AN ABSTRACT OF THE THESIS OF

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Title: Evaluation of Triticale Grain in High Producing Dairy Cow Rations

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The objective of this study was to evaluate triticale grain fed as a concentrate in the diet of high producing dairy cows. A lactation study, in vitro dry matter digestibilities and a preliminary physiological effects trial were conducted to evaluate triticale and used to make feeding recommendations.

In the lactation study, thirty-two multiparous Holstein cows were divided into two groups based on days in milk and initial milk production. A switchback design was employed. Diets were isocaloric, isonitrogenous, and isofibrous total mixed rations. Triticale replaced barley in the experimental ration. Daily feedings were recorded and orts were weighed back biweekly. No significant differences were noted in five day 4% fat corrected milk weights or daily average milk weight for triticale and control diets, 385.27 and 388.47 pounds, 77.05 and 77.69 pounds, respectively, when triticale replaced barley on an equal weight basis. Triticale supported a peak production

for a five day period averaging 114.25 lbs. per day and the control ration a peak five day average production of 109.30 lbs. per day. No significant difference was noted in % milk protein as treatment means were 3.14 and 3.16% for triticale and the control ration. However, five day weights for protein production were significantly higher ($P<.05$) for animals fed the control TMR (13.09 lbs.) than the animals fed the triticale TMR (12.45 lbs.). Triticale fed cows had a significantly higher milk fat % ($P<.03$) than the control group, 3.81 vs. 3.60%. Total lbs. of milk fat produced were not different (3.02 and 2.98 lbs./day for triticale and control, respectively). No difference was noted in ADFI as cows consumed 57.90 and 56.94 # DM daily for the control and triticale TMR, respectively.

Results of the _in vitro_ study indicates that different feedstuffs had different _in vitro_ dry matter digestibilities (IVDMD). Mean IVDMD for corn, barley, 50/50 corn-barley and triticale grain was 92.38, 87.32, 88.19 and 92.78%. Triticale and corn grain had similar IVDMD, which were significantly higher than barley and the 50/50 corn-barley mix. Data also indicated that their was no difference in IVDMD between the control or triticale ration.

Four cull cows were identified and placed on the triticale TMR for approximately 120 days. Upon completion of the feeding period, the cows were slaughtered and the internal organs were examined. No lesions or abscesses were noted in the liver or rumen of any of the animals.

Results from this trial indicate that triticale can successfully be fed (at 24% of diet DM) to high producing dairy cows without significantly effecting performance or health of the animal. On the basis of the results of this trial, constraints of feeding triticale in dairy rations would be price and availability of triticale.

Evaluation of Triticale Grain in High Producing Dairy Cow Rations

by

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Literature Review

Introduction

With increasing costs of milk production, coupled with constant milk prices, more cost effective alternatives to maintain milk production are needed. In the Northwest, there has been increasing interest in utilizing triticale in dairy rations due to its increased market availability and its potential as a least-cost feedstuff. However, lack of data on triticale utilization in dairy cow diets make it difficult to make feeding recommendations for dairy producers.

Triticale is a cereal grain produced by cross-breeding of wheat (*Triticum durum L.*) and rye (*Secale cereale L.*). The purpose of the cross was to develop a superior grain by combining the grain yield, flour quality and disease resistance of wheat with the vigor, winter hardiness, disease resistance and protein content of rye. Early cultivars had many undesirable characteristics such as low yield, shriveled grain, poor test weight, poor seed set, and excessive plant height. Further development (intensive breeding programs, increased chromosome numbers) has generated new cultivars which are similar to wheat in grain production and have bushel weights up to approximately 50 pounds.

Triticale's nutrient composition is similar to cereal grains traditionally utilized as livestock feed (Figure 1a-c). Chemical analysis (NRC, 1988) indicates that triticale has a net energy of lactation (NEL, Mcal/kg) slightly lower than corn and hard and soft wheat, similar to barley and slightly higher than sorghum. Acid detergent fiber (%) values are similar among feedstuffs, with corn and wheat lowest followed by sorghum, barley, and triticale. Triticale has the highest crude protein content (%). Based on chemical analysis, triticale should be able to replace other cereal grains.

In reviewing the literature on triticale, a number of inconsistencies are apparent. These inconsistencies arise from considerable variation in the protein content and amino acid profile of triticale investigated. Numerous crosses and varieties have been developed. Belcher and Withers (1981) reported protein content varied from 10.1% to 17.7% in various varieties. Villegas et al. (1970) reported lysine content of triticale protein varied by 50% (from 2.32 g to 3.42 g per 16 g of nitrogen). Obviously, feeding comparisons against a common standard might yield quite different results depending on the protein and amino acid

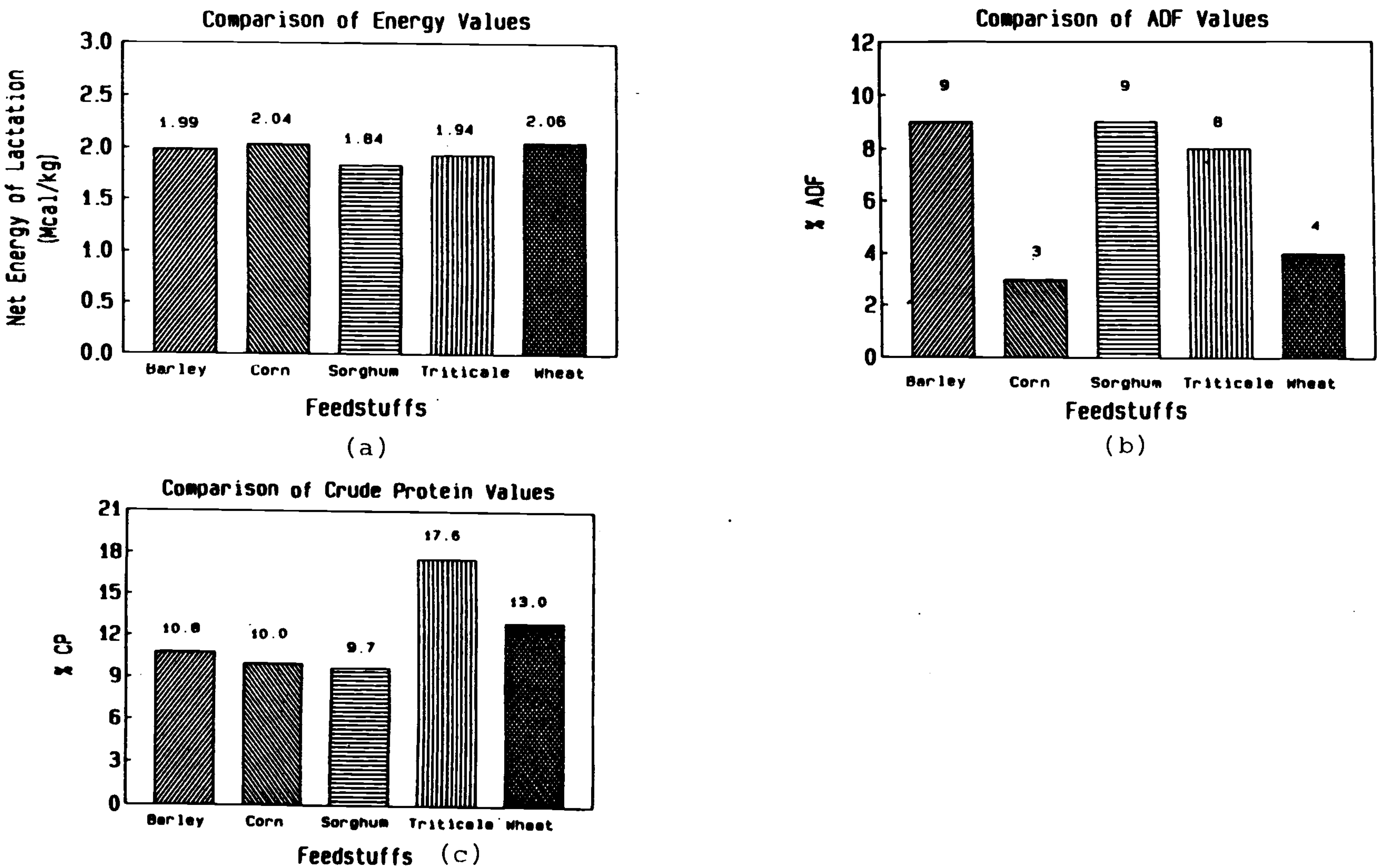

Figure 1a-c. Nutrient comparison of cereal grains (NRC, 1988).

content of the triticale employed.

Much work has been done in evaluating protein utilization of triticale. Rao et al. (1980) compared protein quality of corn, wheat, and triticale, by chemical score and rat bioassay methods. Chemical analysis of the three feeds indicated triticale was higher in lysine and threonine compared to corn and wheat. From the results of the rat bioassay trial, triticale was significantly higher in digestible protein than corn and similar to that of wheat. Triticale protein efficiency ratios (PER) and net protein retention (NPR) values were significantly higher than those of corn. Triticale's net protein utilization (NPU) and biological value (BV) calculations were similar to those of wheat and superior to corn. Knipfel (1969) compared protein quality of triticale, wheat, and rye. Data indicated PER values were similar for triticale and rye and were significantly higher than those for wheat. The superiority of triticale was suggested to be due to a higher content of lysine and sulfur amino acids.

Acceptability of triticale was considered a possible problem when fed to livestock. Conflicting data has been reported on triticale acceptability. Shimada et al. (1974) reported acceptance problems with triticale in the diet of young pigs. Low consumption was thought to be due to factors of triticale itself or to contamination with ergot.

Reddy et al. (1979) reported significantly lower feed intakes of chicks fed triticale and wheat compared to corn based broiler chick diets. However, other studies reported no significant differences in feed intake in swine (Hale and Utley, 1985) and finishing beef (Hill and Utley, 1986) due to dietary triticale.

Triticale as a Non-ruminant Feed

Most of the work evaluating triticale has been in non-ruminants, specifically swine and poultry. Extensive research has been conducted utilizing triticale in swine rations. Meyer and Barnett, (1985) evaluated the nutritional value of Beagle '82 triticale as a replacement for corn and soybean meal in a typical corn-soybean meal based diet for starting and growing-finishing swine. In the starter phase, two diets with equal lysine content were formulated: a corn-soybean meal diet and a triticale-soybean diet. Treatment means for average daily gain (ADG, in kg), average daily feed intake (ADFI, in kg), and feed / gain (F:G) ratio were similar. In the grower-finisher phase, three treatments were compared: 1) corn-soybean meal-based control; 2) triticale soybean meal based diet, equal in lysine to diet 1; 3) same as diet 1 except corn and soybean meal replaced with triticale and L-lysine HCl when pigs reached 56 kg. During the growing phase, ADG and F:G were similar. During the finisher phase, pigs fed the triticale -soybean diet had significantly lower ADG and required slightly more feed per unit gain than pigs fed the corn based diet. However, performance was not different (P>.10) over the entire growing-finishing period for pigs fed either ration.

Hale and Utley (1985) conducted a nursery, growing-finishing, and finishing trial to determine the effects of Beagle '82 triticale on performance and carcass traits of swine. Triticale diets supplemented with lysine or methionine were formulated to contain less soybean meal than the corn soybean meal control diet. No treatment effects were noted in ADG or ADFI for the nursery trial. Pigs in the growing-finishing trial fed a triticale-supplemental lysine diet had significantly lower ADG than pigs fed the corn-soybean diet or the triticale diets, containing 30 and 40 percent less soybean meal in the growing and finishing phases, respectively. In the finishing trial, no significant differences in weight gain, ADG, ADFI and F:G were noted between pigs fed the corn soybean meal control and the triticale-lysine supplemented rations.

Erickson et al. (1979), noted significant differences in pig performance relative to the amount of triticale in the diet. Data suggested that starter pigs fed diets containing 0, 20, 40, and 60 percent triticale gained significantly faster than pigs fed at the 80 and 100 percent triticale levels. This study suggested that triticale can replace up to 60 percent of the corn in a starter diet without affecting performance.

The results of the swine trials suggest that triticale can be used successfully at various levels in starter and grower-finisher diets. Triticale can replace corn and soybean meal in the diets of starting, growing and finishing pigs without any adverse affects on performance. Differences in animal performance may be due to the effects of trypsin inhibitors, ergot contamination, and differing palatibilities of various cultivars.

Triticale has also been evaluated as a feedstuff in poultry rations. Reddy et al. (1979) conducted trials comparing maize, wheat, and two varieties of triticale in broiler chick diets. In experiment 1, triticale and wheat replaced 50 percent of the maize in the chick diets. They observed significantly higher weight gains for birds fed rations containing wheat or triticale 72-S than those on the maize or triticale 171 diets. In a second trial in which all the maize was replaced by wheat or triticale, no significant differences were noted in weight gain, feed consumption, or feed to gain ratio between chicks fed maize and triticale 72-S. In a third trial, isonitrogenous diets containing corn, wheat, and triticale were fed. Chicks fed triticale had poorer weight gains and significantly lower feed / gain ratios than birds fed either of the other diets. Reddy et al. suggested that the decreased performance of chicks fed triticale was due to (1) low metabolizable energy (ME) of the triticale, (2) an amino acid imbalance in the triticale protein, or (3) the presence of trypsin inhibitors.

Bragg and Sharby (1970) compared triticale to wheat as a dietary source of energy and protein for broiler chicks. Results indicated that triticale can replace wheat without an adverse effect on growth or feed / gain ratios. Animal tallow supplemented at 2.5% of the diet improved chick performances, although differences were not statistically significant. Supplementation with DL-methionine significantly improved growth whereas supplemental L-lysine showed no improvement in chick performance.

Data suggests that the replacement of triticale for other cereal grains in chick rations requires the addition of high energy ingredients, as triticale is lower in ME. Supplementation of limiting amino acids improved chick performance.

Rumen environment

In the ruminant foregut, there is a synergistic relationship between the animal and the rumen microbes. The rumen provides an anaerobic environment, constant temperature, and a relatively constant influx of water and feed, the fermentation of the latter giving rise to a considerable amount of volatile fatty acids. The rate and extent at which nutrients are hydrolyzed into simpler, more useful forms have an affect on the rumen environment and the animal's subsequent performance.

A number of interacting factors influence rumen fermentation. Rapid rates of fermentation are dependent upon sufficient substrate for rumen microorganisms. Amount and composition of diets affect rate of digestion, rate of passage and rate of rumen content turnover. Processing and particle size affects availability of feed components to rumen microbes. Campbell (1988a) reported an interaction between particle size and grain source for both ruminal and total tract starch disappearance.

Diets with high energy density and availability have greater rate and extent of acid production. As ruminal pH drifts downward, a shift occurs in microbial populations. Cellulolytic and methanogenic bacteria are less tolerant of decreases in pH and may show decreased numbers and activity (Slyter, 1976). Increasing the rate of starch digestion can reduce fiber digestion by ruminal microbes. With dairy cows, the rate and extent of fiber digestion can have a direct affect on milkfat production.

Feedstuff use in ruminants

When evaluating a feedstuff for ruminant usage, several variables determine its usefulness. Starch fermentation in the rumen has an energetic efficiency of 75 to 80%, i.e. a loss of 25 to 30% due to microbial inefficiency. Therefore, feedstuffs that introduce starch into the abomasum and small intestine for enzymatic digestion should be more efficient than those extensively fermented in the rumen. Toland (1979) compared the rate of disappearance of starch and fiber of two types of oats (light and heavy), triticale, soft wheat and hard wheat from nylon bags suspended in the rumen of steers. Results from the study indicate the rate of starch disappearance of triticale was similar to that of the two types of wheat and greater than the two types of oats. Rate of neutral detergent fiber (NDF) disappearance was also similar for wheat and triticale. Campbell et al. (1988a) compared ruminal and post ruminal starch degradation of wheat and corn using a mobile dacron bag technique. Ruminal and total starch disappearance was significantly greater for wheat than corn. These studies indicate that wheat and triticale are extensively and rapidly degraded in the rumen. This response may decrease ruminal fiber digestion and decrease milkfat test in lactating dairy cows.

Ruminal protein degradation and nitrogen retention is another variable of interest in evaluating a cereal grain. Felix et al. (1985) studied nitrogen retention (NR) in ewes fed either isonitrogenous diets or diets containing equal weights of triticale, wheat and maize. N retained (expressed as g NR/kg absorbed N) and N intake (g NR/kg) were significantly higher in the isonitrogenous trial for the wheat or triticale diets vs. the maize. No significant difference was observed in the isocaloric trial between treatments for the amount of N retained. McCloy et al. (1971) reported somewhat higher N retention in sheep when comparing triticale to sorghum.

Hill and Utley (1986) compared N retention of triticale and corn in steer diets. N retained as a percent of N intake was higher for steers fed triticale compared with the steers fed corn, although total N intake was lower due to decreased dietary CP levels.

Nutrient digestibilities of triticale have been compared to other cereal grains. Hill and Utley (1986) reported crude protein digestibility tended to increase as triticale replaced corn in the diet of finishing beef animals. Felix et al. (1985) reported no statistical differences in CP digestibility when comparing wheat, corn and triticale on an equal weight or isonitrogenous basis in sheep diets.

Results indicated wheat had the numerically highest CP digestibility and maize the lowest. McCloy et al. (1971) observed a significantly higher CP digestibility when comparing triticale to sorghum in the diet of wethers and finishing steers.

Nishimuta and Reddy (1977) reported dry matter, energy and crude fiber digestibilities were not different for dry-rolled triticale or whole triticale compared to cracked corn diets fed to lambs. Hill and Utley (1986) reported crude fiber and acid detergent fiber digestibility tended to be lower for the all triticale diet (69% of diet DM) when compared to corn in finishing beef animal diets. This implies rapid fermentation, increased acid production, and decreased cellulolytic bacteria. In contrast, Felix et al. (1985) reported higher crude fiber digestibility in diets fed to ewes, containing triticale (74% of diet DM) compared to wheat and maize.

Hill and Utley (1986) compared nutrient digestibilities of corn, triticale and a triticale/corn mix. Ether extract (EE) digestibility was significantly lower for diets containing triticale than those with corn. The decline in EE digestibility in the triticale containing rations was related to the lower dietary EE of the triticale diets. In contrast, Felix et al. (1985) reported no differences in EE digestibility in sheep fed maize, wheat or triticale.

Use of Triticale in Large Ruminant Rations

Less research has been conducted utilizing triticale as an concentrate in large ruminant diets. Corn or barley have traditionally been the main energy source fed in ruminant diets. Animals fed these two feedstuffs have high rates of gain with few physiological problems reported (Reddy et al., 1975; Hill and Utley, 1986; Campbell et al., 1988a; Nichols, 1988; Loyacano et al., 1989). Recently, greater success has been experienced feeding rapidly fermentable feedstuffs. In a study comparing corn and wheat in varying levels in finishing beef diets, Loyacano et al. (1989) reported no significant differences in animal performance when wheat was fed at 75% of the concentrate mixture. No differences were noted in average daily feed intake and no liver abscesses were detected. Nichols (1988) reported similar results when wheat was compared to corn or barley, when concentrates were fed as high as 70% of the diet. No significant differences were noted in ADG, F:G or carcass parameters.

Most of the triticale research in ruminants has been with finishing beef animals. McCloy et al. (1971) compared performance, feed consumption, and feed efficiency of finishing steers fed high grain diets. Triticale and sorghum were fed as 92% of the diet and diets were isonitrogenous. Steers fed the sorghum ration had significantly higher ADG and feed intake. However, steers fed the triticale ration were more efficient in feed conversion. Similar results were obtained when performance was expressed on a carcass basis. Steers fed triticale had significantly lower feed per unit carcass gain than the sorghum fed steers. Standard carcass traits were similar between the two treatments. Liver condemnations due to abscesses were significantly greater for steers fed the triticale ration.

McCloy et al. reported a linear decrease in ADFI with successive increases of triticale in the ration from 30% to 60% to 90% of total DM. An attempt to improve palatability and stimulate intake by 5% addition of molasses was not effective.

Reddy et al. (1975) noted similar results when comparing triticale, corn, and wheat in beef cattle finishing rations on an equal weight basis (74% of the diet DM). ADG of steers fed corn was significantly higher than triticale fed steers. No significant difference was found in F:G ratios of the steers fed triticale, corn or wheat. Steers fed corn had significantly higher warm carcass weights than steers fed triticale with wheat fed steers intermediate. A higher frequency of liver abscesses was observed in steers fed triticale or wheat than corn fed steers.

In a more recent beef feedlot trial, Hill and Utley (1986) compared Beagle '82 triticale and corn. Three isocaloric and isonitrogenous diets were fed (1) control ration with 79.6% of the dry matter as corn; (2) a ration with equal parts corn and triticale (41.8% each), and (3) a ration containing 84.2% triticale. The feedlot trial results indicated no significant differences in ADG, ADFI or F:G ratios due to dietary treatment effects.

Rapidly Fermentable Carbohydrates in Dairy Rations

Rapidly fermentable concentrates have been evaluated for lactating dairy cows. Faldet et al (1986) reported a linear decrease in milk yield as the percentage of wheat in the ration increased in the concentrate mixture. Campbell (1988b) compared effects of different protein sources in high wheat rations on milk production. Milk yields for cows fed wheat, regardless of supplementary protein source, were significantly lower than cows fed the corn-based ration. Dry matter intake was significantly lower for cows fed wheat.

Research was conducted to explore the possibility of improving performance of lactating dairy cows by the inclusion of yeast in high wheat diets (Quinonez et al., 1988). Milk yield and milk fat content was significantly higher for cows fed concentrate mixtures containing corn. Rumen fluid pH was higher in cows fed corn than in those fed wheat. Neither yield nor fat content was improved by the inclusion of yeast cultures in the wheat concentrate mixture.

Little research has been conducted on the utilization of triticale in lactating dairy cow diets. Moody (1974) conducted a lactation study comparing triticale and barley in the diets of mid-lactation dairy cows. Twelve lactating Holstein dairy cows (60-120 days post partum) were individually fed rations consisting of cubed alfalfa hay at 1.8% of their body weight (BW) daily, with the balance of their net energy requirements met by one of three concentrate mixes. The concentrate mix consisted of 92% grain, 7% molasses and 1% salt. The grain treatments were: (1) steam rolled triticale, (2) steam rolled barley or (3) equal parts of triticale and barley. Nutrient composition of the dietary treatments were similar for protein, fat, acid detergent fiber and lignin.

Milk yield and composition, apparent DM digestibilities, and ruminal volatile fatty acid (VFA) composition were compared for the three diets. No significant differences for daily milk yields due to treatment were observed. Cows averaged 20.3, 21.0 and 20.3 kg/day for the treatments of triticale, barley and the triticale/barley mix, respectively. These production levels are not indicative of cows under stress of high production. No significant differences were noted in milk composition (fat or solids-not-fat), or yield due to treatment. Ruminal VFA compared were acetic, propionic, iso- and N-butyric, and iso- and N-valeric acids. No significant differences were seen in rumen VFA concentration due to treatment. Apparent digestibility of crude protein, fat, ADF or DM were not different. No significant differences were reported in hay or grain refused with these animals consuming up to 11 kg of triticale daily.

Kincaid (1980) compared the effects of triticale and barley in midlactation dairy cows. Fourteen cows fed a grain mix consisting of 65% triticale, 15% corn, 10% beet pulp, 5% molasses, 2.35% peas, and 2.65% minerals and vitamins. Thirteen cows were fed a control mix which had barley replacing triticale. Twelve pounds of each grain mix was fed outside and all cows received an additional 8 pounds of the control mix in the parlor. In addition, cows were fed 8 pounds of dry matter of a grass legume silage and free choice alfalfa hay. The cows were fed experimental diets for five weeks. Milk yields and percent milkfat were similar for the two treatments. Average daily milk production was 25.2 kg for control cows and 24.1 kg for cows fed triticale. Milkfat percentage was 3.8% for control cows and 3.9% for cows fed triticale. The results from these two trials indicated that triticale may be successfully used as a replacement for barley in diets of midlactation dairy cows.

Proposed Study

The following report is an evaluation of triticale in high producing dairy cow rations. This study was prompted due to a lack of data on feeding triticale to high producing dairy cows, concern with rapidly fermentable carbohydrates in early lactation rations, and questions of the economic feasibility of feeding triticale. The objectives were: (1) to compare triticale to a corn-barley mix in the ration of high producing cows; (2) to evaluate the fermentation properties,via in vitro studies and liver analysis; and, (3) to economically evaluate the use of triticale in dairy rations. This study compares milk production and composition, acceptability, fermentation rates and provides preliminary physiological data on the effects of feeding triticale to dairy cows. Results from this investigation should provide information for the inclusion of a potential high quality, low cost feed ingredient.

Materials and Methods

The study evaluating triticale in high producing dairy cow rations was a three part trial: (1) a lactation study; (2) an *in vitro* study; and (3) a preliminary study on potential long term physiological effects. All cows were housed in free stalls and fed in accordance to current Oregon State University dairy practices.

Lactation Study:

For this trial, 32 multiparous Holstein cows in early lactation were used. Cows were milked twice a day at 12 hour intervals. Milk weights were recorded twice daily and milk samples were taken bimonthly, for two consecutive milkings. Samples were sent to DHIA (Dairy Herd Improvement Association) laboratory in Salem, Oregon for compositional analysis. Cows were housed in free stalls with dried solids as bedding and a housing density of 100%. Alleys were flushed twice daily. The experimental period was from October 28, 1988 to December 30, 1988.

Treatment groups were fed a total mixed ration (TMR) in the morning with feed pushed up several times during the day. Feedstuffs in the diet included corn silage, chopped alfalfa hay, whole cottonseed, a 17% crude protein pellet, and either triticale or a corn/barley mix (Table 1). Diets were formulated to be isonitrogenous, isocaloric, and isofibrous to the extent possible (Table 2). Diets were

Table 1. Composition of the experimental treatment diets.

Diet Composition (DM basis)

	Control	Triticale
Ingredient	%	%
Alfalfa, Chopped	24.79	20.38
Barley, Pacific	22.88	0
Triticale	0	23.77
Corn/Sudangrass Silage	24.24	26.98
Protein Pellet	28.09	28.87

Table 2. Chemical Analysis of Treatment Diets.

	Diet	
Nutrient	Control	Triticale
% DM	44.04	41.69
NEL (Mcal/lb)	0.75	0.75
% CP	16.29	17.26
% UIP[a]	34.47	33.88
% ADF	20.52	19.17
% NDF	39.37	39.67
Ca:P	1.98	1.88
F:Conc.	49.0:51.0	47.4:52.6

[a] Calculated based on NRC, 1988.

formulated to meet nutrient requirements for milk production (NRC, 1978). Protein requirements were calculated for undegradable intake protein (UIP) and degradable intake protein (DIP) (NRC, 1985). Trace minerals were fed free choice in the form of a salt lick block. Daily group feedings were recorded and orts were weighed back biweekly. Samples of feed and orts were collected twice a week and composited monthly for chemical analysis of ADF, NDF, and CP.

A switchback design was employed so that each cow received each treatment. Two groups were balanced for initial milk production and number of days in milk. Cows received each treatment for a period of five weeks. A ten day adjustment period was used as cows were changed from each treatment and milk weights were compared for the last 25 days on treatment.

Cows were weighed on two consecutive days at the beginning and end of each treatment period. Since the majority of the cows were in early lactation (<120 days in milk at initiation) when the animal's nutrient requirements are highest and stress is greatest, any treatment effects of triticale, positive or negative, should be detected.

In Vitro:

Dry matter digestibilities (DMD) were compared for corn, barley, triticale, a 50/50 corn-barley mix, and between the two TMR treatments fed. Rumen fluid was obtained from two mature rumen-cannulated, ovariectomized exotic-British cross heifers. Heifers were fed the control dairy TMR for six weeks prior to rumen fluid collection. Three replications of *in vitro* DMD were conducted, with time of fluid collection varied. Four samples per feedstuff were inoculated per replication. Rumen fluid was collected at 0, 2, and 10 hours post feeding. Samples were ground in a Wiley mill, 20 mesh screen, weighed to 0.5 g and inoculated. Inoculum consisted of a 50 ml mixture of one part rumen liquor, one part nutrient buffer solution (McDougall, 1948), one part phosphate buffer and two parts distilled water. Samples were frozen after 48 hours to stop fermentation. Samples were filtered, dried and weighed to determine DMD.

Preliminary Physiological Effects Study:

Four cull cows were identified and placed on the triticale TMR for approximately 120 days. Upon completion of the trial, cows were slaughtered and livers were examined for abscess or lesions.

Statistical Analysis:

Data from the lactation study and the *in vitro* study were analyzed using Statgraphics statistical software package. For the lactation study, milk weights were analyzed as five-day milk weights. Initial five-day milk weights in each period were used as a covariate to standardize individual cow's production. Two-factor analysis of variance was performed on data for milk production and compositional analysis. Data from the in vitro study was analyzed using a two-way analysis of variance (ANOVA).

Results and Discussion

Lactation Study:

Results for 4 percent fat corrected milk (FCM), percent milk fat (% MF), and percent protein are summarized in Table 3. Five day milk production was compared. Data from two cows was deleted from analysis as they contracted mastitis and had to have a quarter dried off. No significant differences ($P>.10$) were noted in five day 4% FCM weights for triticale and control diets, 385.27 and 388.47 pounds, (77.05 and 77.69 lbs./day), respectively, when triticale replaced barley on an equal weight basis. Triticale total mixed ration (TMR) supported a peak five day 4% FCM average of 114.25 lbs. per day and the control TMR supported a peak five day 4% FCM average of 109.30 lbs. per day.

When comparing milk composition, no significant difference was noted in percent protein as treatment means were 3.14 and 3.16% protein for triticale and the control ration. On a weight basis, five-day protein production values were significantly higher for animals fed the control TMR (13.09 lbs.) than animals fed the triticale TMR (12.45 lbs.). This difference in protein production was due to numerically higher actual milk yields of cows fed the control TMR. When comparing results for % MF, animals fed triticale had significantly higher milk fat content ($P<.03$) than cows fed the control ration (3.81 vs. 3.60, respectively). However,

Table 3. Performance of Dairy Cows Receiving Treatments.

Variable	Diet (S.E.)	
	Control TMR	Triticale TMR
5-day FCM Yield, lbs.	388.43 (4.28)	385.27 (4.88)
Avg. daily FCM yield, lbs.	77.69	77.05
Actual avg. daily milk yield, lbs.	82.57	79.52
Protein, %	3.16 (.04)	3.14 (.05)
5-day protein yield, lbs.	13.09[a] (.12)	12.44[b] (.13)
Milk fat (MF), %	3.60[c] (.09)	3.81[d] (.07)
5-day MF yield, lbs.	15.08 (.22)	14.89 (.19)
ADFI, # DM	57.90	56.94

[a,b] Means differ (P<.05).

[c,d] Means differ (P<.03).

no significant difference was noted in total fat yield as treatment means were 3.02 and 2.98 lbs./day for triticale and the control fed animals, respectively.

Since acceptability has been reported as a problem in some cases (Reddy et al., 1975; Shimada et al., 1974) it was of interest to estimate animal intake. No significant difference was noted in feed refused or average daily feed intake (ADFI) on a dry matter basis. ADFI for the two treatments was 56.94 and 57.90 lbs. dry matter for triticale and control diets, respectively. Animals consumed up to 14 lbs. of triticale (23.77% of TMR dry matter) daily.

Results of this trial are similar to those reported utilizing triticale in mid-lactation dairy cow rations (Moody, 1973; Kincaid, 1980) where no significant differences were noted in milk production and milk composition for triticale fed animals. Data suggests that triticale is equivalent to barley in high producing dairy cow diets without any effect on palatability.

In Vitro Study:

Results of the 48 hr. *in vitro* study are summarized in Table 4. Results of this study are not to be used as *in vivo* digestibilities, but rather as relative comparison of digestibilities of the feedstuffs. The results of this study coupled with results of the preliminary physiological effects study will be used to evaluate fermentation properties of

Table 4. *In Vitro* Dry Matter Digestibilities (IVDMD) for Ground Grains and Experimental Treatments.

Sample	IVDMD % (S.E.)
Corn	92.38[a] (.73)
Triticale	92.78[a] (.62)
Barley	87.32[b] (.85)
50/50 Corn-Barley	88.19[b] (.90)
TMR Control	71.53[c] (1.00)
TMR Triticale	72.47[c] (1.14)

[a,b,c] Means with different superscripts are different ($P<.05$).

triticale.

Statistical analysis indicated that different feedstuffs resulted in varying IVDMD (*in vitro* dry matter digestibility). Mean IVDMD for corn, barley, 50/50 corn-barley and triticale grain was 92.38, 87.32, 88.19 and 92.78%. Triticale and corn grain had similar IVDMD, which were significantly higher than barley or the 50/50 corn-barley mix. Data suggest that total availability of readily fermentable carbohydrates of triticale in the rumen is similar to that of corn. Other workers have reported similar results from *in vivo* studies.
McCloy et al. (1971) reported similar dry matter digestibilities when comparing triticale and sorghum in the diets of finishing beef and lambs. Hill and Utley (1986) reported no differences in dry matter digestibility of corn and triticale in the diet of steers. This suggests that triticale might be more available to the animal for utilization than barley.

A possible explanation for the higher % MF of triticale fed cows might be derived from the results of the *in vitro* study. Triticale was found to have a similar IVDMD to that of corn. Previous reports (Campbell et al., 1988) showed that corn fed in rations (in comparison to wheat) resulted in higher acetate:propionate ratios and numerically higher levels of milk fat production. Decreased A:P ratios are observed in cows with milk fat depression. If fermentation properties of triticale are similar to that of corn, then this could be a possible explanation for the significantly higher milk fat yield of cows fed triticale, and is contrary to hypothesis stated earlier (p. 10-11). Further investigations detailing rates of triticale fermentation could further clarify this mechanism.

IVDMD for the two treatment diets was not different. This suggests that the inclusion of triticale in the TMR probably will not affect the rate or amount of fermentation of carbohydrates in the animal.

Preliminary Physiological Effects Study:

Upon completion of the 120 day period of feeding the triticale TMR, four cull cows were slaughtered and internal organs were examined. No abscesses or lesions were noted in the liver of any of the animals. Other workers (McCloy et al., 1971; Reddy et al., 1975) noted high incidence of liver and/or ruminal epithelium damage when triticale was fed at high levels (74 to 92% of the diet) in finishing beef animals. No liver damage was seen due to lower levels of triticale in the diet and also inherent buffering characteristics of alfalfa. Results of this study suggest that triticale can be fed at lower dietary levels (24% of the diet) without any adverse effect on the dairy cow's health and subsequent performance.

Economic Evaluation:

With steady milk prices and increasing costs of milk production, there is an economic interest in utilizing triticale in lactating cow rations. Feed costs are typically 40-50% of the cost of milk production so there is an interest in reducing feed costs or choosing the most cost effective alternative. Using values generated from the data set, Table 5 summarizes the daily costs and returns for each of the treatments.

In the economic analysis, there are several underlying assumptions. Values for milk production in Table 5 are average daily 4% FCM values from the lactation study. Daily income from milk has been calculated for each of the treatments assuming a $12.73/cwt. 4% FCM price (current milk price of $11.97/cwt. adjusted for fat differential, $.15 for each .1% MF above 3.5%). Feed costs ($/head/day) were actual costs for each of the treatment diets as fed (at the time of the trial) and were calculated assuming that triticale is equal in purchase price to the barley. Feed costs were calculated based on $15/ton corn silage, $9.50/cwt. protein pellet, $5.65/cwt. alfalfa hay and $7.20/cwt. triticale and barley.

Under the above assumptions, triticale fed animals yielded a similar return over feed cost to barley fed animals. Actual cash expenditures for purchased feedstuffs was lower

Table 5. Analysis of feed costs.

	Treatment	
Parameter	Control	Triticale
Avg. daily 4% FCM prod., lbs.	77.69	77.05
Milk price, $/cwt.	12.73	12.73
Daily return from milk sales, $/cow	9.89	9.81
Feed costs, $/cow/day	4.05	3.93
Return over feed cost, $/cow/day	5.84	5.88

for the triticale ration. Triticale's higher crude protein content resulted in less protein being fed in the form of alfalfa hay. This reduced cash expenditures by allowing for the increased feeding of a lower protein and lower cost roughage (corn silage). Although the animals had numerically lower milk production, this analysis indicates that it is still economical to replace barley with triticale in the rations of high producing dairy cattle. However, farmers paid on protein content and/or cheese yield should evaluate returns based on their milk prices.

The results of this study indicate it is economically feasible to substitute triticale on an equal weight basis for barley. Analysis of milk production, cost of feed and returns over feed costs suggest a potential for triticale utilization as a least cost feed ingredient.

Conclusions:

These studies indicate that triticale can successfully replace barley on an equal amount basis in the diet of high producing dairy cows. Data from this trial could benefit two sectors of Oregon agriculture: growers by expanding the market for triticale, and dairy producers by providing information on an alternative high quality, least-cost feed ingredient.

Conclusions from this trial are:

(1) Triticale can effectively replace barley up to 24% of ration DM in high producing cow diets

on an equal weight basis without a significant effect on performance or income over feed costs.

(2) No problem with acceptability was noted as ADFI was not different for triticale and the control TMR fed animals.

(3) No health problems or physiological effects due to inclusion of triticale (at 24% of DMI) were noted when test animals were slaughtered.

(4) Dry matter digestibility (*in vitro*) of triticale was similar to that of corn and greater than that of barley. However, additional work, such as serial sampling for pH changes, rate of fermentation, and VFA production, would be beneficial in determining fermentation patterns.

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APPENDIX

TABLE A1. Lactation Study: cow number, treatment (1=trit., 2=control), 4% fat corrected milk, fat and protein production, and initial production (covariates).

Cow	Trmt	4% FCM (lb.)	Fat (lb)	Protein (lb)	Init. fat	Init. prot.	Init. FCM	Period
399	1	413.17	15.80	12.94	15.58	12.76	407.31	1
	1	389.48	14.90	12.20	15.58	12.76	407.31	1
	1	381.97	14.61	11.97	15.58	12.76	407.31	1
	1	383.61	14.67	12.02	15.58	12.76	407.31	1
	1	366.94	13.76	10.35	15.58	12.76	407.31	1
	2	412.85	16.56	12.49	16.44	12.40	409.84	2
	2	406.57	16.31	12.30	16.44	12.40	409.84	2
	2	394.27	15.82	11.93	16.44	12.40	409.84	2
	2	391.25	15.70	11.84	16.44	12.40	409.84	2
	2	335.70	12.73	11.03	16.44	12.40	409.84	2
413	1	390.06	16.18	11.90	16.57	12.19	399.58	1
	1	328.13	13.61	10.01	16.57	12.19	399.58	1
	1	352.75	14.63	10.76	16.57	12.19	399.58	1
	1	366.77	15.21	11.19	16.57	12.19	399.58	1
	1	294.75	10.24	8.12	16.57	12.19	399.58	1
	2	348.36	14.26	12.21	14.96	12.80	365.45	2
	2	345.25	14.13	12.10	14.96	12.80	365.45	2
	2	334.11	13.67	11.71	14.96	12.80	365.45	2
	2	312.87	12.80	10.96	14.96	12.80	365.45	2
	2	305.96	12.25	11.52	14.96	12.80	365.45	2
460	1	379.14	15.04	12.24	14.99	12.20	377.91	1
	1	361.61	14.35	11.68	14.99	12.20	377.91	1
	1	354.44	14.06	11.44	14.99	12.20	377.91	1
	1	370.50	14.70	11.96	14.99	12.20	377.91	1
	1	344.73	13.16	11.76	14.99	12.20	377.91	1
	2	364.07	14.28	12.89	14.50	13.09	369.66	2
	2	349.25	13.70	12.37	14.50	13.09	369.66	2
	2	352.17	13.81	12.47	14.50	13.09	369.66	2
	2	348.53	13.67	12.34	14.50	13.09	369.66	2
	2	350.82	13.86	12.00	14.50	13.09	369.66	2
464	1	259.54	9.80	9.01	10.77	9.90	285.36	1
	1	333.07	12.57	11.56	10.77	9.90	285.36	1
	1	342.06	12.91	11.87	10.77	9.90	285.36	1
	1	297.11	11.21	10.31	10.77	9.90	285.36	1
	1	180.09	6.35	6.88	10.77	9.90	285.36	1
	2	306.26	11.53	11.20	12.01	11.67	319.12	2
	2	316.37	11.91	11.57	12.01	11.67	319.12	2
	2	327.39	12.33	11.97	12.01	11.67	319.12	2
	2	299.13	11.26	10.94	12.01	11.67	319.12	2
	2	281.96	10.82	10.35	12.01	11.67	319.12	2
481	1	343.20	12.43	10.98	10.83	9.56	298.98	1
	1	362.02	13.11	11.58	10.83	9.56	298.98	1
	1	358.95	13.00	11.48	10.83	9.56	298.98	1

Table A1. Cont.

Cow	Trmt	4% FCM (lb.)	Fat (lb)	Protein (lb)	Init. fat	Init. prot.	Init. FCM	Period
	1	383.91	13.90	12.28	10.83	9.56	298.98	1
	1	390.98	14.81	12.83	10.83	9.56	298.98	1
	2	402.72	14.77	13.23	15.08	13.51	411.16	2
	2	413.16	15.15	13.57	15.08	13.51	411.16	2
	2	408.72	14.99	13.42	15.08	13.51	411.16	2
	2	405.61	14.87	13.32	15.08	13.51	411.16	2
	2	364.65	12.99	13.12	15.08	13.51	411.16	2
490	1	437.76	17.78	13.08	18.54	13.64	456.45	1
	1	435.46	17.69	13.01	18.54	13.64	456.45	1
	1	450.56	18.30	13.46	18.54	13.64	456.45	1
	1	457.47	18.58	13.67	18.54	13.64	456.45	1
	1	364.37	14.16	11.92	18.54	13.64	456.45	1
	2	442.38	18.01	14.60	18.96	15.37	465.74	2
	2	453.93	18.48	14.98	18.96	15.37	465.74	2
	2	449.57	18.30	14.84	18.96	15.37	465.74	2
	2	484.23	19.71	15.98	18.96	15.37	465.74	2
	2	467.43	19.10	15.20	18.96	15.37	465.74	2
501	1	477.74	18.01	13.29	18.27	13.48	484.64	1
	1	485.56	18.30	13.50	18.27	13.48	484.64	1
	1	494.08	18.63	13.74	18.27	13.48	484.64	1
	1	511.34	19.28	14.22	18.27	13.48	484.64	1
	1	467.44	16.95	13.11	18.27	13.48	484.64	1
	2	458.84	15.91	15.80	15.36	15.25	443.01	2
	2	447.17	15.50	15.40	15.36	15.25	443.01	2
	2	455.30	15.79	15.68	15.36	15.25	443.01	2
	2	460.09	15.95	15.84	15.36	15.25	443.01	2
	2	447.10	15.78	15.15	15.36	15.25	443.01	2
529	1	455.62	16.93	14.62	17.30	14.94	465.56	1
	1	432.11	16.06	13.86	17.30	14.94	465.56	1
	1	387.59	14.41	12.43	17.30	14.94	465.56	1
	1	394.82	14.67	12.67	17.30	14.94	465.56	1
	1	419.14	15.50	12.65	17.30	14.94	465.56	1
	2	463.58	18.26	15.37	18.62	15.67	472.87	2
	2	456.25	17.97	15.12	18.62	15.67	472.87	2
	2	467.49	18.41	15.50	18.62	15.67	472.87	2
	2	429.61	16.92	14.24	18.62	15.67	472.87	2
	2	354.85	13.59	11.55	18.62	15.67	472.87	2
581	1	410.02	15.72	11.93	17.27	13.11	450.51	1
	1	408.14	15.65	11.88	17.27	13.11	450.51	1
	1	408.14	15.65	11.88	17.27	13.11	450.51	1
	1	419.91	16.10	12.22	17.27	13.11	450.51	1
	1	411.67	15.78	9.40	17.27	13.11	450.51	1
	2	434.43	16.74	14.76	16.48	14.54	427.80	2
	2	432.30	16.65	14.69	16.48	14.54	427.80	2
	2	423.77	16.32	14.40	16.48	14.54	427.80	2
	2	406.95	15.68	13.83	16.48	14.54	427.80	2

Table A1. Cont.

Cow	Trmt	4% FCM (lb.)	Fat (lb)	Protein (lb)	Init. fat	Init. prot.	Init. FCM	Period
	2	383.43	14.29	12.64	16.48	14.54	427.80	2
595	1	379.08	15.47	11.80	15.32	11.68	375.47	1
	1	367.21	14.99	11.43	15.32	11.68	375.47	1
	1	348.13	14.21	10.83	15.32	11.68	375.47	1
	1	351.23	14.34	10.93	15.32	11.68	375.47	1
	1	328.70	13.57	10.01	15.32	11.68	375.47	1
	2	390.33	16.88	12.21	17.40	12.59	402.57	2
	2	383.51	16.58	12.00	17.40	12.59	402.57	2
	2	378.38	16.36	11.84	17.40	12.59	402.57	2
	2	370.70	16.03	11.60	17.40	12.59	402.57	2
	2	316.04	12.92	11.21	17.40	12.59	402.57	2
603	1	359.63	13.49	11.44	14.42	12.24	384.55	1
	1	363.06	13.62	11.55	14.42	12.24	384.55	1
	1	354.60	13.30	11.28	14.42	12.24	384.55	1
	1	350.02	13.13	11.14	14.42	12.24	384.55	1
	1	345.75	13.60	10.17	14.42	12.24	384.55	1
	2	334.71	12.27	11.82	12.92	12.44	352.27	2
	2	334.93	12.28	11.83	12.92	12.44	352.27	2
	2	326.71	11.98	11.54	12.92	12.44	352.27	2
	2	317.82	11.65	11.23	12.92	12.44	352.27	2
	2	304.05	11.10	10.62	12.92	12.44	352.27	2
636	1	367.62	13.55	12.90	13.90	13.23	377.02	1
	1	358.00	13.20	12.56	13.90	13.23	377.02	1
	1	360.46	13.29	12.65	13.90	13.23	377.02	1
	1	377.91	13.93	13.26	13.90	13.23	377.02	1
	1	384.63	14.90	12.44	13.90	13.02	377.02	1
	2	443.29	18.91	13.49	18.18	12.96	426.07	2
	2	442.18	18.87	13.45	18.18	12.96	426.07	2
	2	433.57	18.50	13.19	18.18	12.96	426.07	2
	2	314.97	13.44	9.58	18.18	12.96	426.07	2
	2	339.65	13.02	12.84	18.18	12.96	426.07	2
667	1	374.10	13.47	13.17	14.09	13.78	391.49	1
	1	361.28	13.01	12.71	14.09	13.78	391.49	1
	1	365.62	13.16	12.87	14.09	13.78	391.49	1
	1	387.36	13.94	13.63	14.09	13.78	391.49	1
	1	422.11	16.26	13.94	14.09	13.78	391.49	1
	2	411.27	15.82	14.78	16.02	14.96	416.24	2
	2	407.02	15.66	14.63	16.02	14.96	416.24	2
	2	413.88	15.93	14.88	16.02	14.96	416.24	2
	2	402.52	15.49	14.47	16.02	14.96	416.24	2
	2	281.36	9.80	11.05	16.02	14.96	416.24	2
674	1	381.38	14.36	12.37	15.62	13.45	414.93	1
	1	365.76	13.77	11.86	15.62	13.45	414.93	1
	1	395.63	14.90	12.83	15.62	13.45	414.93	1
	1	381.16	14.35	12.36	15.62	13.45	414.93	1
	1	433.51	17.85	16.20	15.62	13.45	414.93	1

Table A1. Cont.

Cow	Trmt	4% FCM (lb.)	Fat (lb)	Protein (lb)	Init. fat	Init. prot.	Init. FCM	Period
	2	361.18	13.06	13.18	13.83	13.96	382.59	2
	2	339.77	12.28	12.40	13.83	13.96	382.59	2
	2	383.03	13.85	13.98	13.83	13.96	382.59	2
	2	393.08	14.21	14.35	13.83	13.96	382.59	2
	2	369.38	12.89	14.12	13.83	13.96	382.59	2
299	2	405.45	15.42	13.24	15.04	12.92	395.68	1
	2	421.51	16.03	13.76	15.04	12.92	395.68	1
	2	403.12	15.33	13.16	15.04	12.92	395.68	1
	2	404.29	15.37	13.20	15.04	12.92	395.68	1
	2	378.10	13.83	12.67	15.04	12.92	395.68	1
	1	410.46	16.10	13.39	16.38	13.63	417.75	2
	1	406.33	15.94	13.26	16.38	13.63	417.75	2
	1	416.04	16.32	13.58	16.38	13.63	417.75	2
	1	403.42	15.82	13.16	16.38	13.63	417.75	2
	1	384.42	14.63	12.45	16.38	13.63	417.75	2
370	2	367.28	14.63	12.42	15.45	13.11	387.91	1
	2	361.82	14.41	12.23	15.45	13.11	387.91	1
	2	360.33	14.36	12.18	15.45	13.11	387.91	1
	2	372.00	14.82	12.57	15.45	13.11	387.91	1
	2	353.69	13.89	12.14	15.45	13.11	387.91	1
	1	345.05	14.22	11.62	15.51	12.67	376.23	2
	1	346.89	14.30	11.68	15.51	12.67	376.23	2
	1	353.96	14.59	11.92	15.51	12.67	376.23	2
	1	352.65	14.54	11.88	15.51	12.67	376.23	2
	1	343.49	14.43	11.31	15.51	12.67	376.23	2
487	2	377.78	13.68	13.64	14.12	14.08	390.04	1
	2	361.36	13.08	13.04	14.12	14.08	390.04	1
	2	372.31	13.48	13.44	14.12	14.08	390.04	1
	2	358.30	12.97	12.93	14.12	14.08	390.04	1
	2	366.15	13.04	12.45	14.12	14.08	390.04	1
	1	430.44	17.88	13.26	17.92	13.28	431.23	2
	1	417.70	17.35	12.87	17.92	13.28	431.23	2
	1	418.76	17.40	12.90	17.92	13.28	431.23	2
	1	420.88	17.49	12.97	17.92	13.28	431.23	2
	1	381.60	15.23	12.52	17.92	13.28	431.23	2
493	2	423.84	17.83	12.98	17.24	12.55	409.75	1
	2	382.92	16.11	11.73	17.24	12.55	409.75	1
	2	356.64	15.00	10.92	17.24	12.55	409.75	1
	2	383.74	16.14	11.75	17.24	12.55	409.75	1
	2	311.86	12.22	10.16	17.24	12.55	409.75	1
	1	301.21	12.43	9.99	12.44	10.00	301.47	2
	1	286.78	11.83	9.51	12.44	10.00	301.47	2
	1	274.44	11.32	9.10	12.44	10.00	301.47	2
	1	267.88	11.05	8.88	12.44	10.00	301.47	2
	1	213.25	8.18	7.84	12.44	9.94	301.47	2
508	2	399.45	16.80	13.27	15.33	12.11	364.50	1

Table A1. Cont.

Cow	Trmt	4% FCM (lb.)	Fat (lb)	Protein (lb)	Init. fat	Init. prot.	Init. FCM	Period
	2	372.35	15.66	12.37	15.33	12.11	364.50	1
	2	356.37	14.99	11.84	15.33	12.11	364.50	1
	2	295.39	12.43	9.81	15.33	12.11	364.50	1
	2	231.79	7.86	10.34	15.33	12.11	364.50	1
	1	285.42	11.93	10.36	12.96	11.25	310.08	2
	1	266.66	11.14	9.68	12.96	11.25	310.08	2
	1	270.95	11.32	9.83	12.96	11.25	310.08	2
	1	266.39	11.13	9.67	12.96	11.25	310.08	2
	1	232.27	9.16	9.56	12.96	11.25	310.08	2
601	2	477.66	19.48	15.63	20.75	16.65	508.82	1
	2	444.19	18.11	14.53	20.75	16.65	508.82	1
	2	482.04	19.66	15.77	20.75	16.65	508.82	1
	2	490.54	20.00	16.05	20.75	16.65	508.82	1
	2	429.83	16.62	15.40	20.75	16.65	508.82	1
	1	451.45	18.72	14.76	19.33	15.23	466.00	2
	1	437.69	18.15	14.31	19.33	15.23	466.00	2
	1	455.42	18.89	14.89	19.33	15.23	466.00	2
	1	451.45	18.72	14.76	19.33	15.23	466.00	2
	1	453.30	18.80	14.82	19.33	15.23	466.00	2
612	2	392.92	14.47	13.19	14.48	13.20	393.14	1
	2	393.14	14.48	13.20	14.48	13.20	393.14	1
	2	353.60	13.02	11.87	14.48	13.20	393.14	1
	2	392.92	14.47	13.19	14.48	13.20	393.14	1
	2	392.82	14.81	12.21	14.48	13.20	393.14	1
	1	367.37	14.18	12.41	14.15	12.37	366.42	2
	1	381.63	14.74	12.89	14.15	12.37	366.42	2
	1	371.41	14.34	12.54	14.15	12.37	366.42	2
	1	333.86	12.89	11.28	14.15	12.37	366.42	2
	1	365.14	14.16	11.91	14.15	12.37	366.42	2
640	2	383.76	13.67	14.34	14.03	14.72	393.85	1
	2	383.76	13.67	14.34	14.03	14.72	393.85	1
	2	371.30	13.23	13.88	14.03	14.72	393.85	1
	2	381.18	13.58	14.24	14.03	14.72	393.85	1
	2	388.07	14.05	13.65	14.03	14.72	393.85	1
	1	455.72	19.20	14.21	19.52	14.45	463.33	2
	1	457.08	19.26	14.25	19.52	14.45	463.33	2
	1	457.63	19.28	14.27	19.52	14.45	463.33	2
	1	457.36	19.27	14.26	19.52	14.45	463.33	2
	1	443.98	18.59	14.46	19.52	14.45	463.33	2
643	2	414.67	15.65	13.31	15.69	13.34	415.59	1
	2	404.07	15.25	12.97	15.69	13.34	415.59	1
	2	389.08	14.69	12.49	15.69	13.34	415.59	1
	2	363.50	13.72	11.67	15.69	13.34	415.59	1
	2	374.68	13.61	12.03	15.69	13.34	415.59	1
	1	415.87	16.18	13.85	15.86	13.57	407.46	2
	1	413.23	16.08	13.76	15.86	13.57	407.46	2

Table A1. Cont.

Cow	Trmt	4% FCM (lb.)	Fat (lb)	Protein (lb)	Init. fat	Init. prot.	Init. FCM	Period
	1	420.68	16.37	14.01	15.86	13.57	407.46	2
	1	405.54	15.78	13.50	15.86	13.57	407.46	2
	1	421.70	16.63	12.88	15.86	13.57	407.46	2
644	2	435.85	15.04	14.56	15.51	15.02	449.53	1
	2	426.73	14.72	14.26	15.51	15.02	449.53	1
	2	395.64	13.65	13.22	15.51	15.02	449.53	1
	2	405.80	14.00	13.56	15.51	15.02	449.53	1
	2	380.06	12.48	13.11	15.51	15.02	449.53	1
	1	409.91	15.11	13.69	15.32	13.88	415.50	2
	1	401.18	14.79	13.40	15.32	13.88	415.50	2
	1	405.66	14.96	13.55	15.32	13.88	415.50	2
	1	398.50	14.69	13.31	15.32	13.88	415.50	2
	1	424.15	16.26	12.97	15.32	13.88	415.50	2
655	2	338.12	13.19	11.43	13.41	11.63	343.91	1
	2	331.13	12.92	11.20	13.41	11.63	343.91	1
	2	326.55	12.74	11.04	13.41	11.63	343.91	1
	2	322.22	12.57	10.90	13.41	11.63	343.91	1
	2	335.48	13.38	11.15	13.41	11.63	343.91	1
	1	365.58	15.81	11.44	15.88	11.49	367.29	2
	1	371.56	16.06	11.62	15.88	11.49	367.29	2
	1	369.57	15.98	11.56	15.88	11.49	367.29	2
	1	369.57	15.98	11.56	15.88	11.49	367.29	2
	1	347.47	14.82	11.26	15.88	11.49	367.29	2
660	2	415.34	16.50	13.68	17.27	14.33	434.89	1
	2	375.52	14.91	12.37	17.27	14.33	434.89	1
	2	391.59	15.55	12.90	17.27	14.33	434.89	1
	2	417.57	16.58	13.76	17.27	14.33	434.89	1
	2	363.77	13.17	12.96	17.27	14.33	434.89	1
	1	390.80	15.11	13.67	14.64	13.25	378.66	2
	1	377.23	14.58	13.20	14.64	13.25	378.66	2
	1	377.94	14.61	13.22	14.64	13.25	378.66	2
	1	370.80	14.33	12.97	14.64	13.25	378.66	2
	1	376.20	14.67	12.88	14.64	13.25	378.66	2
661	2	383.44	13.78	14.31	14.00	14.54	389.51	1
	2	364.99	13.12	13.62	14.00	14.54	389.51	1
	2	355.45	12.78	13.27	14.00	14.54	389.51	1
	2	360.00	12.94	13.44	14.00	14.54	389.51	1
	2	361.28	13.01	12.84	14.00	14.54	389.51	1
	1	385.04	15.23	13.35	15.41	13.51	389.71	2
	1	386.76	15.30	13.41	15.41	13.51	389.71	2
	1	389.96	15.42	13.52	15.41	13.51	389.71	2
	1	373.98	14.79	12.97	15.41	13.51	389.71	2
	1	366.49	14.33	13.87	15.41	13.51	389.71	2
669	2	396.78	14.20	13.69	13.99	13.49	390.95	1
	2	388.14	13.89	13.40	13.99	13.49	390.95	1
	2	395.91	14.17	13.66	13.99	13.49	390.95	1

Table A1. Cont.

Cow	Trmt	4% FCM (lb.)	Fat (lb)	Protein (lb)	Init. fat	Init. prot.	Init. FCM	Period
	2	377.13	13.50	13.02	13.99	13.49	390.95	1
	2	362.69	12.01	13.15	13.99	13.49	390.95	1
	1	397.31	14.92	13.79	15.18	14.03	404.18	2
	1	387.93	14.57	13.47	15.18	14.03	404.18	2
	1	396.40	14.89	13.76	15.18	14.03	404.18	2
	1	389.53	14.63	13.52	15.18	14.03	404.18	2
	1	384.92	14.13	13.66	15.18	13.94	404.18	2
670	2	422.48	15.81	12.79	16.27	13.17	434.79	1
	2	412.91	15.45	12.50	16.27	13.17	434.79	1
	2	440.48	16.48	13.34	16.27	13.17	434.79	1
	2	420.66	15.74	12.74	16.27	13.17	434.79	1
	2	374.63	12.54	13.05	16.27	13.17	434.79	1
	1	383.60	13.56	13.52	13.37	13.33	378.28	2
	1	374.87	13.25	13.21	13.37	13.33	378.28	2
	1	369.13	13.05	13.01	13.37	13.33	378.28	2
	1	386.16	13.65	13.61	13.37	13.33	378.28	2
	1	382.02	13.13	12.90	13.37	13.33	378.28	2
687	2	523.52	21.27	15.44	18.86	13.69	464.13	1
	2	496.38	20.17	14.64	18.86	13.69	464.13	1
	2	531.20	21.58	15.67	18.86	13.69	464.13	1
	2	546.56	22.20	16.12	18.86	13.69	464.13	1
	2	517.65	20.01	15.88	18.86	13.69	464.13	1
	1	571.27	24.59	15.58	23.47	14.88	545.31	2
	1	565.63	24.35	15.43	23.47	14.88	545.31	2
	1	552.93	23.80	15.08	23.47	14.88	545.31	2
	1	540.23	23.26	14.74	23.47	14.88	545.31	2
	1	413.32	14.83	14.79	23.47	14.88	545.31	2

TABLE A2. Lactation Study (cont.): milkfat and protein percent of cows on treatment.

Date	Cow	% Fat	% Protein	Tmt.	Per.
11/1	399	3.59	2.94	1	1
11/30	399	4.03	3.04	2	2
11/15	399	3.43	2.34	1	1
12/22	399	3.52	3.05	2	2
11/1	413	4.39	3.23	1	1
11/30	413	4.24	3.63	2	2
11/15	413	2.9	2.62	1	1
12/22	413	4.01	3.77	2	2
11/1	460	3.92	3.19	1	1
11/30	460	3.81	3.44	2	2
11/15	460	3.57	3.13	1	1
12/22	460	3.88	3.36	2	2
11/1	464	3.48	3.2	1	1
11/30	464	3.46	3.26	2	2
11/15	464	2.99	3.49	1	1
12/22	464	3.62	3.62	2	2
11/1	481	3.17	2.8	1	1
11/30	481	3.26	2.92	2	2
11/15	481	3.51	3.19	1	1
12/22	481	3.06	3.09	2	2
11/1	490	4.16	3.06	1	1
11/30	490	4.18	3.39	2	2
11/15	490	3.73	2.99	1	1
12/22	490	4.22	3.36	2	2
11/1	501	3.47	2.56	1	1
11/30	501	2.89	2.87	2	2
11/15	501	3.18	2.46	1	1
12/22	501	3	2.88	2	2
11/1	529	3.36	2.9	1	1
11/30	529	3.85	3.24	2	2
11/15	529	3.22	2.35	1	1
12/22	529	3.6	3.06	2	2
11/1	581	3.61	2.74	1	1
11/30	581	3.65	3.22	2	2
11/15	581	3.61	1.29	1	1
12/22	581	3.38	2.99	2	2
11/1	595	4.21	3.21	1	1
11/30	595	4.92	3.56	2	2
11/15	595	4.23	3.1	1	1
12/22	595	4.23	3.67	2	2
11/1	603	3.43	2.91	1	1
11/30	603	3.26	3.14	2	2
11/15	603	3.84	2.76	1	1
12/22	603	3.23	3.09	2	2

TABLE A2. Cont.

Date	Cow	% Fat	% Protein	Tmt.	Per.
11/1	614	5.96	3.21	1	1
11/30	614	6.94	4.03	2	2
11/15	614	3.99	3.21	1	1
12/22	614			2	2
11/1	636	3.3	3.14	1	1
11/30	636	4.74	3.38	2	2
11/15	636	3.7	3.01	1	1
12/22	636	3.61	3.56	2	2
11/1	667	3.13	3.06	1	1
11/30	667	3.64	3.4	2	2
11/15	667	3.65	3.18	1	1
12/22	667	2.92	3.29	2	2
11/1	671	4.16	3.04	1	1
11/30	671	3.86	3.65	2	2
11/15	671	4.54	3.85	1	1
12/22	671	3.53	3.49	2	2
11/1	674	3.46	2.98	1	1
11/30	674	3.16	3.19	2	2
11/15	674	4.31	3.9	1	1
12/22	674	2.93	3.21	2	2
11/1	299	3.54	3.04	2	1
11/30	299	3.17	3.17	1	2
11/15	299	3.24	2.91	2	1
12/22	299	3.55	3.02	1	2
11/1	370	3.96	3.36	2	1
11/30	370	4.32	3.53	1	2
11/15	370	3.82	3.13	2	1
12/22	370	4.54	3.56	1	2
11/1	487	3.17	3.16	2	1
11/30	487	4.41	3.27	1	2
11/15	487	3.06	2.68	2	1
12/22	487	3.98	3.27	1	2
11/1	493	4.56	3.32	2	1
11/30	493	4.33	3.48	1	2
11/15	493	3.8	2.96	2	1
12/22	493	3.61	3.46	1	2
11/1	508	4.56	3.6	2	1
11/30	508	4.48	3.89	1	2
11/15	508	2.76	3.47	2	1
12/22	508	3.86	4.03	1	2
11/1	601	4.2	3.37	2	1
11/30	601	4.39	3.46	1	2
11/15	601	3.68	3.37	2	1
12/22	601			1	2
11/1	612	3.29	3	2	1
11/30	612	3.67	3.21	1	2

TABLE A2. Cont.

Date	Cow	% Fat	% Protein	Tmt.	Per.
11/15	612	3.47	2.59	2	1
12/22	612	3.71	3.12	1	2
11/1	640	3.06	3.21	2	1
11/30	640	4.58	3.39	1	2
11/15	640	3.17	2.88	2	1
12/22	640	4.5	3.5	1	2
11/1	643	3.48	2.96	2	1
11/30	643	3.74	3.2	1	2
11/15	643	3.19	2.67	2	1
12/22	643	3.86	2.99	1	2
11/1	644	2.86	2.77	2	1
11/30	644	3.3	2.99	1	2
11/15	644	2.59	2.53	2	1
12/22	644	3.61	2.88	1	2
11/1	655	3.76	3.26	2	1
11/30	655	4.92	3.56	1	2
11/15	655	3.97	3.15	2	1
12/22	655	4.74	3.6	1	2
11/1	660	3.93	3.26	2	1
11/30	660	3.68	3.33	1	2
11/15	660	3.17	2.93	2	1
12/22	660	3.76	3.3	1	2
11/1	661	3.12	3.24	2	1
11/30	661	3.89	3.41	1	2
11/15	661	3.13	2.89	2	1
12/22	661	3.78	3.66	1	2
11/1	669	3.09	2.98	2	1
11/30	669	3.44	3.18	1	2
11/15	669	2.63	2.63	2	1
12/22	669	3.27	3.16	1	2
11/1	670	3.41	2.76	2	1
11/30	670	3.01	3	1	2
11/15	670	2.69	2.76	2	1
12/22	670	2.84	2.79	1	2
11/1	687	4.16	3.02	2	1
11/30	687	4.86	3.08	1	2
11/15	687	3.68	2.64	2	1
12/22	687	3.11	3.1	1	2

TABLE A3. Lactation study: orts, by treatment and period.

Date	Orts	Ration	Period
10/31	100	1	1
	125	2	1
11/3	110	1	1
	25	2	1
11/8	5	1	1
	5	2	1
11/11	0	1	1
	50	2	1
11/15	70	1	1
	340	2	1
11/18	20	1	1
	250	2	1
11/20	34	1	2
	230	2	2
11/22	100	1	2
	285	2	2
11/25	25	1	2
	190	2	2
11/29	95	1	2
	70	2	2
12/2	10	1	2
	5	2	2
12/6	50	1	2
	40	2	2
12/9	85	1	2
	60	2	2
12/13	220	1	2
	165	2	2
12/16	360	1	2
	95	2	2
12/20	420	1	2
	195	2	2
12/23	55	1	2
	295	2	2
12/27	135	1	2
	110	2	2
12/30	45	1	2
	95	2	2

TABLE A4. Lactation study: average daily feed intake, diet and period.

ADFI	Diet	Period
66.46	barley	1
66.46	barley	1
66.46	barley	1
66.46	barley	1
62.39	barley	1
62.39	barley	1
62.39	barley	1
59.63	barley	1
59.63	barley	1
59.63	barley	1
59.63	barley	1
58.74	barley	1
58.74	barley	1
58.74	barley	1
56.42	barley	1
56.42	barley	1
56.42	barley	1
56.42	barley	1
56.11	barley	2
56.11	barley	2
56.11	barley	2
53.08	barley	2
53.08	barley	2
52.72	barley	2
52.72	barley	2
53.18	barley	2
53.18	barley	2
53.18	barley	2
53.57	barley	2
53.57	barley	2
53.57	barley	2
53.57	barley	2
54.52	barley	2
54.52	barley	2
54.52	barley	2
56.79	barley	2
56.79	barley	2
56.79	barley	2
56.79	barley	2
58.3	barley	2
58.3	barley	2
58.3	barley	2
58.83	barley	2
58.83	barley	2
58.83	barley	2
58.83	barley	2

TABLE A4. Cont.

ADFI	Diet	Period
59.94	barley	2
59.94	barley	2
59.94	barley	2
58.95	barley	2
58.95	barley	2
58.95	barley	2
58.95	barley	2
57.39	barley	2
57.39	barley	2
57.39	barley	2
60.67	barley	2
60.67	barley	2
60.67	barley	2
60.67	barley	2
56.56	barley	2
56.56	barley	2
56.56	barley	2
60.03	trit	1
60.03	trit	1
60.03	trit	1
60.03	trit	1
65.71	trit	1
65.71	trit	1
65.71	trit	1
59.8	trit	1
59.8	trit	1
59.8	trit	1
59.8	trit	1
59.1	trit	1
59.1	trit	1
59.1	trit	1
58.06	trit	1
58.06	trit	1
58.06	trit	1
58.06	trit	1
60.62	trit	2
60.62	trit	2
60.62	trit	2
57.73	trit	2
57.73	trit	2
56.89	trit	2
56.89	trit	2
57.19	trit	2
57.19	trit	2
57.19	trit	2
57.83	trit	2

TABLE A4. Cont.

ADFI	Diet	Period
57.83	trit	2
57.83	trit	2
57.83	trit	2
56.12	trit	2
56.12	trit	2
56.12	trit	2
52.22	trit	2
52.22	trit	2
52.22	trit	2
52.22	trit	2
53.7	trit	2
53.7	trit	2
53.7	trit	2
53.53	trit	2
53.53	trit	2
53.53	trit	2
53.53	trit	2
54.16	trit	2
54.16	trit	2
54.16	trit	2
54.64	trit	2
54.64	trit	2
54.64	trit	2
54.64	trit	2
53.09	trit	2
53.09	trit	2
53.09	trit	2
55.56	trit	2
55.56	trit	2
55.56	trit	2
55.56	trit	2
57.41	trit	2
57.41	trit	2
57.41	trit	2

TABLE A5. *In Vitro* Study: *In vitro* dry matter digestibilities.

IVDMD	Sample	Feed	Time
90.4	100	corn	10
92.82	200	corn	10
89.94	300	corn	10
92.31	400	corn	10
92.13	10	corn	0
88.6	20	corn	0
92.56	30	corn	0
91.7	40	corn	0
90.16	1	corn	2
96.61	2	corn	2
95.38	3	corn	2
95.99	4	corn	2
86.72	100	barley	10
88.9	200	barley	10
88.26	300	barley	10
89.55	400	barley	10
87.9	10	barley	0
81.33	20	barley	0
86.12	30	barley	0
83.73	40	barley	0
89.47	1	barley	2
85.28	2	barley	2
88.05	3	barley	2
92.58	4	barley	2
92.12	100	trit	10
92.57	200	trit	10
92.83	300	trit	10
90.43	400	trit	10
92.17	10	trit	0
91.11	20	trit	0
94.72	30	trit	0
90.56	40	trit	0
90.21	1	trit	2
94.59	2	trit	2
96.9	3	trit	2
95.12	4	trit	2
81.18	100	c/b	10
86.06	200	c/b	10
88.59	300	c/b	10
88.81	400	c/b	10
88.71	10	c/b	0
85.01	20	c/b	0
90.03	30	c/b	0
85.71	40	c/b	0
91.31	1	c/b	2
91.56	2	c/b	2

TABLE A5. Cont.

IVDMD	Sample	Feed	Time
91.08	3	c/b	2
90.2	4	c/b	2
73.61	100	tmrc	10
68.72	200	tmrc	10
67.2	300	tmrc	10
68.09	400	tmrc	10
68.62	10	tmrc	0
71.32	30	tmrc	0
71.16	40	tmrc	0
72.79	1	tmrc	2
76.1	2	tmrc	2
71.74	3	tmrc	2
77.5	4	tmrc	2
69.45	100	tmrt	10
72.86	200	tmrt	10
70.78	300	tmrt	10
68.26	400	tmrt	10
72.25	10	tmrt	0
71.34	20	tmrt	0
68.95	30	tmrt	0
68.52	40	tmrt	0
80.95	1	tmrt	2
77.62	2	tmrt	2
76.14	3	tmrt	2
72.53	4	tmrt	2