lower ($P<.05$) when wheat comprised 66.7 compared to 33.3% of the concentrate mix. However, differences in production responses observed by Cunningham et al. (1970) compared to McPherson and Waldern (1969) may be attributed to the ingredients that were being replaced by wheat. Cunningham et al. (1970) used wheat as partial replacement for corn and soybean meal whereas McPherson and Waldern (1969) used wheat as a replacement mainly for barley and cottonseed meal.

It seems reasonable to conclude that wheat can be incorporated in a nutrition scheme for dairy cows; however, some management factors are important in successful use of large amounts of wheat in dairy rations. This reasoning stems from some evidence of palatability problems, reduced milk production and reduced milk fat content with high producing cows on high levels of wheat intake. More than likely, a wheat feeding program for a dairyman will be an economical situation, since it is likely that cost effective measures for overcoming the previously mentioned problems can be developed.

## Comparative Nutritive Value of Wheat with Other Cereal Grains

Wheat is available occasionally for livestock feeding at a price that is competitive with other feed grains. Yet, many dairymen are hesitant in feeding wheat to their dairy cows because of the lack of knowledge of the relative nutritive value of wheat compared to other cereal grains. Research reports regarding the comparison of the feeding value of wheat to that of other cereal grains are more abundant than experiments on the maximum safety level of wheat in the concentrate portion. However, it is important to point out that most of the early experiments on the subject were conducted using cows producing considerably less milk and fed much less concentrates than is prevalent in the industry today.

Waldern (1970), in a review article on wheat feeding to dairy cows, reported that as early as 1896, a trial was conducted by Bartlett from Maine Agricultural Station on comparing wheat meal to corn meal. Cows fed wheat meal were reported to have produced as much milk as those fed corn meal while gaining more weight. Several experiments were conducted in the 1930's in regard to comparing nutritive values of wheat with other energy sources for dairy rations. Jacobs (1931) compared a mixed ration containing 53% wheat with a ration containing 60% milo. He reported that at least two-thirds of the concentrate mix may be comprised of wheat and not cause a decline in milk production or concentrate intake and that wheat was equal to milo for dairy cows. Similarly, Copeland (1933) concluded from three double reversal experiments at the Texas Experimental Station, that coarsely ground soft winter wheat can replace ground milo in the dairy ration pound for pound when not more than 50% of the grain mixture is composed of wheat. In this experiment, sorghum silage and alfalfa hay were utilized as the roughage source and grain was fed at one pound for every two and a half pounds of milk produced. He also observed no difference between feeds in feed intake and body weight change of cows. Off-feed conditions were not noted for cows on the wheat ration.

Other earlier experiments compared wheat with barley and/or oats in feeding trials. Bowstead (1930) observed that wheat was practically equivalent in feeding value to oats or barley based on similarity of milk and butterfat production. However, wheat had a higher value for total digestible nutrients (TDN) than oats or barley (84%, 71.5% and 78.7% TDN, respectively). Another trial, by Bowstead in 1942, compared oats to a 30% and 60% hard red spring wheat mix. He reported milk production and body weight gains to be similar for the three treatments. Dice (1932) showed that wheat as a feed for dairy cows is equivalent to barley. He observed similar production responses between treatments and no palatability problems when using ground durum wheat at a 66% level of the concentrate mix.

Hayden and Monroe (1931) compared diets where wheat replaced 75% of the corn. In the wheat mixture, wheat comprised 33% of the concentrate or grain mixture. Alfalfa hay and corn silage were fed at the rate of one and three pounds, respectively, for each 100 pounds of liveweight. Cows fed the two diets had very similar production responses for milk, milk fat content and therefore, 4%-fat-corrected-milk (FCM). Consumption of wheat per day approximately averaged 4.3 pounds. Economics of feeding wheat compared to corn favored the wheat ration. Fitch and Cave (1932) reported similar results when comparing wheat with corn. They reported that wheat could replace corn pound for pound up to 57% of the concentrate mix. However, they noted a slight tendency for cows to go "off-feed" when the wheat ration was fed. Morrison (1956) summarized earlier results on comparing the feeding value of wheat to corn. He stated that wheat protein is of low quality, like most cereal grain protein but it was thought to be superior to that of corn. Energy digestibility is about the same for both grains. Wheat contains more phosphorus than corn and has the same vitamin deficiencies as do other grains but is higher in regards to niacin and choline content than corn. Morrison also states that "ground wheat is equal to ground corn for dairy cattle and is a satisfactory feed, even for long periods if fed in a suitable concentrate mixture and in a properly balanced ration".

A more recent and thorough investigation of the feeding value of wheat was conducted by Tommervik and Waldern (1969). They compared the nutritive value of Gaines soft white wheat to that of corn, barley, milo, oats and a mixed concentrate ration for dairy cows in lactation and acceptability trials. Each of the grains was steam or dry rolled, mixed with other ingredients, and pelleted. The single grain rations contained 95.7% of one of the grains mentioned above plus 3.0% sodium tripolyphosphate, 1% trace mineralized salt plus vitamins A and D. The control ration contained 38% barley, 20% wheat mixed feed, 25% peas, 3.2% cottonseed meal, 9.5% molasses plus the above mentioned premix. The concentrate to alfalfa hay ratio was 47:53 in the lactation trial and 67:33 in the acceptability trial for all treatments. In the acceptability trial, cows on milo and oats consumed the greatest amounts with the least tendency for cows to go "off-feed". Cows on the corn diets consumed the least amount of grain in both trials and those cows on the wheat diet had an average intake of 17.4 pounds of grain per day. Lactating cows fed the concentrate containing wheat performed as well as those fed rations containing other grains, with negligible differences among the concentrates as to palatability or effect on milk production, ranging from 51 to 52.6 pounds per cow per day.

Cunningham et al. (1970) compared the value of two varieties of ground soft red winter wheat as a partial replacement for corn and soybean meal at a level of 33.3 or 66.7% of the concentrate mix. The concentrate mixtures comprised about 48% of the total dry matter intake with the forage component consisting of approximately a 2.8:1 ratio of corn silage and alfalfa hay on a dry basis. Milk production was lower for cows fed either the low or high protein variety of wheat comprising 66.7% of the concentrate than when wheat comprised 33.3% of the concentrate mix. Also, they suggested that as high as 67% of wheat may lower milk fat content and 4% FCM production when fed as unpelleted ground mixtures. It is important to note that results from the previous two trials have more meaning to dairy operations because reasonably high producing cows were used.

More recent experiments have been conducted by Cribeiro et al. (1979) and Moran (1983) with respect to comparing wheat to other cereal grains. In the experiment by Cribeiro et al. (1979), cows were given concentrate mixes in which wheat replaced none, 19, 38, 57 or 77% of the corn. Cows were offered ad libitum amounts of concentrate and Napier grass hay. The ratio of concentrate to roughage averaged 68:32 over all treatments. The cows had a significantly lower dry matter and metabolizable energy intake on the 57 and 77% level of wheat mix. No significant differences were noted among levels of wheat for 4% FCM, milk fat content, milk protein content, total solids and non-fat solids in milk with an average yield per day of 27.3 pounds and 2.5, 3.2, 19.8 and 8.3% for the respective components. Moran (1983) compared wheat to barley and oats with respect to production responses. Cows were fed ad-libitum one of three grain-based diets (wheat, barley or oats). The diets consisted of 60% rolled cereal grain, 17% oaten silage, and 17% lucerne hay, together with protein and mineral supplements. Average daily milk production was significantly lower for the barley diet compared to wheat and oats (50.4, 52.8 and 55.2 lb, respectively). Milk fat yield was significantly higher for the oat diet compared to the wheat and barley diets with an average yield per day of 2.57, 2.22 and 2.27 lb, respectively. This difference in fat yield reflects the crude fiber content of the diets, being highest for the oat-based diet, i.e., 26.1%, and lowest for the wheat-based diet, 15.9%, with barley being intermediate, 18.7%. Yield of milk protein reflected total dietary crude protein contents 17.0, 16.9 and 18.0 percent for oat, barley and wheat-based diets, respectively.

It seems reasonable to suggest from evidence in the literature that wheat compares favorably under certain circumstances with the other feed grains for dairy cattle. However, it is important to point out that response differences in feeding wheat to dairy cows may be attributed to the difference in milk production level by the animals, type of forage utilized, variety or type of wheat, or method of grain processing.

## Metabolic Problems, Digestive Disturbances and Rumen Parameters

A high producing cow requires large amounts of grain to provide the energy required to maintain milk yields. Heavy producers may be fed up to 35 and 40 pounds of a concentrate mix per day, which would indicate a consumption from 21 to 32 pounds of wheat daily. Some of the main concerns about feeding high levels of a readily fermentable carbohydrate, like wheat, to cows are the possibilities of an "off-feed" condition, an acute phase of lactic acidosis, displaced abomasums and a decreased milk fat test.

There is little information concerning these metabolic problems or digestive disturbances when feeding high levels of wheat to lactating dairy cows. However, around 1930 some researchers reported a tendency for some cows to go "off-feed" when wheat comprised 57% of the concentrate mix (Fitch and Cave, 1932). A more recent observation summarized by Bailey (1965) reports in herds that were fed very high amounts of wheat during a shortage of roughage due to drouth and fires in New South Wales, Australia, that cases of "off-feed", large reduction in milk yield, and laminitis or founder were observed. These problems were not apparent in recent work by researchers most likely because an adequate amount of dry roughage was fed and an adequate adjustment period was used during their experiments (Cunningham et al., 1970; McPherson and Waldern, 1969; Moran, 1984; Tommervik and Waldern, 1969).

The major concern when feeding high grain diets to ruminants is lactic acidosis or acidosis. An increase in acidity, osmolarity, and lactic acid concentration in the rumen and the increase in D-lactic acid in the blood characterizes the acute phase of lactic acidosis (Ahrens, 1967). It is caused by ingestion of relatively large amounts of starch or sugar which tends to produce conditions conducive to rapid growth of the lactic acid-producing bacteria, **Streptococcus bovis** followed by **Lactobacillus sp.** (Allison et al., 1964; Slyter et al., 1970; Russell and Hino, 1985). Once ruminants succumb to acidosis, the condition can be difficult to reverse.

Lactic acid is a mixture of two isomers, D-lactic acid and L-lactic acid. The proportion of the two isomers vary considerably with L(+) lactic acid predominant over D(-) lactic acid in normal ruminants, following which D(-) lactic acid increases to equal or exceed the concentration of L(+) lactic acid with ruminants on high levels of a highly fermentable carbohydrate diet (Dunlop et al., 1964; Dunlop and Hammond, 1965). However, the significance with D(-) lactic acid stems from it being more slowly metabolized by animal tissue, and the liver in ruminants has a limited capacity to utilize it (Dunlop, 1970; Hinkson et al., 1967; Huber, 1969). Therefore, an engorged animal that has a chronic case of acidosis will have a high blood lactic acid concentration (Williams and Mackenzie, 1965). This increased rumen and blood acidity causes symptoms such as dehydration, decreased blood flow, which leads to circulatory difficulties, reductions in the rates of salivary secretion and urine formation, disturbed performance of the central nervous system, increased pulse rate, and decreased rumen motility which may be followed by coma and death (Dunlop, 1970). Other complications that can arise due to acidosis are liver abscesses and laminitis (Dunlop, 1970; Oltjen et al., 1970). The more serious economic problem of liver abscesses is attributed to migration of microorganisms to the liver via the portal circulation.

Slyter et al. (1970) compared diets fed to steers comprised of 90% corn or 90% wheat and observed that wheat-fed steers appeared to have more Streptococcus bovis. Also, Lactobacilli and other aciduric bacteria were present in large numbers in steers fed concentrate, regardless of level of intake or ruminal pH. Similarly, Oltjen et al. (1966) compared rumen parameters of steers fed 90% cracked corn, 90%

cracked, soft red winter wheat, and 60:30 mixes of both grains and reported that steers fed the 90 and 60% wheat diets had lower rumen pH, higher volatile fatty acid (VFA) concentrations, higher concentrations of ruminal lactic acid (although variation among animals was great) and greater rumen ammonia concentrations. They felt that higher crude protein content of wheat rations lowered the ruminal pH or the fact that wheat protein is more rapidly degraded in the rumen may have contributed to the increase in ammonia levels observed.

Lee et al. (1982) studied the changes in rumen fluid composition and in the rumen epithelium when whole wheat was introduced to the diet of sheep. They noted a need to minimize the accumulation of acids in the rumen and the decline in rumen pH when wheat is first added to the diet of sheep. Low rumen pH was associated with depressed feed intake and damaged rumen epithelium. They observed high lactate levels (total, D(-) and L(+)) in sheep fed wheat diets with D(-) lactic acid being predominant. They also noted a relationship between high rumen lactate levels and low ruminal pH values with low dry matter intake levels by sheep. Rumen acidity was thought to be affected by such parameters as preceding intakes, relatively slow absorption of lactate and reduced numbers of the acid-sensitive lactate utilizing bacteria. Another observation was an association between high rumen ammonia concentration and low rumen pH, which was attributed to higher dietary nitrogen intakes by sheep which were likely to have lower rumen pH values than with sheep fed no wheat. They also suggested other factors that may contribute to high ammonia values correlated to low rumen pH such as reduced absorption of ammonia from the rumen, reduced protein synthesis, and deamination (ammonia formation) of bacteria and protozoa destroyed by low pH. They reported that hay consumption had a stablizing effect on the rumen, apparently allowing the microbial population to multiply and the acid-sensitive lactate utilizers to persist. Overall, the general effects of wheat intake were to increase VFA concentrations and rumen acidity, decrease the proportion of acetate and increase the proportions of propionate and butyrate.

Fulton et al. (1979) made similar observations on feed intake and rumen microbial fermentation patterns of steers being adapted to high concentrate corn and wheat diets. The concentrate levels were 35, 55, 75 and 90% of two grain base diets with corn cobs used as the nonconcentrate portion. Steers fed the wheat-based diet consumed less total feed and had lower ruminal pH values than steers fed the corn-based diet. Steers fed the wheat diet markedly shifted their intake patterns from greater consumption in the 0 to 12-hour interval to the 12 to 24-hour interval as percentage concentrate increased. Ruminal lactate means were higher for the wheat diet compared to the corn diet (195 and 122 ug/ml, respectively). However, highest lactate values for both diets occurred on the 35% concentrate level with decreasing amounts of lactate observed as the concentrate increased. They reported small amounts of lactate present at the 90% concentrate level which indicated that microbial adaptation to high grain diets had occurred. They did observe significant diet by concentrate percentage interactions with regard to VFA concentrations. This interaction was due to acetic acid having different rates of decline in concentration between the two diets from 55 to 90% concentrate. Also, they observed at the 55% concentrate level with the wheat diet a sharp drop in propionate levels coinciding with high levels of lactate present. They suggested that the low rumen pH (5.58) and high lactate concentrations (224 ug/ml) may represent an acidic fermentation condition not conducive to the normal metabolism of lactate to propionate, which is in agreement with Lee et al. (1982) and Jayasuriya and Hungate (1959). The normal metabolism of lactate to propionate has been thoroughly investigated by Baldwin et al. (1962) by determining the contribution of the randomizing (succinate) and nonrandomizing (acrylate) routes to propionate with labelled lactate at carbon 2 or 3 as substrates. They concluded that the "acrylate" pathway contributes 70 to 90% of the total propionate formed from lactate involving acrylyl coenzyme A. However, they did recognize that the experimental conditions were not strictly parallel to the conditions existing in vivo; less $CO_2$ tension and a higher pH (7.0 experimental vs. 6.2 to 6.8 for rumen fluid).

As mentioned earlier, increasing amounts of grain are being fed to dairy cows to provide the energy required to sustain very high milk yields. However, a detriment to the production response of cows on high energy diets that may be observed is decreased milk fat test. Many researchers have reviewed and reported specific guidelines that are needed to avoid detrimental production responses by dairy cows (Jorgensen et al., 1965; Kesler and Spahr, 1964; Stallcup, 1968; Van Soest, 1963; Warner, 1965). Kesler and Spahr (1964) suggested that crude fiber levels below 13 to 14% (dry basis) may be detrimental to the lactating animal. However, a level of 17.3% crude fiber and 19.4% acid-detergent fiber in the diet (dry matter) maintained milk fat content at normal levels (Lofgren and Warner, 1970). Stallcup (1968) reported complete rations containing 16% crude fiber appear adequate to avoid severe milk fat depression. In general, high levels of dietary concentrates tend to decrease milk fat percentage, increase milk protein, depress digestion of dietary fiber, and alter the proportions of rumen volatile fatty acids (mainly narrowing the ratio of acetic to propionate) (Kesler and Spahr, 1964; Jorgensen et al., 1965). Also, maximum nutrient intake is reached when concentrates make up 50 to 60% of the total dry matter consumed (Kesler and Sspahr, 1964). It was suggested that feeding above 60% concentrates to dairy cows may force the animal into a fattening type of metabolism which may be antagonistic to a metabolism geared to produce milk efficiently (Kesler and Spahr, 1964). Also, it was suggested that at high levels of concentrate feeding to dairy cows the nature of the concentrate and its starch content determines whether diet will affect milk fat percentages (Jorgensen et al., 1965). Cunningham et al. (1970) reported a significant decrease in fat test when cows were fed wheat at 66.7% as compared to 33.3% of the concentrate mix. They stated that forage dry matter intakes and percent crude fiber levels were adequate for maintenance of normal milk fat content. It may be important to note that the carbohydrate portion of wheat appears to be more rapidly fermented in the rumen compared to other cereal grains, which results in lower ruminal pH, greater VFA concentrations, and altered molar proportions of VFA concentrations in favor of propionate (Oltjen, 1970). The increased propionate production may be attributed to the numbers of the acid-sensitive lactate-utilizing bacteria which use the acrylate-nonrandomizing route and, therefore, may have a secondary effect of lowering milk fat test that was observed by the experiment conducted by Cunningham et al. (1970).

The major problems referred to in this section are not likely to occur in dairy cows fed high wheat diets because the high proportions of concentrates fed in the above experiments are rarely used in dairy rations. If they were, cows would go "off-feed" and experience decreased milk production prior to having a severe case of lactic acidosis. However, good feeding and management practices are required when high levels of any cereal grain are fed to lactating cows.

## Wheat Starch - A Readily Fermentable Carbohydrate

The diet of the ruminant is attacked and degraded extensively by anaerobic microbes in the reticulo-rumen. The microbial cells and their by-products of volatile fatty acids (VFA) are utilized to meet the major portion of protein and energy demands of the ruminant. Pressure to meet the energy needs for high producing dairy cows has been met by increasing the amount of concentrates or grain in the rations. The concentrates contain much starch, which is digested by microbial fermentation in the rumen, with its consequent production of cells and VFA, or escapes to enzymatic digestion in the small intestine producing glucose. The relative digestion of starch by these two pathways should influence 1) the efficiency of transforming feed energy into animal product, 2) the substrates used by ruminants for forming glucose, 3) the magnitude of non-protein nitrogen fixation into microbial cell protein, and 4) the distribution of energy in the product of ruminants, i.e., milk fat depression (Waldo, 1973). It has been suggested that the escape of starch from ruminal fermentation may play an important role in meeting the glucose requirements of high producing animals (Armstrong and Smithard, 1979). Greater glucose absorption from the small intestine should allow propionic acid and glucogenic amino acids produced in the rumen to be utilized for functions other than gluconeogenesis (Sutton, 1971).

The relative production of VFA and glucose from starch digestion should have important effects on the metabolism of the ruminant. However, there is limited data available on digestion of starch or absorption of glucose and VFA with respect to feeding wheat compared to other cereal grains for dairy cows. Thivend and Vermorel (1971) reported starch distribution in slaughter animals showed that barley starch is most readily attacked followed by wheat, corn and sorghum. Waldo (1973) reported that barley, flaked corn, steam flaked sorghum and probably wheat and oat starches are about 94% fermented in the rumen. However, he stated that ground corn is 74% fermented in the rumen and that this value is less on 40 and 60% corn rations compared to 20 and 80% rations. Thus, corn starch may have more bypass starch compared to other grains and, therefore, it would be hydrolyzed to glucose and the efficiency of energy use should be greater, provided small intestine starch digestion is complete.

Lee et al. (1982) indicated that the general effects of wheat intake were to increase VFA concentrations, decrease the proportion of acetate, and increase the proportions of propionate and butyrate. These changes may have a detrimental effect on milk fat content, which was observed by Cunningham et al. (1970), with dairy cows fed a 66.7% wheat mix compared to those on a 33.3 % wheat mixture. However, Waldo (1973) suggests that increasing levels of starch digestion in the small intestine may have a similar effect as to increased propionate levels on milk fat synthesis. He suggested that milk fat depression could be understood better if studies would consider both ruminal VFA production and starch digestion in the small intestine.

## Amino Acid Supply for Milk Synthesis

In order to maximize production in ruminants, a well balanced diet is essential. Indispensible amino acid requirements have been studied extensively in non-ruminants; however, they are less understood in ruminants. Ruminants pose a special problem in regard to assessing their amino acid requirements in that amino acids absorbed from the small intestine are variably supplied by microbial protein (synthesized in the rumen), undegraded or escaped food proteins, escaped amino acids, and endogenous secretions. Also, the dietary amino acid composition does not completely reflect the quantity and quality of amino acids flowing post ruminally in chyme. Therefore, requirements for essential amino acids are difficult to assess on a quantitative basis because of 1) the intervention of ruminal fermentation between the diet and the duodenum and 2) variation in requirements due to amino acid utilization in various functions (Owens and Bergen, 1982).

A major concern with respect to feeding dairy cows is that of providing an adequate supply and balance of amino acids for milk synthesis. On the basis of studies with lactating dairy cows, it has been suggested that microbial crude protein may be insufficient to meet the high demands for production of animal protein (Huber and Kung, 1981; Satter et al., 1977). Since amino acid requirements for lactation are high, the efficiency with which dietary protein and non-protein nitrogen are used to supply amino acids at the site of absorption is an important consideration. Moreover, there is evidence that the overall efficiency of this process can be improved if a substantial portion of high quality dietary protein escapes the rumen without degradation (Pena and Satter, 1984; Tyrell et al., 1984).

It is possible to predict extent of degradation from known rates of ruminal passage of feed proteins if the rate of ruminal protein degradation can be assessed accurately using in situ and in vitro procedures (Broderick, 1982). However, it is important that these methods be sensitive to the real variation in ruminal degradability within and among feedstuffs (Waldo and Goering, 1979). Many in situ and in vitro techniques have attempted to predict ruminal degradation or proteolysis for various feedstuffs. In situ methods include the use of dacron bags and controlled porosity bags (Broderick, 1982). In vitro procedures consist of solubility measurements in various buffers and other solvents, loss of protein or accumulation of ammonia or amino acids in vitro, and loss of protein upon inoculation with various proteolytic enzymes (Owens and Bergen, 1982). The accuracy of applying the results of these techniques to in vivo proteolysis is questionable. Zinn and Owens (1983b) have developed an alternative to these measurements, whereby protein solubility plus in situ measurements are combined and then correlated with bypass values and adjusted with a reference protein source.

Protein solubility has received the most attention in its use of estimation of rumen degradability (Owens and Bergen, 1982), stemming from the concept that readily solubilized compounds are digested to a greater extent in the rumen than their more insoluble counterparts.

Because ruminal microbes adapt to digest soluble organic compounds (Owens and Bergen, 1982) the correlation between in vitro and in vivo solubilities should be critically evaluated. Stern and Satter (1982) reported that the amino acid composition of the more soluble fraction usually differs from that of the more insoluble fraction; therefore, bypass for some amino acids may be greater than for others. Owens and Bergen (1982) advised that solubility alone is a poor indicator for extent of ruminal degradation across a variety of diets and feeding conditions. This problem is confounded when matching the estimated indispensible amino acid requirements of the animal with the quantity of the indispensible amino acid constituents of the feed. Estimates of ruminal degradation of insoluble protein, with various ruminal buffers, range from 35 to 50% (Tamminga, 1979).

There are many factors that can markedly alter bypass potential such as rate of passage (amount of time for ruminal digestion), type of basal diet, and chemical and physical modifications of protein source. High bypass protein sources such as fish meal, meat meal, and distillers products have slower rates of proteolysis after four hours of rumen incubation (Owens and Bergen, 1982). In contrast, protein sources such as soybean meal, sunflower meal, and alfalfa meal are degraded more continuously (Owens and Bergen, 1982). Also, bypass potential is enhanced with increased feed intake in steers (Zinn and Owens, 1983a) and dairy cattle (Tamminga et al., 1979). Ward et al. (1986) observed that ruminal escape of soybean meal protein supplemented to dairy cows increased as the concentrate percentage increased. Dietary soybean meal protein escaping ruminal degradation was 45.9 and 18.0% for the 65 amd 35% concentrate diets, respectively. This was based on the differences in nitrogen flow leaving the abomasum between diets supplemented versus not supplemented with soybean meal. They suggested that escape values for protein sources to be used in formulating diets should be adjusted for concentrate level and feed intake level. Similarly, when cattle consumed forage versus concentrate diets, a longer rate and extent of ruminal degradation was observed in vivo (Zinn and Owens, 1983b) and in vitro (Ganev et al., 1979). The more common ways that have been attempted to modify the availability of amino acids in the small intestine include: formaldehyde treatment, encapsulated (coated) free amino acids, and supplementation with high bypass protein feeds. However, there may be certain drawbacks to their uses. For instance, formaldehyde treatment may render the protein partially undegradable in the small intestine. High bypass protein supplements are usually unpalatable; therefore, intake may limit their use. Rumen protected amino acids may escape absorption in the small intestine. Also, it is important to point out that various bypass proteins, such as distillers by-products, chemically-treated proteins, and heat-treated compounds may have an inferior amino acid balance or contain unrepresentative high quantities of indigestible nitrogen (Owens and Bergen, 1982). However, it may soon be possible to optimize amino acid supply by incorporating the knowledge gained from ruminal protein digestion studies into systems to predict and optimize site and extent of protein digestion.

In spite of these complications, indispensible and first-limiting amino acids have been proposed by various researchers for ruminants. However, in this section, only limiting amino acids for milk protein synthesis or milk production for dairy cows will be summarized. Methionine and valine have been calculated by Chandler (1970) to be first-limiting amino acids for milk production; isoleucine, tryptophan, and lysine would be limiting at high levels of production. Abomasal infusion of methionine-supplemented casein to cows fed a 16% protein ration significantly increased milk protein content and protein production (Broderick et al., 1970). They also noted significant effects in plasma concentrations of isoleucine, leucine, phenylalanine, valine and total indispensible amino acids being elevated, while plasma glycine and total dispensible amino acids were depressed. The cows used in their trial averaged 68.2 pounds of milk per day while on a basal diet consisting of concentrate and a urea-supplemented corn silage. Similarly, Broderick et al. (1974) reported that indispensible amino acid concentrations in jugular and mammary vein plasma for cows at all intakes of formaldehyde-treated casein indicated that methionine, valine, and lysine were the most likely limiting amino acids for milk production. Cows were fed a corn silage and corn-based basal ration. Chandler and Polan (1972) compared serum amino acids on milk protein output rather than on changes in serum concentration. Based on an assumed mammary blood flow rate of 450 liters per liter of milk produced, minimum transfer efficiencies were calculated for the essential amino acids. They concluded that methionine, lysine, phenylalanine, tyrosine and threonine were the most critical amino acids for high-producing cows (81.4 pounds per day); the minimum transfer efficiencies for the five amino acids were 96, 89, 76, 80 and 62%, respectively. Methionine was always the most critical amino acid but the order of the other four shifted at lower production. For instance, lysine seemed to be more critical at higher than at lower production. Schwab et al. (1976) suggested that lysine and methionine were first and second limiting or co-limiting, for secretion of milk protein when cows were fed primarily corn, corn silage, and alfalfa-grass hay. They stated that the primary effect was on content of milk protein rather than milk yield.

Several workers have reported significant production responses by dietary supplementation with methionine hydroxy analog (MHA) (Bishop, 1971; Griel et al., 1968; Kim et al., 1971; Polan et al., 1970a). According to Bishop (1971), dairy cows showed a positive effect on milk, milk fat content, and 4% fat-corrected-milk when supplemented with MHA. The trial by Kim et al. (1971) resulted in cows supplemented with MHA producing more milk fat than the control cows. Furthermore, significant stimulatory effect on milk production was noted with cows supplemented with MHA (Griel et al., 1968). Similarly, a response curve for milk production revealed a maximum response for animals consuming 25g of MHA per day (Polan et al., 1970a). They also noted from the regression equation a marked decrease in milk production when MHA is consumed in excess of 45g per day. In their trial, a urea-supplemented corn silage and concentrate ration was used. In the trials previously mentioned, MHA presumably works by escaping significant degradation in the rumen, is converted to methionine in the liver (Belasco, 1972) and, therefore, increases the availability of methionine, which may be the limiting amino acid, to the mammary cell. However, in other studies, no stimulation of milk protein production was observed with MHA (Burgos and Olson, 1970; Holter et al., 1970; Hutjens and Schultz, 1970; Kenna and Schwab, 1981). Broderick et al. (1970) reported no effect on milk production or composition when they fed encapsulated methionine at 5, 15 or 45g per day to lactating dairy cows. Milk production, stage of lactation during which the MHA was fed, and feeding systems may explain the conflicting results.

Ingredient composition of the ration will influence which amino acids are most limiting for milk production and/or milk protein synthesis. This is primarily due to differences in protein amino acid composition and extent of ruminal degradation. Therefore, the difference in production responses of dairy cows being fed high levels of wheat with different roughage sources may be attributed to the difference in the ruminal degradation of wheat protein. The protein of wheat and wheat by-products has been observed to be more soluble than that of other cereal grains, except for rye (Wohlt et al., 1973; MacGregor et al., 1978). Also, ruminal degradation of wheat protein has been estimated to be higher than that of other cereal grains (Mertens, 1977).

Experiments by Lebzien et al. (1984) compared nitrogen metabolism in the digestive tract of dairy cows given wheat or corn grain with hay as the roughage source. The ratio of grain to hay was 33:67. They reported that the proportion of rumen undegraded total feed protein was 25% with corn and 9% with wheat. This difference explained why, in spite of a lower microbial synthesis with the corn diet, similar amounts of total nitrogen and nonammonia nitrogen were found in duodenal contents on both treatments. Amino acid nitrogen as a percentage of nonammonia nitrogen in duodenal contents was higher with the corn (71.5%) diet than with the wheat (63.8%) diet. With respect to individual amino acids, lysine was lower and leucine and proline were higher with the corn treatment. There was no difference with regard to amino acid nitrogen disappearance from the intestine. However, the fraction of rumen undegraded protein for a corn-based diet with a roughage source was reported (Zinn and Owens, 1983b; Aquirre et al., 1984) to be higher than the value observed by Lebzien et al. (1984). Zinn and Owens (1983b) observed values of 0.58 and 0.73 for the fraction of rumen undegraded protein for steers fed a 74% dry rolled grain and 20% chopped prairie hay ration. Aguirre et al. (1984) reported a value of 0.64 for the fraction of undegraded protein of a basic diet for steers (530 kg) consisting of 80% corn grain (15-35% moisture), 14% cottonseed hulls, and 6% pelleted supplement. Also, Madsen and Huelplund (1985) reported a nylon bag degradability of protein for corn and wheat of 31 and 82%, respectively when using an outflow rate of 0.08 per hour. Similarly, values for protein degradability of 55 and 72% for corn and wheat, respectively have been observed when using the synthetic fiber bag technique (Commonwealth Agricultural Bureaux, 1984).

Therefore, when feeding wheat to dairy cows, a major factor in maintaining maximum milk synthesis would be to maximize the efficiency with which dietary protein and non-protein nitrogen are used to supply amino acids at the site of absorption. This may be optimized by including some ingredients characterized as being low in terms of ruminal degradability of protein, such as corn gluten meal, in concentrate mixtures containing a high percentage of wheat or wheat byproducts. Also, optimizing the efficiency of supplying amino acids at the site of absorption may be obtained by supplementation of the limiting amino acid or acids for milk synthesis when dairy cows are fed high levels of wheat in the concentrate mix. However, more work is definitely needed to elucidate the factors relating amino acid supplementation of the diet and milk production, and also to determine the limiting amino acids for milk synthesis for dairy cows fed typical roughage to concentrate diets.

## CHAPTER III

## EFFECT OF DIFFERENT LEVELS OF WHEAT IN CONCENTRATION MIXTURE ON RESPONSES OF LACTATING DAIRY COWS FED SORGHUM SILAGE AS THE ONLY FORAGE

### Summary

A feeding trial was conducted to compare the performance of 21 lactating cows fed concentrate mixtures containing different amounts of wheat included in a complete ration with sorghum silage as the only forage. The concentrate mixtures contained 0, 40 and 60% ground hard red winter wheat with the latter level representing the highest percent that can be used and still maintain protein, fiber and energy content of the total ration at an acceptable level. All concentrates were formulated to be isocaloric and isonitrogenous. Cows were assigned near the peak of lactation to treatment sequences of a switchback design with three 4-week periods. Total dry matter consumption was similar for all treatment groups. No incidence of off-feed or other indication of digestive disorders was noted with wheat intake averaging 6.2 and 9.2 kg per day for cows fed the 40 and 60% wheat mixtures. There was a linear decrease in milk yield (28.8, 28.0 and 27.3 kg/day) with a slight increase in fat test (3.68, 3.7 and 3.81%) as percentage of wheat in the concentrate increased. The increase in milk fat content did not offset the decrease in milk yield rendering 4% fat-corrected milk to decrease

(27.4, 26.7 and 26.4 kg/day) as level of wheat in the concentrate increased. Milk protein percentage did not differ among treatments. Also, the amount of wheat in the ration had no effect on body weight and condition score changes, rumen pH, rumen ammonia, rumen volatile fatty acids, and blood plasma urea. High levels of wheat can be utilized in a complete mixed ration wherein sorghum silage is the only forage; however, economic feasibility varies and should be considered.

## Introduction

In areas of the country where substantial quantities of wheat are produced, this grain is occasionally competitively priced with that of other feed grains used as an energy source in dairy rations. When this is the situation, wheat can be used to advantage in formulating high energy rations for lactating dairy cows. However, the limits to which wheat can be used in concentrate mixtures and the extent to which other grains can be replaced by wheat in dairy rations has not been well defined, especially under conditions where silage comprises all or a large part of the forage. Also, much of the research on feeding wheat was conducted using cows producing considerably less milk and fed much less concentrates than is common in the industry today.

McPherson and Waldern (1969) found that cows fed alfalfa hay plus concentrate mixtures containing from 20 to 93% Gaines soft white wheat had no problems with "off-feed" and no significant differences in milk production attributable to amount of wheat in the ration. However, their results may not be applicable to herds with higher milk production or where cows are fed ground hard red winter wheat rather than steam-rolled soft white wheat. Cunningham et al. (1970) fed lactating cows concentrate mixtures containing corn and either 33.3 or 66.7% of two varieties of ground soft red winter wheat. A combination of alfalfa hay and corn silage (about 1:2.8 on a dry basis) comprised the forage component of the ration. For cows fed either the low or high protein variety of wheat, milk yield and milk fat content was lower ($P<.05$) when wheat comprised 66.7 compared to 33.3% in the concentrate mix. However, average yield and composition of milk by cows fed the two rations containing wheat was similar to that of cows fed a control corn-based concentrate mixture.

Tommervik and Waldern (1969) observed Gaines soft white wheat to be comparable in its nutritive value to that of corn, oats, barley and milo with respect to palatability and milk production. In their trial, the ratio of alfalfa hay to concentrate was 47:53. Similarly, Cribeiro et al. (1979) observed no differences among levels of wheat for 4% FCM, milk fat content, and milk protein content ($P>.05$).

This experiment was conducted to determine the extent to which hard red winter wheat can be utilized in a complete, mixed ration for lactating cows where sorghum silage is the only forage. Also, the effect of different levels of wheat in the concentrate mix on ruminal fermentation was evaluated.

## Materials and Methods

Twenty-one Holstein cows in their second or greater lactation were started 6 to 10 weeks postpartum on a feeding trial. The treatments were 0, 40 and 60% ground hard red winter wheat in the concentrate mixture. A switchback design with three four-week periods was used (Lucas, 1956). The first 2 weeks of each period were allowed for adjustment to rations and recovery from possible carry-over effects and the last 2 weeks of each period were used for comparisons among treatments. The cows were assigned to three blocks based on date of calving and then randomly to treatment sequences. Six treatment sequences were used, each of which included two treatments (Appendix, Table XVII), one treatment applied in the first and third periods, and the other applied during the second period.

The highest level of wheat represented the highest percent that could be used and still maintain protein, fiber, energy content of the total ration at an acceptable level (Table III). Cows were fed a complete, mixed ration consisting of 55% concentrate and 45% sorghum silage on a dry basis. The rations were divided into three equal parts and fed to cows in individual pens at 1100, 1900 and 0300 hours. Cows had free access to water. Calculated composition for the total ration was 15.5% crude protein (CP), 157 Mcal net energy for lactation ($NE_{\ell}$)/100 kg and 16.4% crude fiber (CF). The three mixtures were formulated to be isocaloric and isonitrogenous by replacing corn and some soybean meal with wheat (Table III). Cows were fed sufficient feed throughout the trial to allow a minimum amount of feed refusal. This was accomplished by increasing the amount of concentrate .45 kg and sorghum silage a proportional amount (depending upon dry matter content). Also, if cows left weighbacks for two consecutive days the amounts of concentrate and silage were reduced in a similar manner. Feed weighbacks for each cow were collected daily and composited on a weekly basis for determination of dry matter (DM) by drying at 60 C for

TABLE III

CONCENTRATE MIXTURES FED WITH SORGHUM SILAGE[1]

| | Percent wheat in mix | | |
|---|---|---|---|
| Composition | 0 | 40 | 60 |
| Ingredients, % as fed | | | |
| Corn, ground | 53 | 18 | -- |
| Wheat, ground[2] | -- | 40 | 60 |
| Soybean meal | 30 | 25 | 23 |
| Fixed portion[3] | 17 | 17 | 17 |
| Calculated analysis, as fed | | | |
| Net energy, Mcal/100 kg | 161 | 161 | 162 |
| Crude fiber, % | 5.5 | 5.7 | 5.8 |
| Total protein, % | 20.1 | 19.9 | 20.0 |
| Rumen undegradable protein (RUP), % | 8.4 | 6.6 | 5.8 |
| Lysine, undegraded, % | .41 | .31 | .26 |
| Methionine, undegraded, % | .12 | .09 | .08 |
| Actual analysis, % dry basis | | | |
| Acid-detergent fiber | 8.5 | 8.6 | 6.3 |
| Crude protein | 20.9 | 20.9 | 21.5 |
| Soluble nitrogen, % of total N[4] | 16.7 | 16.5 | 17.7 |

[1]Conc:forage, 55:45 (dry basis); Total ration (dry): $NE_{\ell}$ 157 Mcal/100 kg; protein 15.5%; fiber 16.4%.

[2]Hard red winter wheat, No. 2 grade, test wt. 60 lb/bu (Appendix, Table XXII).

[3]Fixed portion: cottonseed meal 4, cottonseed hulls 4, oats 4, limestone 1.5, dicalcium phosphate 1.25, sodium bicarbonate 1.0, salt .75 and magnesium oxide .50%.

[4]Solubility in borate-phosphate buffer.

48 hr and CP (N x 6.25) by the macro-kjeldahl method (A.O.A.C., 1975). A sample of silage and each concentrate mixture were analyzed for these components each week so that intake could be calculated. DM content of sorghum silage was determined by using the toluene distillation method (A.O.A.C., 1975). The silage was ground with dry ice before Kjeldahl determination. The silage and each concentrate were analyzed for soluble nitrogen content using the procedure outlined by Krishnamoorty et al. (1981). The procedure entailed the addition of a borate-phosphate buffer to the samples and their incubation in a water bath provided with a shaker for 1 hr at 39 C. The shaker was set at 110 to 120 rotations per minute. After incubation, the samples were filtered and the nitrogen content of the residue was determined by macro-kjeldahl procedure. Acid-detergent fiber was determined for each concentrate mix and for sorghum silage by the procedure outlined by Goering and Van Soest (1970).

Milk weights were recorded daily and samples were taken at four consecutive milkings each week for determination of fat percentage using a Milko Tester MK III F-3140 and protein percentage using a Pro-milk MK II F-12500. Each cow was weighed prior to the trial and on two consecutive days during the last week of each period. The cows were weighed just before milking; therefore, the weight of milk by each cow at the subsequent milking was subtracted from the respective body weight. Body condition of each cow was evaluated initially and on the last day of each period using the scoring system described by Aalseth et al. (1983).

During the last day of each period, rumen fluid samples were taken by stomach tube 3 to 4 hr after the 1100 AM feeding. Approximately 250 to 300 ml of rumen fluid were collected from each animal. The fluid was strained through four layers of cheesecloth, and pH was measured immediately with a pH meter with a glass electrode. A 200 ml aliquot of the strained fluid sample was acidified with 8 ml of 50% hydrochloric acid and frozen. This sample was subsequently thawed and centrifuged (1000 x g) for 10 min. Two 50 ul aliquots of the supernatant solution were assayed for rumen ammonia nitrogen ($NH_3$-N) concentration following the procedure of Broderick and Kang (1980). The concentration of ammonia was determined on the basis of absorbance measured by a Varian DMS 90 spectrophotometer using a wavelength of 630 nm.

Fifty milliliter aliquots of strained rumen fluid were mixed with .5 ml of a saturated solution of mercuric chloride and frozen. Later, these were thawed and centrifuged (1000 x g) for 10 min and 5 ml of the supernatant solution from each was prepared for volatile fatty acid analysis. Preparation included addition of 1 ml of 25% (w/v) meta-phosphoric acid and centrifugation at 25,000 x g for 20 min. Meta-phosphoric acid was combined with the supernatant solution to convert the volatile fatty acids (VFA) that are in a salt form to a free form in order to determine VFA concentration by gas-liquid chromatography. The supernatant solution was withdrawn, 2-ethylbutyric acid was added as an internal standard, and samples were then subjected to gas-liquid chromatography for VFA analysis. The sample (2 microliters) was injected onto a 240 cm, 6 mm O.D. glass column packed with 100/120 chromosorb WAW 15% SP-1220 1% $H_3PO_4$ on fire brick; nitrogen was the carrier gas at a flow rate of 40 ml/min, the column detector temperature was 130 C, and attenuation settings were 5 and 50.

A sample of blood from the median caudal vein of each cow was taken during the same time period as rumen fluid samples. The blood was withdrawn into vacutainer tubes, and .2 ml oxalic acid (12.98 g/200 ml .9% saline) was added immediately per 20 ml of blood. Samples were chilled in an ice water bath and later centrifuged at 2000 x g for 30 minutes. The supernatant solution was frozen and later analyzed in duplicate for blood urea nitrogen as described by Fawcett et al. (1960). This entails addition of 200 microliters of urease buffer, 5 ml phenol reagent, and 5 ml hypochlorite reagent to 100 microliters of sample supernatant solution and measurement of concentration on the basis of absorbance read by a Varian DMS 90 spectrophotometer using a wavelength of 625 nm.

Data for the different response variables were summarized on a "per period" basis for further statistical analysis. An analysis of variance on the response data followed that described by Lucas (1956). An example of the analysis of variance is shown in the Appendix, Table XXIII. The adjusted treatment means were compared using pre-planned orthogonal contrasts (linear and quadratic).

## Results and Discussion

Feed intake was not affected by the amount of hard red winter wheat in a complete ration with sorghum silage as the only forage (Table IV). Wheat intake averaged approximately 6.2 and 9.2 kg per day for the cows fed the 40 and 60% wheat mixtures, on as-fed basis. Also, a few cows reached a wheat intake of 12.9 kg/day (as-fed basis) . No problems were encountered with feed intake or clinical acidosis, even though

TABLE IV

FEED INTAKE BY COWS

| Item | Percent wheat in mix 0 | 40 | 60 | SE[a] |
|---|---|---|---|---|
| Dry matter, kg/day | | | | |
| Concentrate | 13.9 | 13.8 | 13.6 | .01 |
| Silage | 11.3 | 11.2 | 11.0 | .10 |
| Total | 25.2 | 25.0 | 24.6 | .02 |
| Protein | | | | |
| Intake, kg/day | 3.67 | 3.65 | 3.67 | .043 |
| Requirement, kg/day | 2.97 | 2.90 | 2.88 | |
| % of NRC requirement | 124 | 126 | 127 | |
| % of total DM intake | 14.6 | 14.6 | 14.9 | |
| Wheat intake (as fed), kg/day | 0 | 6.2 | 9.2 | |

[a]Standard error of the mean.

concentrate intake averaged more than 13.7 kg/cow/day for the entire trial. Similarly, McPherson and Waldern (1969) observed that cows had no problems with "off-feed" or acidosis even when fed a concentrate mixture with 93% wheat so that consumption of wheat was over 11.4 kg/cow/day. In their experiments, Gaines soft white wheat was used and alfalfa hay was the only forage in the ration. Cunningham et al. (1970) also observed no obvious off-feed conditions when soft red winter wheat replaced corn and soybean meal with an average wheat DM intake of 5.8 kg/cow/day for two varieties of wheat at a 66.7% level of the concentrate portion.

Crude protein intake was similar across diets and averaged 26% above NRC requirements. This discrepancy is mainly due to the assumed milk production for cows of 36.4 kg/day, whereas the actual milk yield averaged across treatments was 28 kg/day, resulting in an overestimation of protein requirements for lactation. Crude protein intake as a percent of total DM intake was 14.6, 14.6 and 14.9% for the concentrates containing 0, 40 and 60% wheat, respectively (Table IV).

Proper management may have averted problems with feed intake or clinical acidosis when feeding high levels of wheat in this study. These practices entailed: a) cows adjusted to new rations over a period of 5 days, and b) mineral buffers, sodium bicarbonate and magnesium oxide (Table III), included in the concentrate mixtures for the purpose of stabilizing conditions in the rumen to reduce the likelihood of digestive disorders. A cow was considered to be "off-feed" if she left 30% or more of her feed for two consecutive days. Feed intake was maintained at a concentrate to roughage ratio of 55.2:44.8 on a dry basis.

There was a linear decrease ($P<.001$) in milk yield as the amount of wheat in the ration increased (Table V), although milk yield of cows fed the highest level of wheat was sustained at a high level, i.e., 27.3 kg/day. Similarly, Cunningham et al. (1970) observed that milk yield was lower ($P<.05$) when two varieties (normal and high protein content) of soft red winter wheat comprised 66.7% compared to 33.3% of a concentrate mixture (27.0 vs. 28.2 and 25.7 vs. 27.3 kg/day). In contrast, in a trial where concentrate rations contained 20 to 93% Gaines soft white wheat, McPherson and Waldern (1969) observed no significant difference among groups with an overall average milk production of 23.3 kg/day. However, milk yield was moderately low in their experiment compared to the one previously mentioned and wheat replaced barley rather than corn in the concentrate mixtures. The calculated amount of rumen undegradable protein (Table III), and particularly lysine and methionine, was reduced when wheat replaced corn and some soybean meal to make mixtures equal in total protein content. In dairy rations, it has been suggested that lysine and/or methionine are the limiting amino acids for milk protein synthesis or milk production (Broderick et al., 1974; Chandler and Polan, 1972; Schwab et al., 1976). Valine has also been reported to be one of the limiting amino acids for milk production (Chandler, 1970; Broderick et al., 1974). These factors may affect the performance of cows fed large amounts of wheat.

Milk fat test increased ($P<.05$) as wheat in the ration increased, which averaged 3.68, 3.71 and 3.81% for cows receiving the 0, 40 and 60% wheat mixes, respectively (Table V). This slight increase in milk fat content may have been simply a reflection of the decrease in milk

TABLE V

MILK PRODUCTION AND COMPOSITION

| Item | Percent wheat in mix 0 | 40 | 60 | SE[a] |
|---|---|---|---|---|
| Milk prod., kg/day[b] | 28.8 | 28.0 | 27.3 | .20 |
| Fat test, %[c] | 3.68 | 3.71 | 3.81 | .031 |
| FCM, kg/day[c] | 27.4 | 26.7 | 26.4 | .25 |
| Milk protein, % | 3.15 | 3.12 | 3.15 | .033 |

[a]Standard error of the mean

[b]Significant linear trend (P<.001).

[c]Significant linear trend (P<.05).

production. In contrast, Cunningham et al. (1970) observed significantly lower milk fat content ($P<.05$) when soft red winter wheat comprised 66.7% compared to 33.3% of a concentrate mixture (3.06 vs. 3.37 and 3.21 vs. 3.56%). A decrease in milk fat content may be attributed to the starch in wheat appearing to be more readily fermented in the rumen than that of corn (Waldo, 1973), which would result in lower ruminal pH, greater VFA concentrations, and altered molar proportions of VFA in favor of propionate (Oltjen, 1970; Lee et al., 1982). Forage dry matter intakes in our experiment appeared to be adequate for maintenance of normal milk fat content in view of published recommendations (Kesler and Spahr, 1964; Jorgensen et al., 1965). The calculated crude fiber of the complete rations as consumed in this trial was 14.8% (dry basis). Actual acid-detergent fiber (ADF) levels were 8.5, 8.6 and 6.3% (dry basis) for the 0, 40 and 60% wheat concentrate mixtures, respectively (Table III). Sorghum silage had an ADF value of 38.5% (dry basis); therefore, total ADF content of each ration were estimated to be 21.9, 22.0, and 20.7% (dry basis) for the 0, 40 and 60% wheat-based rations. These were equal to or above the level of 21% ADF for which has been suggested as the concentration needed in the total ration to maintain normal milk fat percentage (NRC, 1978). The increase in milk fat content did not offset the decrease in milk production since 4% fat-corrected milk (FCM) was significantly lower ($P<.05$) as wheat in the concentrate mix increased. The amount of wheat in the ration had no significant effect ($P>.05$) on the percentage of milk protein (Table V).

No significant difference ($P>.05$) was observed among levels of wheat in regard to body weight and condition score changes of the cows (Table VI). However, body weight gains have been noted to be higher for

TABLE VI

BODY WEIGHT AND CONDITION SCORE CHANGE

| | Percent wheat in mix | | | |
|---|---|---|---|---|
| Item | 0 | 40 | 60 | SE[a] |
| Weight change, kg/period | .8 | 9.7 | -1.9 | 3.82 |
| Condition score change | .3 | .2 | .1 | .06 |

[a]Standard error of the mean.

TABLE VII

RUMEN PH, RUMEN AMMONIA AND BLOOD UREA

| | Percent wheat in mix | | | |
|---|---|---|---|---|
| Item | 0 | 40 | 60 | SE[a] |
| Rumen pH | 6.7 | 6.7 | 6.5 | .07 |
| Rumen ammonia, mg/dl | 6.8 | 6.3 | 6.5 | .43 |
| Blood plasma urea, mg/dl | 12.0 | 11.6 | 11.6 | .41 |

[a]Standard error of the mean.

cows on wheat compared to corn diets (Tommervik and Waldern, 1969). This response may be attributed to higher propionic acid relative to acetic acid concentration in the rumen fluid, which might divert nutrients for fat synthesis from the mammary gland, resulting in higher weight gains and lower milk fat production, as observed in their acceptability trial.

Ruminal pH levels were similar across diets being typical for cows fed mixed diets (Table VII). Rumen ammonia levels were similar among mixes with an average of 6.5 mg/dl, which should be adequate to maintain maximum microbial growth, being above 5 mg/dl. Also, blood plasma urea levels were not different (P>.05) for cows fed different amounts of wheat. The percentages of soluble nitrogen in the concentrate mixtures were 16.7, 16.5 and 17.7% for 0, 40 and 60% wheat mixes, respectively (Table III). However, wheat protein has been observed to be more soluble than that of corn (Wohlt et al., 1973; MacGregor et al., 1978). Also, ruminal degradation of protein in wheat has been estimated to be higher than that of other cereal grains (Mertens, 1977; Madsen and Huelplund, 1985; Commonwealth Agricultural Bureaux, 1984). Although rumen ammonia, blood plasma urea and soluble nitrogen values did not reflect a response difference in production of milk, other observations did. Calculated rumen undegradable protein percent decreased (Table III) as wheat increased in the concentrate mixture.

Total concentration and the molar proportions of acetic, propionic, butyric, isobutyric, valeric and isovaleric acids were similar (P>.05) for cows fed different levels of wheat (Table VIII). The ratio of molar percentages of acetic to propionic acids was 3.1:1 across treatments and was adequate for maintenance of normal milk fat test.

TABLE VIII

TOTAL CONCENTRATION AND MOLAR PERCENTAGES OF RUMEN VFA

| | Percent wheat in mix | | | |
|---|---|---|---|---|
| Item | 0 | 40 | 60 | SE[a] |
| Total VFA, mM/l | 90.7 | 83.1 | 83.6 | 4.15 |
| Acid, molar % | | | | |
| Acetic | 64.0 | 63.6 | 63.7 | .90 |
| Propionic | 20.3 | 20.7 | 20.1 | .74 |
| Butyric | 11.8 | 11.6 | 12.0 | .31 |
| Isobutyric | .7 | .7 | .7 | .04 |
| Valeric | 1.5 | 1.8 | 1.8 | .07 |
| Isovaleric | 1.7 | 1.6 | 1.7 | .07 |
| Acetic to propionic ratio | 3.15 | 3.07 | 3.17 | |

[a]Standard error of the mean.

The economics of feeding wheat where sorghum silage constitutes the only forage merits consideration. Small differences among treatments were observed in feed intake; therefore, the same amount of intake was assumed for each ration in the economic analysis. Thus, the economic feasibility of feeding wheat was estimated on the basis of observed responses in milk yield and current milk and feed prices. A concentrate mixture containing 40% wheat, replacing 35 lb corn and 5 lb soybean meal, must cost 62¢ /cwt less than a typical corn-soybean meal mixture to give the same return over feed cost (Table IX). Similarly, a concentrate mixture containing 60% wheat must cost about 92¢ /cwt less to obtain equal return over feed cost. With current prices (Jan. '86) for corn and soybean meal, wheat would need to be priced around $4.65/cwt to make the substitution profitable. On the other hand, if corn were priced at $6.40/cwt and soybean meal at $9.25/cwt as it was March '85, it would be feasible to use wheat priced around $5.25/cwt. At times the price of wheat is competitive with that of other feed grains used as an energy source in dairy rations and can be used to an advantage. Although it is possible to use high levels of wheat in formulating high energy rations for lactating dairy cows where sorghum silage is the only forage, the economic feasibility of doing so should be considered. In future research it should be possible to identify the factor(s) responsible for reduced milk yield when cows are fed complete rations containing a large amount of wheat and sorghum silage as the only forage. If so, it is likely that cost-effective measures for overcoming this problem can be developed.

TABLE IX

ECONOMICS OF FEEDING WHEAT WITH SORGHUM SILAGE AS THE ONLY FORAGE

| Item | Percent wheat in mix | | |
|---|---|---|---|
| | 0 | 40 | 60 |
| Amount of milk, lb/cow/day | 63.4 | 61.5 | 60.0 |
| Value of milk produced per day, \$[a] | 8.02 | 7.81 | 7.71 |
| Feed Costs | | | |
| Conc. mix, \$/100 lb[b] | 7.22 | 6.98 | 6.89 |
| Silage, \$/100 lb | 1.25 | 1.25 | 1.25 |
| Daily ration consumed, \$ | 3.25 | 3.17 | 3.14 |
| Return over feed costs/cow, \$[ab] | 4.77 | 4.64 | 4.57 |
| Price needed for same return as with control ration | | | |
| Conc. mix, \$/100 lb | | 6.60 | 6.30 |
| Wheat price[c] | | 4.67 | 4.65 |

[a]Milk priced at \$12.36/cwt for 3.5% test, with 16¢ differential.

[b]Ingredient prices (January 1986) per 100 lb: wheat \$5.12, corn \$5.74, soybean meal \$9.50, oats \$5.90, cottonseed meal \$9.25, cottonseed hulls \$2.70, limestone \$4.00, dicalcium phosphate \$20.50, sodium bicarbonate \$18.00, salt \$4.40, and magnesium oxide \$17.00.

[c]Assuming all other ingredient prices are those indicated above.

CHAPTER IV

# INFLUENCE OF DIFFERENT LEVELS OF WHEAT IN THE CONCENTRATE MIXTURE ON PRODUCTION RESPONSES OF LACTATING DAIRY COWS FED ALFALFA HAY AS THE ONLY FORAGE

## Summary

A feeding trial was conducted to compare the performance of 24 lactating dairy cows fed concentrate mixtures containing 0, 40, 60 and 80% of hard red winter wheat with alfalfa hay comprising the only forage in the ration. All concentrates were formulated to be isocaloric and isonitrogenous. Cows were assigned near the peak of lactation to treatment sequences of a switchback design with three 4-week periods. Intake of both concentrate and hay was lower when cows were fed the rations containing wheat; however, there was little difference among rations containing different amounts of wheat. No problems were noted with feed refusals or clinical acidosis. Ration dry matter digestibility was similar across treatments; however, crude protein digestibility was significantly lower for the control diet compared to the wheat-based diets. Milk yield tended to decline as the amount of wheat in the concentrate increased (30.4, 29.8, 29.6 and 28.9 kg/cow/day). Milk fat test (2.82, 2.74, 2.53 and 2.56) and 4% fat-corrected milk (24.9, 24.1, 23.0 and 22.7) decreased linearly as the percentage of wheat in the concentrate increased, whereas milk protein

percentage was not affected by treatment. The amount of wheat in the ration had no effect on body weight and condition score changes. Rumen pH and rumen ammonia levels decreased linearly as percentage of wheat in the concentrate increased, whereas blood plasma urea levels were similar among treatments. The molar percentage of acetic acid decreased linearly as the amount of wheat increased in the concentrate mix. Molar percentage of propionic acid increased cubicly due to increased levels of wheat in the ration. As the level of wheat increased in the concentrate mixture, the molar percent of valeric acid increased quadratically while isovaleric decreased quadratically. No differences were observed for the molar percentages of butyric and isobutyric acid due to treatments.

## Introduction

Wheat is often competitive in price with other feed grains used as an energy source in dairy rations. When this is the situation, wheat can be used to advantage in formulating high energy rations for lactating cows. Therefore, there as a need to more clearly define the limits to which wheat can be included safely in rations for high-producing dairy cows and the extent to which other grains can be replaced by wheat in dairy rations. Much of the past research on feeding wheat was conducted using cows producing considerably less milk and fed much less concentrates than is common in the industry today.

McPherson and Waldern (1969) found that cows fed alfalfa hay plus concentrate mixtures containing from 20 to 93% Gaines soft white wheat had no problems with "off-feed" and no significant differences in milk production attributable to amount of wheat in the ration. However, their results may not be applicable to herds with higher milk production or where cows are fed ground hard red winter wheat rather than steam-rolled soft white wheat.

Cunningham et al. (1970) fed lactating cows concentrate mixtures containing corn and either 33.3 or 66.7% of two varieties of ground soft red winter wheat. A combination of alfalfa hay and corn silage (about 1:2.8 on a dry basis) comprised the forage component of the ration. For cows fed either the low or high protein variety of wheat, milk yield and milk fat content was lower ($P<.05$) when wheat comprised 66.7 compared to 33.3% in the concentrate mix. However, average yield and composition of milk by cows fed the two rations containing wheat was similar to that of cows fed a control corn-based concentrate mixture.

Tommervik and Waldern (1969) observed Gaines soft white wheat to be comparable in its nutritive value to that of corn, oats, barley and milo with respect to palatability and milk production. In their trial, the ratio of alfalfa hay to concentrate was 47:53. Similarly, Cribeiro et al. (1979) observed no differences ($P>.05$) among levels of wheat for 4% FCM, milk fat content, and milk protein content.

This experiment was conducted to help define the extent to which hard red winter wheat can replace other grains in the rations for lactating dairy cows while utilizing alfalfa hay as the only forage.

## Materials and Methods

Twenty-four Holstein cows (12 in first lactation and 12 in second or later lactation) were used in a feeding trial starting 6 to 10 weeks postpartum to compare concentrate mixtures containing 0, 40, 60 and 80% hard red winter wheat. The 80% level of wheat represents the maximum that can be used if protein, net energy and fiber contents are maintained at acceptable levels. The four concentrate mixtures were calculated to be isocaloric and isonitrogenous (Table X) with the total ration calculated to have 159 Mcal net energy for lactation ($NE_{\ell}$)/100 kg, 16.5% protein, and 17.0% crude fiber on a dry basis. The rations were adjusted as necessary to maintain consumption of the desired ratio of 55% concentrate to 45% alfalfa hay on a dry basis. Each cow was fed to appetite throughout the trial, allowing a minimum amount of feed refusal. This was obtained by decreasing (or increasing) the amount of concentrate (1.6 lb) and alfalfa hay (1.3 lb) fed to cows if a weighback (or weighbacks) was (or was not) left for two consecutive days.

A switchback design was used, with three 4-week periods. The first two weeks of each period were allowed for adjustment to rations and recovery from possible carry-over effects. Data collected the final two weeks of each period were used for comparison among treatments. The cows were assigned to two blocks based on lactation number and then assigned randomly to treatment sequences. Twelve treatment sequences were used, each of which included two treatments (Appendix, Table XVIII), one treatment applied in the first and third periods, and the other applied during the second period. Also, each treatment sequence was assigned to one cow from each block. Alfalfa hay was fed twice daily (at 1000 and 1900 hours) separate from the concentrate mixtures (at 0400 and 1600 hours). Cows were fed in individual pens and had free access to water. Weighbacks of both concentrate and alfalfa hay were composited on a weekly basis for analysis of dry matter (DM) by drying

TABLE X

CONCENTRATE MIXTURES FED WITH ALFALFA HAY[1]

| Composition | Percent wheat in mix 0 | 40 | 60 | 80 |
|---|---|---|---|---|
| Ingredients (%, as fed) | | | | |
| Wheat, ground[2] | -- | 40 | 60 | 80 |
| Corn, ground | 75 | 38 | 19 | -- |
| Cottonseed meal | 12 | 6.5 | 3.5 | 2 |
| Oats, ground | 4 | 6.5 | 8.5 | 9 |
| Fixed portion[3] | 9 | 9 | 9 | 9 |
| Calculated analysis, as fed | | | | |
| Net energy, Mcal/100 kg | 164 | 165 | 165 | 165 |
| Crude fiber, % | 5.5 | 5.5 | 5.6 | 5.6 |
| Total protein, % | 12.2 | 12.0 | 11.9 | 12.4 |
| Rumen undegradable protein (RUP), % | 6.2 | 4.3 | 3.4 | 2.7 |
| Lysine, undegraded, % | .19 | .13 | .10 | .08 |
| Methionine, undegraded, % | .11 | .07 | .06 | .04 |
| Actual analysis, % dry basis | | | | |
| Acid detergent fiber | 6.9 | 6.5 | 6.4 | 7.9 |
| Crude protein | 13.2 | 13.1 | 13.2 | 13.3 |
| Soluble nitrogen, % of total N[4] | 17.0 | 19.1 | 20.7 | 18.0 |

[1]Conc:hay, 55:45; Total ration (dry): $Ne_{\ell}$ 159.5 Mcal/100 kg; protein, 16.5%; crude fiber, 17.0%.

[2]Hard red winter wheat, No. 2 grade, test wt. 60 lb/bu (Appendix, Table XXII).

[3]Fixed portion: cottonseed hulls 5, dicalcium phosphate 1.75, sodium bicarbonate 1.0, salt .75 and magnesium oxide .50%.

[4]Solubility in borate-phosphate buffer.

at 60 C for 48 hr and crude protein (CP) (N x 6.25) by the macro-kjeldahl method (A.O.A.C., 1975). A sample of hay and each concentrate mixture were also analyzed for these components each week so that intake could be calculated. Also, these samples were analyzed for content of soluble nitrogen using the procedure outlined by Krishnamoorty et al. (1981). The procedure entailed the addition of a borate-phosphate buffer to the samples and their incubation in a water bath provided with a shaker for 1 hr at 39 C. The shaker was set at 110 to 120 rotations per minute. After incubation, the samples were filtered and the nitrogen content of the residue was determined by macro-kjeldahl procedure. Acid-detergent fiber was determined for each concentrate mix and for alfalfa hay by the procedure outlined by Goering and Van Soest (1970). Chromic oxide ($Cr_2O_3$) was included in the concentrate portion at a level of .27% (ranging from 27 to 31 g/cow/day) the last three weeks of each period and used as an indigestible marker to calculate DM and CP digestibility of each ration.

Milk weights were recorded at each milking and samples were taken at four consecutive milkings. Samples were analyzed for fat (Milko Tester MK III F3140), and protein percentage (Pro-milk II F-12500). Each cow was weighed on two consecutive days prior to the trial and during the last week of each period. The cows were weighed just before milking; therefore, the weight of milk by each cow at the subsequent milking was subtracted from the respective body weight. Body condition also was evaluated prior to the beginning of the trial and during the last week of each period using the system described by Aalseth et al. (1983).

During the last day of each period, rumen fluid samples were taken by stomach tube 3 to 4 hr after the 0400 feeding. Approximately 200 to 250 ml of rumen fluid were collected from each animal. The fluid was strained through four layers of cheesecloth, and pH was immediately measured with a pH meter with a glass electrode. The strained fluid samples were then acidified (in order to stop microbial activity) with meta-phosphoric acid (crystal) at a level of 2 g/100 ml of fluid and frozen. The samples were subsequently thawed and centrifuged (1000 x g) for 10 min. Two 50 microliter aliquots of the supernatant solution were assayed for rumen ammonia nitrogen ($NH_3$-N) concentration following the procedure of Broderick and Kang (1980). The concentration of ammonia was determined on the basis of absorbance read by a Varian DMS 90 spectrophotometer using a wavelength of 630 nm. Also, 5 ml of the supernatant solution was prepared for volatile fatty acid (VFA) analysis. Preparation included centrifugation at 25,000 x g for 20 min and addition of 2-ethylbutyric acid (internal standard) to the supernatant solution. The sample was then subjected in duplicate to gas-liquid chromatography for VFA analysis. The sample (2 microliters) was injected onto a 240 cm, 6 mm O.D. glass column packed with 100/120 chromosorb WAW 15% SP-1220 1% $H_3PO_4$ on fire brick and nitrogen was the carrier gas at a flow rate of 40 ml/min., the column detector temperature was 130 C, and attenuation settings were 5 and 50.

A sample of blood from the median caudal vein of each cow was taken during the same time period as rumen fluid samples. The blood was withdrawn into vacutainer tubes, and .2 ml oxalic acid (12.98 g/200 ml .9% saline) was added immediately per 20 ml of blood to prevent coagulation. The samples were chilled by putting them on ice and later centrifuged at 2000 x g for 30 min. The supernatant solution was frozen and later analyzed in duplicate for blood urea nitrogen as described by Fawcett et al. (1960). This entails addition of 200 microliters of urease buffer, 5 ml phenol reagent, and 5 ml hypochlorite reagent to 100 microliters of sample supernatant solution and measurement of concentration on the basis of absorbance measured by a Varian DMS 90 spectrophotometer using a wavelength of 625 nm.

Fecal samples were taken twice daily for 5 days during the last week of the second period. Correction for diurnal variation was made on the basis of samples from a random group of four cows from which fecal samples were obtained at 4-hr intervals for two days. In order to determine chromium intake, a sample of each concentrate mix and a composite of concentrate orts were taken two days prior to and at the end of each collection period. Chromium in the sample was estimated by atomic absorption spectophotometry as described by Kotb and Lackley (1972) to calculate ration DM and CP digestibility.

Data for the different response variables were summarized on a "per period" basis for further statistical analysis. An analysis of variance on the response data followed that which is described by Lucas, 1956. An example of this analysis of variance is shown in the Appendix, Table XXIV. The adjusted treatment means were compared using pre-planned orthogonal contrasts. Treatment differences for ration digestibility values were determined by analysis of variance, protected LSD procedure (Appendix, Table XXV).

## Results and Discussion

Intake of both concentrate and hay decreased linearly ($P<.05$) as the amount of hard red winter wheat in the concentrate mix increased (Table XI). However, there was little difference among rations containing different levels of wheat. No problems were noted with clinical acidosis or digestive disorders in cows on any of the treatments. Intake of wheat averaged 4.7, 6.9, and 9.0 kg/day on an as-fed basis for cows fed the 40, 60 and 80% wheat mixtures, respectively (Table XI). Similarly, no problems with "off-feed" or acidosis were observed by McPherson and Waldern (1969) with cows fed levels from 20 to 93% of Gaines soft white wheat in the concentrate mix and fed alfalfa hay at a rate of 1 kg per 100 kg of body weight. In our trial, a cow was considered to be "off-feed" if she left 30% or more of her feed for two consecutive days. At the 93% level, wheat intake was over 11.4 kg/cow/day. It seems reasonable to conclude that wheat can be incorporated in a nutrition scheme for dairy cows; however, some management practices are important in successful use of large amounts of wheat in dairy rations. In this experiment, these practices entailed: a) cows being adjusted to new rations over a period of 5 days, and b) mineral buffers, sodium bicarbonate and magnesium oxide (Table X), being included in the concentrate mixtures for the purpose of stabilizing conditions in the rumen to reduce the likelihood of digestive disorders. Feed intake was maintained at a concentrate to roughage ratio of 56.7:43.3. Ration DM digestibility was not affected by increased levels of wheat in the concentrate mix (Table XI).

TABLE XI

FEED INTAKE BY COWS

| Item | Percent wheat in mix 0 | 40 | 60 | 80 | SE[a] |
|---|---|---|---|---|---|
| Dry matter intake, kg/day | | | | | |
| Concentrate mix[b] | 11.4 | 10.5 | 10.3 | 10.0 | .22 |
| Hay[b] | 8.8 | 8.0 | 7.7 | 7.8 | .26 |
| Total[b] | 20.2 | 18.5 | 18.0 | 17.9 | .45 |
| DM digestibility, % | 62.0 | 66.9 | 66.5 | 64.4 | 1.97 |
| Protein intake, kg/day | | | | | |
| Concentrate mix[b] | 1.50 | 1.38 | 1.36 | 1.33 | .033 |
| Hay | 1.79 | 1.62 | 1.58 | 1.58 | .076 |
| Total[b] | 3.29 | 3.00 | 2.94 | 2.91 | .105 |
| CP digestibility, % | 59.8[c] | 68.9[d] | 71.3[d] | 70.2[d] | 1.94 |
| Protein requirement, kg/day | 2.80 | 2.74 | 2.66 | 2.62 | |
| Protein, % of NRC requirement | 117 | 109 | 110 | 111 | |
| Protein, % of total DM intake | 16.3 | 16.2 | 16.3 | 16.3 | |
| Wheat intake (as fed), kg/day | 0 | 4.7 | 6.9 | 9.0 | |

[a]Standard error of the mean

[b]Significant linear trend (P<.05).

[c,d]Means in rows with different superscripts differ (P<.005).

Total crude protein intake decreased as the amount of wheat in the concentrate mix increased (Table XI). This decrease is associated with the decrease in feed intake that was observed. Crude protein content (dry basis) determined by analysis was 13.2, 13.1, 13.2 and 13.3% for the concentrates containing 0, 40, 60 and 80% wheat, respectively (Table X). These actual analyses of CP content for the mixes are similar to the calculated CP content averaged across treatments of 13.5% (dry basis). Crude protein intake as a percent of total DM intake was 16.3, 16.2, 16.3 and 16.3% for the rations including concentrates containing 0, 40, 60 and 80% wheat, respectively (Table XI), which is similar to the calculated CP content of 16.5% (dry basis) and an average of 12% above NRC requirements (Table XI). This discrepancy is mainly due to the assumed milk production for cows of 36.4 kg/day, whereas the actual milk yield averaged across treatments was 29.7 kg/cow/day, resulting in an overestimation of the protein requirements for lactation. Crude protein digestibility was significantly lower ($P<.005$) for the control ration compared to the wheat-based rations (Table XI). The decrease in digestibility of CP for the control diet compared to the wheat-based diets may be attributed to a combination of a higher intake observed by the cows on the control diet and corn having a lower rumen degradability compared to wheat. Values for degradability in the rumen using the in situ method range from 31 to 55% for corn and 72 to 82% for wheat (Madsen and Huelplund, 1985; Commonwealth Agricultural Bureaux, 1984). The lower degradability of protein in corn may result in an increase of nitrogen passing through the intestine which may attribute to lower digestibility of CP for the control diet compared to the wheat-based diets. Also, microbial fermentation in the large intestine may contribute to the lower apparent digestibility of CP for the control ration. This is attributed to corn having more bypass starch compared to wheat (Waldo, 1973) which may contribute to microbial fermentation in the large intestine resulting in increased microbial nitrogen and, therefore, lower apparent CP digestibility for the control diet.

Milk yield tended to decrease linearly as the amount of wheat in the concentrate increased (Table XII). However, milk yield of cows in their second or greater lactation was still sustained at a high production level, i.e., 35.6 kg/day, even when fed the concentrate mixtures with 80% wheat. Milk yield of the control group was 37.3 kg/day. Cows in their first lactation averaged 22.3 kg/day when fed the high-wheat ration, compared to 23.5 kg/day for controls. Similarly, Cunningham et al. (1970) reported that milk production was lower ($P<.05$) when two varieties (normal and high protein content) of soft red winter wheat comprised 66.7% compared to 33.3% of a concentrate mixture (27.0 vs. 28.2 and 25.7 vs. 27.3 kg/day). In contrast, McPherson and Waldern (1969) reported that milk production was similar for cows fed concentrate mixtures containing 20 to 93% Gaines soft white wheat. However, milk yield was moderately lower in their experiment compared to the one previously mentioned and wheat replaced barley rather than corn in the concentrate mixtures. The calculated amount of rumen undegradable protein (Table X), and particularly lysine and methionine, was reduced when wheat replaced corn and some cottonseed meal to make mixtures equal in total protein content. In dairy rations, it has been suggested that lysine and/or methionine are the limiting amino acids for milk protein synthesis or milk production (Broderick et al., 1974; Chandler and Polan, 1972; Schwab et al., 1976). Valine has also been

TABLE XII

MILK PRODUCTION AND COMPOSITION

| | Percent wheat in mix | | | | |
|---|---|---|---|---|---|
| Item | 0 | 40 | 60 | 80 | SE[a] |
| Milk production, kg/day[b] | 30.4 | 29.8 | 29.6 | 28.9 | .51 |
| Fat test, %[c] | 2.82 | 2.74 | 2.53 | 2.56 | .063 |
| FCM, kg/day[c] | 24.9 | 24.1 | 23.0 | 22.7 | .44 |
| Milk protein, % | 2.74 | 2.78 | 2.82 | 2.83 | .035 |

[a]Standard error of the mean.

[b]Linear trend approaching statistical significance (P<.08).

[c]Significant linear trend (P<.01).

reported to be one of the limiting amino acids for milk production (Chandler, 1970; Broderick et al., 1974). These may be factors affecting the performance of cows fed large amounts of wheat.

Milk fat test decreased (P<.01) as wheat in the ration increased; tests averaged 2.82, 2.74, 2.53 and 2.56% for cows receiving the 0, 40, 60 and 80% wheat mixes, respectively (Table XII). Similarly, Cunningham et al. (1970) observed lower milk fat content (P<.05) when soft red winter wheat comprised 66.7% compared to 33.3% of a concentrate mixture (3.06 vs 3.37 and 3.21 vs 3.56%). A decrease in milk fat content may be attributed to more rapid fermentation of starch in wheat in the rumen than that of corn (Waldo, 1973), which would result in lower ruminal pH, greater VFA concentrations, and altered molar proportions of VFA in favor of propionate (Oltjen, 1970; Lee et al., 1982). The calculated crude fiber content of the complete rations as consumed in this trial was 17.0% (dry basis); however, the alfalfa hay used in the experiment was higher in quality than assumed in the calculations making total fiber content of the ration lower than expected. This is apparent as milk fat test was low for all the experimental groups. Actual acid-detergent fiber (ADF) levels were 6.9, 6.5, 6.4 and 7.9% (dry basis) for the 0, 40, 60 and 80% wheat concentrate mixtures, respectively (Table X). Alfalfa hay had an ADF value of 34.4% (dry basis); therefore, total ADF values for each ration were estimated to be 18.9, 18.6, 18.4 and 19.5% (dry basis) for the 0, 40, 60 and 80% wheat-based rations. These were all lower than the level of 21% ADF which has been suggested as the concentration needed in the total ration to maintain normal milk fat percentage (NRC, 1978). Also, the decrease in milk fat content as the amount of wheat in the concentrate mix increases can be attributed to the increase in the molar percentage of propionic acid and the decrease in the molar percentage of acetic acid, which is shown also by the narrowing of the ratio of acetic to propionic acid (3.0:1 down to 1.8:1). The decrease in milk yield and milk fat content resulted in a linear decrease ($P<.01$) in 4% fat-corrected milk (FCM) as wheat in the concentrate mix increased (Table XII). The amount of wheat in the ration had no significant effect ($P>.05$) on the percentage of milk protein.

No significant difference ($P>.05$) was observed among levels of wheat in regard to body weight and condition score changes of the cows (Table XIII). However, body weight changes appeared to be higher at the higher levels of wheat in the concentrate mix. Similarly, body weight gains were noted to be higher for cows on wheat compared to corn diets (Tommervik and Waldern, 1969). This response may be attributed to higher propionic acid relative to acetic acid concentration in the rumen fluid, which might divert nutrients for fat synthesis from the mammary gland, resulting in higher weight gains and lower milk fat production, as observed in their acceptability trial and our trial.

Ruminal pH levels declined linearly ($P<.001$) as the percentage of wheat in the concentrate mixture increased (Table XIV). Although rumen pH was lowest at the 80% wheat mix (6.09), it is well above the level generally observed to be associated with problems of digestive disorders of "off-feed" in cows fed large amounts of grain. Rumen ammonia levels decreased linearly ($P<.05$) as wheat in the concentrate increased (Table XIV). Blood plasma urea levels were similar for cows fed different amounts of wheat. The percentages of soluble nitrogen in the concentrate mixtures were 17.0, 19.1, 20.7 and 18.0% for 0, 40, 60 and

TABLE XIII

BODY WEIGHT AND CONDITION SCORE CHANGE

| | Percent wheat in mix | | | | |
|---|---|---|---|---|---|
| Item | 0 | 40 | 60 | 80 | SE[a] |
| Weight change, kg/period | 3.5 | -2.5 | 11.0 | 13.9 | 5.7 |
| Condition score change/period | 0.03 | 0.07 | -0.13 | -0.05 | .242 |

[a]Standard error of the mean.

TABLE XIV

RUMEN PH, RUMEN AMMONIA AND BLOOD UREA

| | Percent wheat in mix | | | | |
|---|---|---|---|---|---|
| Item | 0 | 40 | 60 | 80 | SE[a] |
| Rumen pH[b] | 6.65 | 6.42 | 6.41 | 6.09 | .086 |
| Rumen ammonia, mg/dl[c] | 4.5 | 5.1 | 3.4 | 2.4 | .56 |
| Blood plasma urea, mg/dl | 13.8 | 15.2 | 14.4 | 13.4 | .64 |

[a]Standard error of the mean.

[b]Significant linear trend ($P<.001$).

[c]Significant linear trend ($P<.05$).

80% wheat mixes, respectively (Table X). However, wheat protein has been observed to be more soluble than that of corn (Wohlt et al., 1973; MacGregor et al., 1978). Also, ruminal degradation of protein in wheat has been estimated to be higher than that of other cereal grains (Madsen and Huelplund, 1985; Commonwealth Agricultural Bureaux, 1984; Mertens, 1977). Response difference in production of milk and milk fat content may be attributed to calculated decrease in rumen undegradable protein percent (Table X), lower pH values, lower rumen ammonia levels, and a decrease in the ratio of acetic to propionic acid as wheat increased in the concentrate mixture.

Molar proportion of acetic acid decreased linearly ($P<.001$) as wheat in the concentrate mix increased (Table XV). Molar proportions of propionic acid increased cubicly ($P<.004$) as the amount of wheat in the ration increased in that the percentage for the 80% wheat ration was lower than that of the ration with 60% wheat. As the level of wheat increased in the concentrate mixture the molar percent of valeric acid increased quadratically while isovaleric decreased quadratically (Table XV). The molar percentage of butyric and isobutyric acid did not differ among levels of wheat. Similarly, Lee et al. (1982) and Oltjen (1970) observed altered molar proportions of VFA in favor of propionate when comparing wheat to corn rations fed to ruminants. This was noted in our trial by the narrowing of the ratio of acetic to propionic acid as wheat in the concentrate mix increased (3.0:1 down to 1.8:1).

An economic analysis was performed to determine whether or not wheat can be used to an advantage in formulating rations for dairy cows under the conditions existing in our trial. Less feed was consumed when wheat was included in the concentrate mixtures; therefore, reduced in-

TABLE XV

MOLAR PERCENTAGE OF RUMEN VFA

| Item | Percent wheat in mix | | | | |
|---|---|---|---|---|---|
| | 0 | 40 | 60 | 80 | SE[a] |
| Acid, molar % | | | | | |
| Acetic[b] | 63.4 | 61.5 | 54.9 | 53.6 | 1.27 |
| Propionic[c] | 20.8 | 23.7 | 31.0 | 29.7 | 1.51 |
| Butyric | 12.3 | 11.4 | 10.5 | 12.2 | .50 |
| Isobutyric | 0.3 | 0.2 | 0.1 | 0.0 | .10 |
| Valeric[d] | 1.8 | 1.8 | 2.7 | 4.1 | .29 |
| Isovaleric[d] | 1.4 | 1.4 | 0.8 | 0.4 | .12 |
| Acetic to propionic ratio | 3.0 | 2.6 | 1.8 | 1.8 | |

[a]Standard error of the mean.

[b]Linear trend significant (P<.001).

[c]Cubic trend significant (P<.04).

[d]Quadratic trend significant (P<.004).

take of both alfalfa hay and concentrate was considered. The daily ration ingredient cost per animal declined from $2.70 for cows consuming the control ration without wheat to $2.26 for cows fed the concentrate with 80% wheat. In our trial, the highest return over feed ingredient costs was for the group fed the concentrate mixture containing 40% wheat (Table XVI). The decline in milk yield and fat test of cows fed concentrate mixes containing 60 and 80% wheat was such that with current prices for other ingredients (Jan '86), wheat would need to be valued at about $4.75/cwt to produce equal returns over feed cost. However, with corn priced at $6.40/cwt and cottonseed meal at $8.44/cwt as they were in March '85, it would be economically feasible to use wheat priced around $5.30/cwt. Also, if one assumes that with adequate fiber in the ration no depression in fat test would occur and milk yield would be the same as observed in our experiment, it can be calculated that feeding wheat would be profitable at all the different levels with current feed ingredient prices.

TABLE XVI

ECONOMICS OF FEEDING WHEAT WITH ALFALFA HAY AS THE ONLY FORAGE

| | Wheat in conc. mix | | | |
|---|---|---|---|---|
| Item | 0 | 40 | 60 | 80 |
| Amount of milk, lb/day | 66.9 | 65.5 | 65.1 | 63.7 |
| Value of milk produced per day, $[a] | 7.54 | 7.30 | 7.04 | 6.92 |
| Feed ingredient costs | | | | |
| Conc. mix, $/100 lb[b] | 6.44 | 6.21 | 6.08 | 6.00 |
| Alfalfa hay, $/100 lb | 4.00 | 4.00 | 4.00 | 4.00 |
| Daily ration consumed, $ | 2.70 | 2.43 | 2.32 | 2.26 |
| Return per day over feed costs, $[a,b] | 4.84 | 4.87 | 4.72 | 4.66 |
| Price needed for same return as with control ration | | | | |
| Conc. mix, $/100 lb | | | 5.60 | 5.26 |
| Wheat, $/100 lb | | | 4.82 | 4.70 |

[a] Milk priced at $12.36/cwt for 3.5%, with 16¢ differential.
[b] With wheat @ $5.12, corn @ $5.74, cottonseed meal @ $9.25, and oats @ $5.90/cwt (January, 1986).

## CHAPTER V

## CONCLUSIONS AND RECOMMENDATIONS

Hard red winter wheat can be incorporated in a nutrition scheme for lactating dairy cows. Milk yield of dadiry cows fed large amounts of wheat was sustained at a high level; however, yield did decline as the percentage of wheat in the concentrate mixture increased. In the first trial, cows were fed concentrate mixtures containing 0, 40, or 60% wheat in a complete ration with sorghum silage as the only forage. Wheat replaced corn and some soybean meal so that protein content was held constant. Mineral buffers ($NaHCO_3$ and MgO) were included to aid in prevention of possible digestive disorders. No problems were encountered with feed intake or clincial acidosis, even though concentrate intake averaged more than 13.6 kg/cow/day for the entire trial. However, milk production declined as the percentage of wheat in the concentrate increased (28.8, 28.0 and 27.3 kg/day for cows fed mixes with 0, 40 and 60% wheat).

In the second trial, cows were fed concentrate mixtures containing 0, 40, 60 and 80% wheat with alfalfa hay comprising the only forage in the ration. Intake of both concentrate and hay was lower when cows were fed the rations containing wheat; however, there was very little difference among rations containing different amounts of wheat. Also, milk yield declined as the amount of wheat in the concentrate increased (30.4, 29.8, 29.6 and 28.9 kg/cow/day for cows fed mixes with 0, 40, 60 and 80% wheat). Mineral buffers were included in the concentrate mixes as in the first trial. No problems were encountered with digestive disorders or clincial acidosis; however, cows fed wheat-based diets did have lower feed intake, ruminal pH, ammonia levels and higher molar percentage of acetic acid compared to cows fed a corn-based diet, which may be signs of subclinical acidosis. Also, feeding wheat had a detrimental effect on milk fat content of cows when fed the concentrate and roughage source separately. This may be attributed to the starch of wheat being readily fermentable in the rumen compared to corn, which leads to a shift of volatile fatty acid production in favor of propionate.

In both trials the calculated amount of rumen undegradable protein was reduced when wheat replaced corn and some protein supplement to make mixtures equal in protein content. Whether this is the factor limiting production of dairy cows when wheat replaces corn in a concentrate mixture needs to be determined since it is likely that cost effective measures for overcoming this problem can be developed.

## LITERATURE CITED


Aalseth, E. P., G. D. Adams, L. J. Bush and K. Jones. 1983. A system for evaluating the body condition of dairy cows. Okla. Agr. Exp. Sta. MP-114:261.

Aguirre, E.O., A.L. Goetsch and F.N. Owens. 1984. Fermented corn grain - site and extent of nutrient digestion in steers. Okla. Agr. Exp. Sta. Res. Rep. MP-116:194.

Ahrens, F. A. 1967. Histamine, lactic acid, hypertonicity as factors in the development of rumenitis in cattle. Am. J. Vet. Res. 28:1335.

Allison, M. J., R. W. Dougherty, J. A. Bucklin and E. E. Snyder. 1964. Ethanol accumulation in the rumen after overfeeding with readily fermentable carbohydrate. Sci. 144:54.

A.O.A.C. 1975. Official methods of analysis. 12th edition. Association of Official Analytical Chemists, Washington, D.C.

Armstrong, D. G. and R. R. Smithard. 1979. The fate of carbohydrates in the small and large intestines of the ruminant. Proc. Nutr. Soc. 38:283.

Bailey, R. W. 1965. Wheat feeding for dairy cows. Milk Board J., August. New South Wales, Australia.

Baldwin, R. L., W. A. Wood and R. S. Emery. 1963. Conversion of glucose-$C^{14}$ to propionate by the rumen microbiota. J. Bact. 85:1346.

Bateman, G. Q. 1942. The conversion of surplus wheat into much needed milk. Utah Agr. Exp. Sta., Farm and Home Sci. 3 (4).

Belasco, I. J. 1972. Stability of methionine hydroxy analog in rumen fluid and its conversion _in vitro_ to methionine by calf liver and kidney. J. Dairy Sci. 55:353.

Bishop, R. B. 1971. Effect of methionine hydroxy analog on complete lactation of dairy cows. J. Dairy Sci. 54:1240.

Bowstead, J.E. 1930. Wheat as a concentrate for dairy cows. Dept. of Anim. Husbandry, Univ. of Alberta, June Animal Feeder's Day.

Bowstead, J.E. 1942. Wheat for milk production. Dept. of Anim. Husbandry, Univ. of Alberta, Mimeograph III.

Bragg, D. S. A., M. R. Murphy and C. L. Davis. 1986. Effect of source of carbohydrate and frequency of feeding on rumen parameters in dairy steers. J. Dairy Sci. 69:392-402.

Broderick, G. A., T. Kowalczyk and L. D. Satter. 1970. Milk production response to supplementation with encapsulated methionine per os or casein per abomasum. J. Dairy. Sci. 53:1714.

Broderick, G. A., L. D. Satter and A. E. Harper. 1974. Use of plasma amino acid concentration to identify limiting amino acids for milk production. J. Dairy Sci. 57:1015.

Broderick, G. A., and J. H. Kang. 1980. Automated simultaneous determination of ammonia and total amino acids in ruminal fluid and in vitro media. J. Dairy Sci. 63:64.

Broderick, G. 1982. Estimation of protein degradataion using in situ and in vitro methods. In: F. N. Owens (Ed.). Protein requirements of cattle: symposium. Okla. State Univ., MP-109:72-80.

Burgos, A. and H.H. Olson. 1970. Effects of 40 g of methionine hydroxy analog on yield and composition of milk. J. Dairy Sci. 53:647.

Chalupa, W. 1975. Rumen bypass and protection of proteins and amino acids. J. Dairy Sci. 58:1198.

Chandler, P. T. 1970. Improving protein nutrition of ruminants. Proc. Va. Feed Convention and Nutr. Conf., p. 1.

Chandler, P. T. and C. E. Polan. 1972. Considerations in interpretations of serum amino acids in lactating cows. J. Dairy Sci. 55:709. (Abstr.)

Cochrane, J. E. 1986. Oklahoma Farm Statistics. Okla. Crop and Livestock reporting service. Vol. 6, No. 3, Feb. 86.

Cochrane, J. E. 1986. Oklahoma Farm Statistics. Okla. Crop and Livestock reporting service. Vol. 6, No. 4, Feb. 86.

Commonwealth Agricultural Bureaux. 1984. The nutrient requirements of ruminant livestock. 2nd ed. The Lavenham Press Ltd., Lavenham, Suffolk.

Copeland, O. C. 1933. Wheat versus milo for dairy cows. Texas Agr. Exp. Sta. Bull. 480.

Cribeiro, T. E., A. Elias and I. Denis. 1979. Substitution levels of maize by wheat in concentrates and their effects on milk production and composition. Cuban J. Agr. Sci. 13 (1):19-24.

Cunningham, M. D., F. L. Albright and W. T. Howard. 1970. Percent protein and amounts of soft red winter wheat for lactating cows. J. Dairy. Sci. 53:1787.

Dice, J. R. 1932. Home grown feed. North Dakota Agr. Exp. Sta. Biennial Progress Report 1929-1931. Bull. 256, p. 32.

Dunlop, R. H., P. B. Hammond and C. E. Stevens. 1964. D-Lactate in bovine blood following carbohydrate engorgement. Fed. Proc. 23:262.

Dunlop, R. H. and P. B. Hammond. 1965. D-lactic acidosis of ruminants. Ann. N.Y. Acad. Sci. 119:1109.

Dunlop, R. H. 1970. Rumen malfunctions - Acidosis problems with high grain rations. Wheat in livestock and poultry feeds, Proceedings of an international sympsoium. June 18-19. Okla. State Univ., Stillwater.

Fawcet, J. K. and J. E. Scott. 1960. A rapid and precise method for the determination of urea. J. Clin. Path. 13:156.

Fitch, J. B. and H. W. Cave. 1932. Ground wheat versus ground corn for dairy cows. Kansas Station Biennial Report.

Fulkerson, W. J. and P. J. Michell. 1985. Production response to feeding wheat grain to milking cows. Aust. J. Exp. Agr. 25 (2):253-256.

Fulton, W. R., T. J. Klopfenstein and R. A. Britton. 1979. Adaptation to high concentrate diets by beef cattle. I. Adaptation to corn and wheat diets. J. Anim. Sci. 49 (3):775-784.

Ganev, G., E. R. Orskov and R. Smart. 1979. The effect of roughage or concentrate feeding and rumen retention time on total degradation of protein in the rumen. J. Agr. Sci. (Camb.) 93:651.

Goering, H.D. and P.J. Van Soest. 1970. Forage fiber analysis (apparatus, reagents, procedures and some applications). Agricultural Handbook. 379. USDA, ARS.

Griel, L. C., Jr., R. A. Patton, R. D. McCarthy and P. T. Chandler. 1968. Milk production response to feeding methionine hydroxy analog to lactating dairy cows. J. Dairy Sci. 51:957.

Hayden, C. C. and C. F. Monroe. 1931. Wheat as a substitute for corn in the dairy ration. Ohio Agr. Exp. Sta. BiMonthly Bull. 153.

Hewitt, A. C. T. and H. O. Turner. 1944. Wheat as a feed for dairy cows. Experience of those who have tried it. J. of Agr., Victoria, 42:437.

Hinkson, B. S., W. H. Hoover and B. R. Poulton. 1967. Metabolism of lactic isomers by rat and sheep liver and by rumen epithelial tissue. J. Anim. Sci. 26:799.

Holter, J.B., C.W. Kim and N.F. Colovos. 1972. Methionine hudroxy analog for lactating dairy cows. J. Dairy Sci. 55:460.

Huber, T. L. 1969. Lactic acidosis and renal function in sheep. J. Anim. Sci. 29:612.

Huber, J. T. and L. Kung, Jr. 1981. Protein and nonprotein nitrogen utilization in dairy cattle. J. Dairy Sci. 64:1170.

Hutjens, M.F. and L.H. Schultz, 1970. Effects of ground soybeans or methionine analogue in rations depressing milk fat test. J. Dairy Sci., 53:663.

Jacobs, E. E. 1931. Can low priced wheat be fed to dairy cows at a profit? Panhandle Agr. Exp. Sta. Bul. 29.

Jayasuriya, G. C. N. and R. E. Hungate. 1959. Lactate conversions in the bovine rumen. Arch. Biochem. Biophys. 82:274.

Jorgensen, N. A., L. H. Schultz and G. R. Barr. 1965. Factors influencing milk fat depression on rations high in carbohydrates. J. Dairy Sci. 48:1031.

Kenna, T. M. and C. G. Schwab. 1981. Evaluation of N-hydroxymethyl-DL-methionine-CA and Dihydroxymethyl-L-lysine-Ca in a blended corn based ration for lactating cows. J. Dairy Sci. 64:775.

Kentucky Agricultural Experiment Station. 1931. Cracked wheat versus cracked corn for cows. Forty-fourth Annual Report. Part 1. p. 46.

Kesler, E.M. and S.L. Spahr. 1964. Symposium: Effect of various levels of grain feeding. Physiological effects of high level concentrate feeding. J. Dairy Sci. 47:1122.

Kim, C.W., J.B. Holter, N.F. Colovos and W.E. Urban. 1971. Microbial growth dependence on ammonium nitrogen in the bovine rumen: a quantitative study. J. Dairy Sci. 54:1240.

Kotb, A.R. and T.D. Luckey. 1972. Markers in nutrition. Nutr. Abstr. and Reviews. 42:813.

Krishnamoorthy, U., T. V. Muscato, C. F. Sniffen and J. P. Van Soest. 1982. Nitrogen fractions in selected feedstuffs. J. Dairy Sci. 65:217.

Lebzien, P., K. Rohr and H. Schafft. 1984. Nitrogen metabolism in the digestive tract of dairy cows given wheat or maize grain. Nutr. Abstr. and Reviews - Series B. Vol. 54, No. 2-3, Abs. 345.

Lee, G. J., W. R. McManus and V. N. E. Robinson. 1982. Changes in rumen fluid composition and in rumen epithelium when wheat is introduced to the diet of sheep: The influence of wheat and hay consumption. Aust. J. Agr. Res. 33(2):321-333.

Leng, R. A. and J. V. Nolan. 1984. Nitrogen metabolism in the rumen. J. Dairy Sci. 67:1072.

Lofgren, P.A. and R.G. Warner. 1970. Influence of various fiber sources and fractions on milk fat percentage. J. Dairy Sci. 53:296.

Lucas, H. L. 1956. Switchback trials for more than two treatments. J. Dairy Sci. 39:146-154.

MacGregor, C. A., C. J. Sniffen and W. H. Hoover. 1978. Amino acid profiles of total and soluble protein in feedstuffs commonly fed to ruminants. J. Dairy Sci. 61:566-573.

Madsen, J. and T. Hvelplund. 1985. Protein degradation in the rumen. A comparison between in vivo, nylon bag, in vitro and buffer measurements. Acta. Agr. Scand. Suppl. 25:103.

McPherson, R. G. and D. E. Waldern. 1969. Pacific Northwest soft white wheat for lactating cows. J. Dairy Sci. 52:84.

Mertens, D. R. 1977. Importance and measurement of protein insolubility in ruminant diets. Georgia Nutr. Conf. p. 30.

Monroe, C. F., C. C. Hayden and C. E. Knopp. 1933. Feeding wheat to dairy cows. Fifty-first Annual Report. Ohio Agr. Exp. Sta. Bull. 516, p. 71-72.

Monroe, C. F. and C. C. Hayden. 1934. Feeding wheat to dairy cows. Fifty-second Annual Report. Ohio Agr. Exp. Sta. Bull. 532, p. 50.

Moran, J. B. 1983. Barley, wheat, or oats grain as cereal sources for dairy cows. Proc. of the Second Symposium of the International Network of Feed Information Centres. p. 429.

Morrison, F. B. 1956. Feeds and feeding. 22nd ed. The Morrison Publishing Co., Clinton, Iowa.

National Research Council. 1978. Nutrient requirements of dairy cattle. 5th revision. National Academy Press, Washington, D.C.

National Research Council. 1982. United States-Canadian tables of feed composition. 3rd revision. National Academy Press, Washington, D.C.

National Research Council. 1985. Ruminant nitrogen usage. National Academy Press, Washington, D.C.

Oke, B. O., S. C. Loerch and L. E. Deetz. 1986. Effects of rumen-protected methionine and lysine on ruminant performance and nutrient metabolism. J. Anim. Sci. 62:1101.

Oltjen, R. R., P. A. Putnam, E. E. Williams, Jr. and R. E. Davis. 1966. Wheat versus corn in all-concentrate cattle rations. J. Anim. Sci. 25:1000.

Oltjen, R. R. 1970. Metabolic aspects of feeding wheat to beef cattle. Proc. International Symposium on Wheat in Livestock and Poultry Feeds. June 18-19. pp. 126-133.

Ontario Department of Agriculture. 1932. Wheat for dairy cattle feeding. Annual Report, p. 72. Guelph, Ontario.

Oregon Agricultural Experiment Station. 1940. Surplus wheat feeding experiments in Oregon. Sta. Circ. 137, p. 33.

Owens, F. N. and W. G. Bergen. 1982. Nitrogen metabolism of the ruminant. J. Anim. Sci. 57:498.

Pena, F. and L. D. Satter. 1984. Effect of feeding heated soybean meal and roasted soybeans on milk production in Holstein cows. Abst., J. Dairy Sci. 67:(Supp 1), 123.

Polan, C. E., P. T. Chandler and C. N. Miller. 1970a. Methionine hydroxy analog: Varying levels for lactating cows. J. Dairy Sci. 53:607.

Polan, C. E., P. T. Chandler and C. N. Miller. 1970b. Methionine analog effect on ruminant digestion. J. Anim. Sci. 31:251.

Russell, J. B. and T. Hino. 1985. Regulation of lactate production in streptococcus bovis: A spiraling effect that contributes to rumen acidosis. J. Dairy Sci. 68:1712.

Satter, L. D., L. W. Whitlow and G. L. Beardsley. 1977. Resistance of protein to rumen degradation and its significance to the dairy cow. Proc. Distiller's Feed Research Council. p. 63.

Schwab, C. G., L. D. Satter and A. B. Clay. 1976. Response of lactating dairy cows to abomasal infusison of amino acids. J. Dairy Sci. 59:1254.

Searcy, R. L., G. S. Gough, J. L. Korotzer and L. M. Berquist. 1961. Evaluation of a new technique for estimation of urea nitrogen in serum. Am. J. Med. Tech. 27:255.

Slyter, L. L., R. R. Oltjen, D. L. Kern and F. C. Blank. 1970. Influence of type and level of grain and diethylstilbestrol on the rumen microbial population of steers fed all-concentrate diets. J. Anim. Sci. 31:996-1002.

Stallcup, O. T. 1968. The influence of ration on milk fat test in dairy cows. Feedstuffs. 40:3.

Stern, M. D. and L. D. Satter. 1982. In vivo estimation of protein degradability in the rumen. In: F. N. Owens (ed.). Protein Requirements of Cattle: Symposium. Okla. State Univ. MP-109:72-80.

Sullivan, T. W. 1970. Utilization of wheat in turkey feeding programs. Proceedings of an international symposium. June 18-19. Okla. State Univ., Stillwater.

Sutton, J. D. 1971. Carbohydrage digestion and glucose supply in the gut of the ruminant. Proc. Nutr. Soc. 30:243.

Tamminga, S., C. F. van der Koelen and A. M. Van Vuuren. 1979. Effect of level of feed intake on nitrogen entering the small intestine of dairy cows. Livestock Prod. Sci. 6:255.

Thivend, P. and M. Vermorel. 1971. Digestive utilization of starch by the growing lamb. Ann. Biol. Anim. Biochem. Biophys. 11:292.

Tommervik, R. S. and D. E. Waldern. 1969. Comparative feeding value of wheat, corn, barley, milo, oats and a mixed concentrate ration for lactating cows. J. Dairy Sci. 52:68.

Tyrrell, H. F., G. P. Lynch and B. P. Glenn. 1984. Effect of level and solubility of dietary protein on concentration of plasma amino acids in dry and lactating cows by two methods of analysis. Abst., J. Dairy Sci. 67:(Supp. 1), 122.

Van Soest, P. J. 1963. Ruminant fat metabolism with particular reference to factors affecting low milk fat and feed efficiency. A review. J. Dairy Sci. 46:204.

Waldern, D. E. 1970. Nutritive value and suitable levels of wheat for dairy cattle. Wheat in livestock and poultry feeds. Proceedings of an international symposium. June 18-19. Okla. State Univ., Stillwater.

Waldo, D. R. 1973. Extent and partition of cereal grain starch digestion in ruminants. J. Anim. Sci. 37:1062.

Waldo, D. R. and H. K. Goering. 1979. Insolubility of proteins in ruminant feeds by four methods. J. Anim. Sci. 49:1560.

Ward, J.W., F.N. Owens, M.R. Putman and L.J. Bush. 1986. Ruminal escape, turnover rate and in situ disapperance of soybean meal protein in lactating cows fed diets at two concentrate to forage ratios. Okla. Agr. Exp. Sta. Res. Rep. MP-118:59.

Warner, R. G. 1965. The impact of diet on milk-fat percentage. 1965. Cornell Nutrition Conference Proceedings. p. 119.

Williams, V. J. and D. D. S. MacKenzie. 1965. The absorption of lactic acid from the reticulo-rumen of the sheep. Aust. J. Biol. Sci. 18:917.

Wohlt, J. E., C. J. Sniffen and W. H. Hoover. 1973. Measurement of protein solubility in common feedstuffs. J. Dairy Sci. 56:1052-1057.

Zinn, R. A. and F. N. Owens. 1983a. Influence of feed intake level on site of digestion in steers fed a high concentrate diet. J. Anim. Sci. 56:471.

Zinn, R. A. and F. N. Owens. 1983b. Site of protein digestion in steers: Predictability. J. Anim. Sci. 56:707.

APPENDIX

TABLE XVII

TREATMENT SEQUENCE CODES - TRIAL 1

| Trt. Seq.[a] | Code Number |
|---|---|
| 1-2-1 | 1 |
| 2-3-2 | 2 |
| 3-1-3 | 3 |
| 1-3-1 | 4 |
| 2-1-2 | 5 |
| 3-2-3 | 6 |

[a]0% wheat = 1; 40% wheat = 2; 60% wheat = 3.

TABLE XVIII

TREATMENT SEQUENCE CODES - TRIAL 2

| Treatment sequence[a] | Code number |
|---|---|
| 1-2-1 | 1 |
| 2-3-2 | 2 |
| 3-4-3 | 3 |
| 4-1-4 | 4 |
| 1-3-1 | 5 |
| 2-4-2 | 6 |
| 3-1-3 | 7 |
| 4-2-4 | 8 |
| 1-4-1 | 9 |
| 2-1-2 | 10 |
| 3-2-3 | 11 |
| 4-3-4 | 12 |

[a]0% wheat = 1; 40% wheat = 2; 60% wheat = 3; 80% wheat = 4.

TABLE XIX

BLOCK, LACTATION, CALVING DATE, TREATMENT SEQUENCE, POSTPARTUM DAYS WHEN STARTED, AND MILK PRODUCTION PER PERIOD FOR EACH COW - TRIAL 1

| Cow No. | Block No. | Lact. No. | Calving date, '84 | Trt. seq. | Postpartum days | Ave. milk yield (lb/day) Per. 1 | Per. 2 | Per. 3 |
|---|---|---|---|---|---|---|---|---|
| 305 | 1 | 2 | 6/13 | 1 | 72 | 64.3 | 58.0 | 54.6 |
| 269 | 1 | 3 | 6/18 | 2 | 67 | 61.4 | 55.3 | 54.4 |
| 327 | 1 | 2 | 6/19 | 3 | 66 | 71.1 | 64.8 | 61.6 |
| 247 | 2 | 4 | 8/8 | 4 | 58 | 68.7 | 57.2 | 54.6 |
| 295 | 2 | 3 | 8/17 | 5 | 49 | 63.1 | 58.3 | 49.5 |
| 360 | 2 | 3 | 8/23 | 6 | 43 | 65.1 | 63.9 | 55.7 |
| 968 | 2 | 5 | 8/25 | 1 | 48 | 84.2 | 78.6 | 72.4 |
| 076 | 2 | 5 | 8/25 | 2 | 48 | 71.3 | 62.3 | 60.2 |
| 401 | 2 | 2 | 8/31 | 3 | 42 | 56.4 | 55.1 | 48.0 |
| 303 | 2 | 3 | 9/1 | 4 | 48 | 67.2 | 60.0 | 60.4 |
| 378 | 2 | 2 | 9/5 | 5 | 44 | 58.4 | 58.6 | 46.0 |
| 241 | 2 | 3 | 9/16 | 6 | 43 | 73.6 | 66.3 | 60.6 |
| 504 | 3 | 8 | 9/15 | 1 | 48 | 68.6 | 65.5 | 61.1 |
| 380 | 3 | 2 | 9/18 | 2 | 48 | 51.0 | 49.2 | 42.3 |
| 338 | 3 | 3 | 9/10 | 3 | 46 | 70.4 | 69.3 | 58.0 |
| 294 | 3 | 3 | 9/9 | 4 | 47 | 84.6 | 76.1 | 75.1 |
| 427 | 3 | 2 | 9/9 | 5 | 47 | 68.9 | 68.2 | 55.0 |
| 456 | 3 | 2 | 9/10 | 6 | 46 | 58.4 | 59.5 | 52.4 |
| 413 | 3 | 2 | 9/16 | 4 | 47 | 65.7 | 57.7 | 53.9 |
| 376 | 3 | 2 | 9/18 | 5 | 45 | 57.8 | 56.0 | 49.5 |
| 298 | 3 | 3 | 9/18 | 6 | 45 | 70.8 | 66.0 | 53.0 |

TABLE XX

BLOCK, LACTATION, CALVING DATE, TREATMENT SEQUENCE, POSTPARTUM DAYS WHEN STARTED, AND MILK PRODUCTION PER PERIOD FOR EACH COW - TRIAL 2

| Cow No. | Block No. | Lact. No. | Calving date, '85 | Trt. seq. | Postpartum days | Ave. milk yield (lb/day) Per. 1 | Per. 2 | Per. 3 |
|---|---|---|---|---|---|---|---|---|
| 563 | 1 | 1 | 3/12 | 1 | 52 | 64.4 | 62.6 | 56.1 |
| 567 | 1 | 1 | 3/9 | 2 | 55 | 59.6 | 64.1 | 54.0 |
| 570 | 1 | 1 | 3/9 | 3 | 55 | 78.3 | 68.2 | 60.1 |
| 574 | 1 | 1 | 3/7 | 4 | 57 | 64.7 | 64.9 | 51.8 |
| 579 | 1 | 1 | 3/6 | 5 | 58 | 58.4 | 61.5 | 52.8 |
| 584 | 1 | 1 | 2/24 | 6 | 68 | 65.5 | 68.7 | 57.1 |
| 588 | 1 | 1 | 3/12 | 7 | 52 | 71.6 | 72.6 | 59.3 |
| 597 | 1 | 1 | 3/11 | 8 | 53 | 66.5 | 65.3 | 50.1 |
| 923 | 2 | 7 | 3/13 | 1 | 58 | 96.8 | 87.3 | 73.8 |
| 515 | 2 | 2 | 3/11 | 2 | 60 | 74.6 | 71.2 | 63.4 |
| 472 | 2 | 2 | 3/16 | 3 | 55 | 85.6 | 78.9 | 67.3 |
| 479 | 2 | 2 | 3/3 | 4 | 68 | 69.5 | 75.9 | 59.0 |
| 463 | 2 | 2 | 3/26 | 5 | 52 | 74.3 | 70.6 | 61.9 |
| 465 | 2 | 2 | 3/18 | 6 | 60 | 78.3 | 68.8 | 57.9 |
| 481 | 2 | 2 | 3/27 | 7 | 51 | 67.9 | 70.2 | 56.3 |
| 497 | 2 | 2 | 3/26 | 8 | 52 | 72.6 | 72.9 | 62.7 |
| 596 | 1 | 1 | 3/18 | 9 | 67 | 64.9 | 56.3 | 54.8 |
| 595 | 1 | 1 | 4/6 | 10 | 48 | 52.3 | 51.9 | 47.0 |
| 606 | 1 | 1 | 4/10 | 11 | 44 | 66.3 | 63.5 | 55.2 |
| 610 | 1 | 1 | 4/12 | 12 | 42 | 61.5 | 54.5 | 50.2 |
| 461 | 2 | 2 | 4/4 | 9 | 57 | 69.0 | 59.3 | 59.9 |
| 475 | 2 | 2 | 4/12 | 10 | 49 | 84.0 | 66.4 | 60.9 |
| 366 | 2 | 3 | 4/18 | 11 | 43 | 81.5 | 73.2 | 69.5 |
| 416 | 2 | 2 | 4/15 | 12 | 46 | 69.6 | 59.3 | 54.6 |

TABLE XXI

ACTUAL ANALYSIS OF FEEDS, % DRY BASIS

| Item | Wheat 1[a] | Wheat 2[a] | Sorghum Silage | Alfalfa Hay |
|---|---|---|---|---|
| Dry matter | 89.4 | 88.6 | 40.2 | 88.8 |
| Crude protein | 13.5 | 14.3 | 6.8 | 20.3 |
| Acid detergent fiber[b] | -- | -- | 38.5 | 34.4 |

[a]Hard red winter wheat grain analysis in Trial 1 and 2 (1 observation)

[b]Number of observations for acid detergent fiber content is 10.

TABLE XXII

USDA GRADE ANALYSIS[a]

| | US grade no. | | | | Wheat[b] | |
|---|---|---|---|---|---|---|
| Item | 1 | 2 | 3 | 4 | Exp. 1 | Exp. 2 |
| Min. test weight per bushel, lb | 60 | 58 | 56 | 54 | 61 | 60 |
| Damaged kernals (total), % | 2 | 4 | 7 | 10 | 1.9 | 2 |
| Foreign material, % | .5 | 1 | 2 | 3 | 1 | .9 |
| Moisture control, % | -- | -- | -- | -- | 12.7 | 11.5 |

[a]US Standards for Grains, USDA, Revised Dec. 1975.

[b]Two observations per experiment.

TABLE XXIII

ANALYSIS OF VARIANCE FOR MILK YIELD - TRIAL 1

| Source[a] | Degrees of freedom | Sum of squares | F value | PR>F[b] |
|---|---|---|---|---|
| Block | 2 | 14.07 | 2.28 | .1346 |
| Cows (block) | 18 | 3345.27 | 60.22 | .0001 |
| Period | 1 | 1182.43 | 383.14 | .0001 |
| Per * blk | 2 | 6.80 | 1.10 | .3561 |
| Per * per | 1 | 8.25 | 2.67 | .1215 |
| Per * per * blk | 2 | 26.43 | 4.28 | .0324 |
| Per * cow (blk) | 18 | 81.26 | 1.46 | .2247 |
| Trt - linear | 1 | 83.55 | 27.07 | .0001 |
| Trt - quadratic | 1 | 1.22 | .39 | .5387 |
| Error | 16 | 49.38 | | |
| Corrected total | 62 | 4798.66 | | |

[a]Abbreviations for sources are period (per), block (blk), treatment (trt).

[b]Probability of a larger F value.

TABLE XXIV

ANALYSIS OF VARIANCE FOR MILK YIELD - TRIAL 2

| Source[a] | Degrees of freedom | Sum of squares | F value | PR>F[b] |
|---|---|---|---|---|
| Block | 1 | 1684.42 | 111.33 | .0001 |
| Cow (block) | 22 | 2319.36 | 6.97 | .0001 |
| Period (cow) | 24 | 2193.54 | 6.04 | .0003 |
| Per * per | 1 | 104.55 | 6.91 | .0182 |
| Per * per * blk | 1 | 16.47 | 1.09 | .3123 |
| Trt - linear | 1 | 54.06 | 3.57 | .0770 |
| Trt - quadratic | 1 | 1.04 | .07 | .7970 |
| Trt - cubic | 1 | 1.19 | .08 | .7827 |
| Trt * blk - linear | 1 | 3.72 | .25 | .6267 |
| Trt * blk - quadratic | 1 | 2.66 | .18 | .6804 |
| Trt * blk - cubic | 1 | 6.24 | .41 | .5300 |
| Error | 16 | 242.07 | | |
| Corrected total | 71 | 6629.32 | | |

[a]Abbreviations for sources are period (per), block (blk), treatment (trt).

[b]Probability of a larger F value.

TABLE XXV

ANALYSIS OF VARIANCE FOR DM DIGESTIBILITY

| Source | Degrees of freedom | Sum of squares | F value | PR>F[a] |
|---|---|---|---|---|
| Treatment | 3 | .912 | 1.31 | .3066 |
| Block | 1 | 4.560 | 19.60 | .0004 |
| Block * treatment | 3 | 2.994 | 4.29 | .0211 |
| Error | 16 | 3.722 | | |
| Corrected total | 23 | 12.188 | | |

[a]Probability of a larger F value.

TABLE XXVI

COEFFICIENTS OF VARIATION FOR RESPONSE VARIABLES

| Response | Trial 1 | Trial 2 |
|---|---|---|
| Conc. DM intake | 3.72 | 7.16 |
| Roughage DM intake | 3.49 | 10.90 |
| Total DM intake | 3.49 | 8.35 |
| Total CP intake | 4.62 | 12.00 |
| DM digestibility | -- | 7.42 |
| CP digestibility | -- | 7.02 |
| Milk production | 2.85 | 5.96 |
| Milk fat content | 3.32 | 8.16 |
| 4% FCM | 3.69 | 6.42 |
| Milk protein content | 4.22 | 4.27 |
| Body weight | 533 | 302 |
| Body condition score | 125 | 2047 |
| Rumen pH | 4.07 | 4.63 |
| Rumen ammonia | 25.8 | 52.0 |
| Blood plasma urea | 13.8 | 15.3 |
| Total VFA | 19.2 | -- |
| Individual acids | | |
| Acetic | 5.60 | 7.48 |
| Propionic | 14.4 | 19.5 |
| Isobutyric | 24.5 | 234 |
| Butyric | 10.5 | 14.7 |
| Isovaleric | 16.5 | 39.7 |
| Valeric | 17.1 | 37.5 |

# VITA

Martin Allen Faldet

Candidate for the Degree of

Master of Science

Thesis: INFLUENCE OF DIFFERENT LEVELS OF WHEAT IN CONCENTRATE MIXTURE ON RESPONSES OF LACTATING DAIRY COWS

Major Field: Dairy Science

Biographical:

Personal Data: Born in Decorah, Iowa, August 13, 1962, the son of Merlin and Suzanne Faldet.

Education: Graduated from Thomas Roberts High School, Decorah, Iowa, May, 1980; received a Bachelor of Science Degree in Dairy Science from Iowa State University, Ames, Iowa, May 1984; completed requirements for Master of Science Degree in Animal Science at Oklahoma State University, December, 1986.

Experience: Family dairy and crop farm; herdsman of a dairy and livestock farm, David Wise, Decorah, Iowa, summer 1982; surveyor of agricultural courthouse records, Agri Finance Magazine, Skokie, Illinois, summer 1983; Lab technician, Nutritional Physiology Department, Iowa State University, summer 1984; Graduate teaching assistant at Oklahoma State University, 1984-1986.

Membership: Gamma Sigma Delta Honor Society, American Dairy Science Association, Delta Upsilon Fraternity.