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PERFORMANCE OF LACTATING DAIRY CATTLE FED DIETS CONTAINING WET OR DRY CORN GLUTEN FEED

A Thesis
Presented for the
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Degree
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ABSTRACT

Effect of adding wet or dry corn gluten feed to the ration of lactating dairy cattle was investigated in two separate experiments. In experiment one, 133 Holstein cows in a commercial dairy herd were randomly assigned to two groups based on parity and production and fed one of two diets during a 26 wk continuous study. The control diet consisted of 74.2% corn silage, 25.7% concentrate (20% Protein), .1% minerals and vitamins on a DM basis. Wet corn gluten feed replaced 25% of the control diet DM in the second diet. In experiment two, 48 lactating Holstein cows from the University of Tennessee's dairy herd at Knoxville were blocked by parity and production into groups of three. Cows within blocks were assigned to one of three dietary treatments and housed in a tie stall barn for a 2 wk preliminary period followed by a 20 wk experimental period. The basal diet for experiment two consisted of (DM basis) 35.8% corn silage, 8.4% alfalfa hay, 20.3% corn grain, and 35.6% concentrate. Wet or dry corn gluten feed replaced 25% of the control diet DM in the two experimental diets. Alfalfa hay was held constant for all treatments at 2.3 kg per cow per day.

In experiment one, there were no differences in milk yield or composition due to treatment for multiparous cows. However, primiparous heifers consuming the wet corn gluten feed diet produced more milk ($P<.005$) and 4% FCM ($P<.002$) although percentage fat or protein was not different.

In experiment two, there were no differences in actual or 4%

FCM milk production. Percentage milk fat was lowest (P<.03) for cows consuming the diet containing dry corn gluten feed. Intake of DM, CP, NDF, and ADF was higher (P<.01) for cows consuming the dried corn gluten feed diet compared to that of cows consuming the control diet. Apparent digestibility of DM was higher (P<.01) when cows consumed the diet containing dried corn gluten feed compared to the control diet. All cows gained weight regardless of treatment. The calculated efficiency of production (kg 4% FCM/kg DM intake) was lowest for cows consuming the dry corn gluten feed diet (1.33), highest for the wet corn gluten feed treatment (1.50), and intermediate for cows fed the control diet (1.40).

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CHAPTER 1

INTRODUCTION

It is generally unrecognized that the price of soft drinks has been partially influenced by livestock producers. The popularity of high fructose corn syrup as a sweetener in the mid-eighties has resulted in over 15 billion kg of corn processed annually by the wet milling industry (38). Wet corn gluten feed (WCGF) is a by-product of the wet corn milling process in which corn oil, starch, nutritive sweeteners, gluten meal, germ meal, and condensed fermented corn extractives are also produced (Figure 1). Wet corn gluten represents 28% of the original corn dry matter (DM) (16) and consists of steepwater, screenings, bran, germ, and some starch and gluten (10). Wet corn gluten feed has potential as a protein and energy supplement for poor quality forage diets because of its protein and digestible fiber content (9, 18). It is WCGF's potential as a feedstuff and income from the sale of WCGF to livestock producers which enable the wet corn milling industry to market other products, such as corn oil, starch, and fructose, more cheaply than products competing for the same market space.

Approximately 84% of all WCGF produced is dried and sent to Europe Terpestra (40), but a change in its duty free import status has been threatened by the European Common Market. Recently, plants in England have begun production of corn gluten feed (CGF) which may compete with CGF from the United States (8). The proximity of

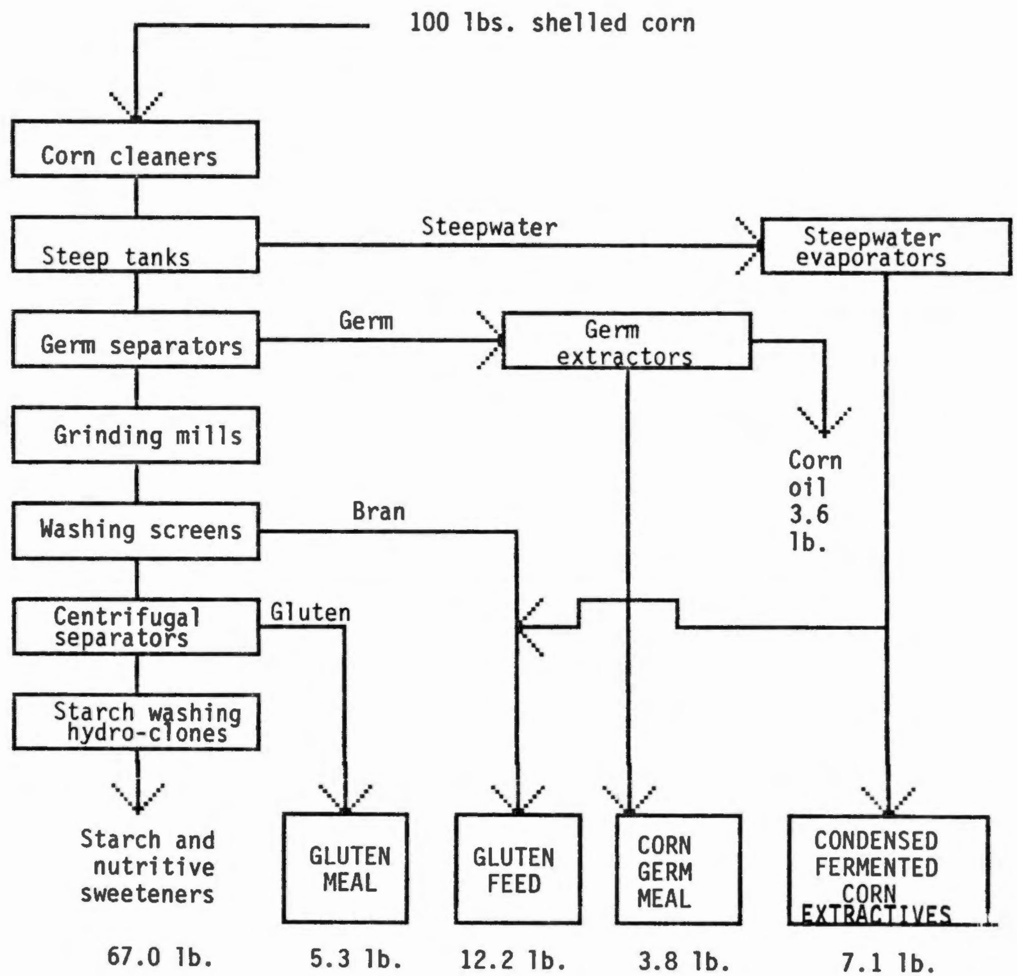

FIGURE 1. Schematic outline of the wet corn milling process (33).

dairies to corn processing plants, especially in the Midwest, suggest more WCG could be incorporated directly into dairy herd feeding programs (3). Additional reasons for local use of WCG include energy requirements and air pollution both caused from the drying process (3).

CHAPTER 2

REVIEW OF LITERATURE

Nutrient Composition

Corn gluten feed (CGF) as listed in the 1988 Nutrient Requirements of Dairy Cattle (31) contains (DM basis) 3.25 Mcal/kg metabolizable energy (ME), 25% CP, 9.7% crude fiber (CF), 12% ADF, and 45% NDF; although it has commonly been marketed at 21% CP and 8.5% CF (11). Variations in its uniformity and quality must be considered when using CGF as a feedstuff. Of the nutrients reported, CP has been the most constant, ranging from 21 (23) to 23% (20). Fiber fractions have varied widely, ranging from 7.4 (14) to 14% (20) ADF and from 39.9 (23) to 49.3% (20) NDF. The greatest variability and potential problem associated with wet CGF (WCGF) may be found in its DM content which has been reported to vary from 43.8 (14) to 56.9% (20).

This range in DM may be due to source and type of corn or be influenced by the co-products produced with WCGF. Droppo et al. (14) reported the variability of the nutrient content of 14 loads of WCGF. Nutrient means (ranges), SD between load means, and SD within loads were 22.5 (17.1 - 27.4), 2.59, and .51 for CP; 43.8 (40 - 48), and 1.9 for DM; 7.4 (5.1 - 9.1), 8.1, and .43 for ADF; and 7.2 (5.1 - 10.4), .94, and .46 for ash.

Droppo et al. (14) repeated these measurements with dry corn gluten feed (DCGF) and reported 90% DM , 25.6% CP, and 7.5% ash. Dry corn gluten feed also may have great differences in its CP, ADF, and

NDF content but because of the extensive drying process its DM is always fairly consistent around 90%.

Storage Characteristics

Jaster et al. (23) reported that by-product feeds are usually stored in concrete or wooden bunks, but stated it was common to find wet by-product feeds, such as WCGF, in unprotected piles. Storage of wet by-products unprotected may result in mold growth, discoloration, and DM deterioration (2). The amount of loss due to storage appears to vary with length and type of storage, ambient temperature, and the extent of air exposure (23). Droppo et al. (14) found WCGF could be kept at $6^{o}C$ for 21 d without noticeable spoilage, but when stored at 17 or $26.5^{o}C$ it remained free of spoilage for only 1 or 2 d at most. Wet CGF has been successfully stored anaerobically with chemical additives or mixed with other feedstuffs (26). Dry CGF does not have a storage problem because of its high degree of DM and can be stored much the same as other concentrates or protein supplements.

Dietary Levels

Amounts of wet or dry CGF fed to ruminants have varied depending on the type of production, source, and the cost of feed. Wet CGF has comprised up to 40% of the rations DM for lactating cows (38), however in most research from 26 to 30% of the dietary DM was replaced by WCGF (3, 28). Those rations or diets using DCGF are traditionally about 25% DCGF on a DM basis (28). Wet or dry CGF has been fed up to 90% of the rations DM (17), however, the study was considering finishing rations for steers and may have very different implications in lactating dairy cattle. In an experiment completed with Holstein dairy heifers, Jaster et al. (23) fed WCGF on a DM basis at 2.4% of body weight and since WCGF comprised almost the total diet, besides a mineral premix, it would seem impractical for lactating cows. Wet CGF has been reported to be generally acceptable when fed separately or in a total mixed ration (TMR); however, Armentano and Dentine (3) observed sizable portions of refusal when WCGF was fed separately at 36% of the total ration DM.

Dry Matter Consumption

Researchers have reported increased DM intake (18, 39, 42), no effect (3), or decreased DM intake when WCGF has been fed (29). In a study by Armentano and Dentine (3), DM intake was unaffected by increased feeding of WCGF up to 36% of the rations DM; however, interactions were found between treatment and age, treatment and period for total DM intake, intake of DM per kg body weight (BW), and intake of CP. Substituting WCGF for a portion of soybean meal (SBM) tended to increase DM intakes from .98 and 1.01% of BW, respectively, for SBM and CGF to 1.06% of BW for SBM and CGF combined (18). Trenkel (42) observed increased DM consumption by finishing steers when WCGF was added to the diet at 30 and 60%. Stern et al. (39) reported that the increase in DM intake was due to a faster rate of passage. In contrast, Staples et al. (38) concluded that for every 10% increase of WCGF in a diet a .59 kg/d decrease in DM intake could be expected. These authors attributed this finding to decreased organic matter (OM) and protein digestibility which is in agreement with the observations of Firkens et al. (16). Macleod et al. (28) compared TMR's containing (DM basis) 26% DCG, 18.6, 26, or 37.1% WCG fed to lactating dairy cows. Dry matter intake was lower when cows consumed WCGF compared to that observed on the DCGF diet but was similar to that for cows consuming the control diet; 16.3 kg/d, 19.4 kg/d, and 17.2 kg/d for WCGF, DCGF, and control, respectively. Macleod et al. (28) observed an immediate drop in DM intake followed by a gradual recovery when WCGF was fed. Crude protein and energy intakes have been reported to increase 20% when cows were fed a DCGF based diet compared to a SBM based diet (28). The increase in CP and energy consumption was attributed to a greater protein concentration in the diet and increased in DM intake of 2.2 kg/d greater for the DCG treatment. In the previous study (28) it was reported that lactating cows fed a WCGF based diet had DM intakes similar to control diet (SBM and corn based) but lower CP and energy intakes. Intake of metabolizable energy by beef cows was increased from 12.3 Mcal/d to 16.9, 18.4, or 17.5 Mcal/d when the low quality forage diets were supplemented with SBM, SBM plus WCGF, or WCGF (18). Replacement of 0, 20, 30, or 40% of dietary DM with WCGF resulted in linear increases in the intake of ADF, NDF, and hemicellulose (38) and a quadratic effect for NDF and hemicellulose. Firkens et al. (17) did not observe any difference in NDF intake between wet and dry CGF when they were fed as a supplemental protein source to steers. Wet CGF is recommended at 25 to 30% of dietary DM (38) up to 10 kg (as is basis) per cow per day or in the dry form of DCGF at 5 kg a day per cow (8).

Digestibility Estimates

Although varying results have been reported, effects of WCG on digestibility have generally been promising when it is compared with other fibrous feeds. Hemicellulose and ether extract fractions of WCGF undergo the most extensive digestion. The NDF fraction of WCGF vwas also extensively digested in vitro and was more completely degraded in the rumen than the NDF portion of SBM (13). Neutral detergent fiber digestibilities of CGF have been reported above 80% (1). Digestibility of WCGF fed to heifers was 76.6% compared to only 60.7% for alfalfa haylage (23). Higher digestibilities of NDF and acid detergent lignin (ADL), hemicellulose, and CP were also reported for WCGF than for alfalfa haylage, oatlage, or sorghum-soybean silage. Fleck et al. (18) found similar results and suggested replacement of SBM with CGF increased forage digestibility by altering rumen fermentation. Dry matter digestibility decreased linearly from 74.1% to 71.5, 68.9 and 69.3% when WCGF replaced 20, 30, and 40% of DM in the diet of lactating dairy cows (38).

A study with lactating cows showed digestibilities of energy and DM for WCGF and control diets but lower for the DCGF diet (29). The cellulose in WCGF is more extensively digested than the cellulose of DCGF which may explain the increase in ADF and NDF digestibilities when WCGF was compared to DCG (16).

Nitrogen (N) from WCGF is less soluble (41%) than that in DCGF

(54%), but both are more soluble than N from SBM (22%) (17). However, Macleod et al. (28) observed that 71% of the total N in WCGF was soluble compared to 21 and 30% for SBM and DCGF and 85% of the soluble N is in the NPN form for wet or dry CGF compared to 16.5% in SBM (28). Krishnamoothy et al. (24) reported that the percentage of total N in NPN form averaged 39% in DCGF, 7.7% in corn, and 11.3% in SBM. Protein escaping rumen fermentation is greater for WCGF (26%) than for DCGF (14%) (17). These differences have been suggested to be caused by the processing method used in the wet milling and subsequent drying of CGF (6).

Addition of corn gluten to the diet has had a variable influence on rumen fluid concentrations of key volatile fatty acids. Staples et al. (38) reported an increase in molar percentage of acetate, and a decrease in molar percentage propionate as WCGF was increased in the ration. In contrast, Firkens et al. (16) reported decreased molar percentage acetate and increased molar percentage propionate when WCGF was increased in the ration. When CGF was added to the diet of rumen and abomasal cannulated steers a increase in propionate was observed (5). An increase in propionate was observed when CGF was fed with fescue hay (21) and was attributed to the digestion of hemicellulose in CGF (23).

<u>Milk</u> <u>Performance</u>

Effects of the addition of WCGF to the diet of lactating cows on milk yield have varied considerably. Decreased milk yield accompanied lower DM intakes when increasing amounts of WCGF were added to the diet in some (14, 28, 38), but not all studies (3). Milk yield adjusted for DM intake was lower for cows consuming WCG (24.7% of the dietary DM) compared to DCGF (26.2% of the dietary DM) (28).

Replacement of 30% of dietary DM intake of lactating cows with WCGF increased efficiency of production from 1.11 to 1.15 kg 3.5% FCM/kg DM intake (20). Staples et al. (38) reported efficiencies of 1.07, 1.09, 1.11, and 1.15 kg 4.0 FCM/kg DMI for lactating cows fed diets containing 0, 20, 30, and 40% WCGF on a DM basis. When corrected for changes in body weight, efficiencies were highest (1.06 kg 4% FCM/kg DMI) for cows consuming the 0% WCGF diet and lowest (.96 kg 4% FCM/kg DMI) for cows consuming the 40% WCGF diet (38).

Changes in milk composition due to feeding CGF have also been reported. Although milk production was reduced by addition of WCGF to the diet, several researchers reported no change in FCM because milk fat percentage was increased (28, 29, 38). Macleod et al. (28) observed the highest fat percentage in milk of cows fed WCGF but SNF was similar to that in milk of cows not consuming WCGF. In addition, feeding DCGF increased SCM and protein percentages in milk more than either the control or WCGF diets (28). Linear depressions in percentages and yields of SNF and milk protein have been attributed to WCGF (14, 38). Staples et al. (38) suggested that the trend for decreased milk solids was due to ingesting higher amounts of N in the form of NPN. Polan et al. (34) reported a decrease in percentage milk protein as urea replaced protein in corn silage based diets fed to lactating cows which supports the observation of Staples et al. (38).

Body Weight Change

Weight change resulting from incorporation of WCGF in the diet is of importance due to the tendency of lighter cows to produce more milk and fat on a BW basis than heavier cows (36). When WCGF was fed at 0, 20, 30, and 40% of the ration, Staples et al. (38) reported a decrease of body weight (kg/d) with each increase in the amount of WCGF fed. Weight losses associated with WCGF fed at 40% of the rations DM indicate that DM intake was inadequate to support milk production (38). Another report in which wet or dry CGF were fed at 26% of the rations DM found no difference in gain between animals consuming WCGF or control diets, but there was an increase in weight gain in those animals consuming DCGF (3). Heifers have been reported to gain at faster rates when supplemented with DCGF compared to a corn urea based diet (9). Steers fed a WCGF based diet tended to gain less but were more efficient in weight gain than steer fed a DCG based diet (16). Feed to gain ratios of beef calves were reduced slightly when CGF replaced SBM and corn in isocaloric diets (27). Higher total gains and growth measurements have also been reported in heifers fed WCGF as compared to several different silages (23).

Wet or dry CGF has been reported to be a viable energy and protein source that can partially replace traditional feeds such as corn, SBM, and in some cases urea (6, 17). Addition of SBM appears to improve the use of CGF which suggests a combination of SBM with wet or dry CGF is a more useful supplement than CGF alone (18). Reports suggest that WCGF can be fed up to 30% of the ration DM or replace 80% of the dietary concentrate in corn silage based diets without affecting 4% FCM production, or DMI (3, 20, 38). Corn gluten feed, especially WCGF, may be a good source of protein for raising dairy replacements. This would allow for rapid use of this highly perishable feed and for maximum economic feasibility (3). A decision whether to use CGF should be based on a cost benefit analysis which considers the large variability in nutrient content, cost of alternative feeds, and milk pricing formulas. Other potential problems must also be addressed, such as storage, handling, consistency of the product, and availability (28).

CHAPTER 3

MATERIALS AND METHODS

Experiment One

One hundred and thirty-three Holstein cows in a commercial dairy herd were paired by age, previous lactation performance, stage of lactation, and current production. One cow in each pair was randomly assigned to one of two treatments in a 26 wk continuous trial. Diets were formulated to contain 16% CP and 18% ADF and were control or 25% WCGF (Table 1).

The experiment was conducted at the Bill and Larry Stafford dairy farm located north of Loudon Tennessee on route 72. Both experiments were supported financially by the A. E. Staley corporation headquartered at Decatur, Illinois and CGF for both experiments was trucked to the farms from the Staley plant located at Loudon, Tennessee. The A. E. Staley plant at Loudon produces the wet and dry CGF from the wet milling process of corn in which corn products for human consumption or ethanol are also produced.

Diets were fed as total mixed rations (TMR). The commercial protein supplement1 contained 20% CP, 4% crude fat, 7% CF, and supplemental vitamins A and D-3. Additional 20% dairy feed was fed to each cow in the parlor according to individual production. Both groups were allowed to graze one of two pastures which were rotated weekly. Cows were milked twice daily and fed immediately following each milking.

TABLE 1. Components of diets fed to lactating cows in experiment one.

Ingredients	Treatment	
	Control	WCG
Corn Silage	74.18	65.26
29% Concentrate[1]	25.72	9.29
Min and Vit	.10	.54
Wet Corn Gluten	.00	24.91

[1]Co-op 20% Golden Dairy pellet form; 20% CP, 4% crude fat, 7% crude fiber, 4,000 USP units/lb vitamin A, and 1,500 USP units/lb vitamin D-3.

Samples were taken of individual feedstuffs and TMR weekly. Rations were adjusted 1 wk later according to analysis to provide the desired nutrient concentrations. Milk production was recorded twice monthly by a DHIA tester and samples taken for analysis of fat, protein, and lactose by the DHIA lab in Blacksburg, VA.

Cows that freshened during the trial were randomly assigned to one of the two groups, attempting to keep the two groups as even as possible.

Experiment Two

Forty-eight Holstein cows in the University of Tennessee dairy herd were blocked by calving date, age, and previous production into 16 groups of three. One cow from each block was then randomly assigned to one of three treatments. All cows were housed in a tie stall barn. Each animal was fed the control ration (Table 2) for a 2 wk preliminary period. At the beginning of wk 3, cows were assigned to experimental diets for the following 20 wk.

Diets were formulated to contain 18% ADF and 16% CP on a DM basis. The control diet consisted of alfalfa hay, corn silage, and a concentrate mix of 23% CP (Table 2). The wet or dry CGF replaced 12% of the corn silage, and 41.5% of the concentrate (DM basis) in the control diet, such that 25% of the total ration DM was replaced. The amount of hay was held constant at 2.3 kg/cow fed for all treatments and fed once daily. The remainder of the diet was hand mixed and offered for ad libitum consumption three times a day. Daily records were kept monitoring the feed and hay offered and refused for each

TABLE 2. Components of diets fed to lactating cows in experiment two.

Ingredients[1]	TREATMENT		
	Control	WCG	DCG
Corn Silage	35.78	28.82	29.29
West Corn Gluten	.00	24.81	.00
Dry Corn Gluten	.00	.00	24.95
Alfalfa Hay	8.36	8.56	7.87
Corn Grain	20.30	13.94	14.16
Concentrate[2]	35.56	23.87	23.73

[1]All components on DM basis.

[2]The concentrate, custom mixed by Purina Mills, Inc., St. Louis, MO 63144, contained 56.8% ground yellow corn, 39% dehulled soybean meal, 1.1% calcium carbonate, 2.1% dicalcium phosphate, .45% plain salt, D premix.

cow. Samples of the total diets and individual feedstuffs were taken weekly and diets were adjusted to desired nutrient concentrations.

Milk weights were recorded daily, and samples were taken twice a month for fat, protein, lactose, and solids non-fat analyses. Cows were weighed at the beginning of the preliminary period and every 3 wk on d 1.

Digestion Trial

Apparent digestibilities of total DM and individual nutrients of the diets were estimated at the beginning, middle, and toward the end of the 20 wk experimental period (Table 3) using indigestible ADF as an internal digestibility indicator (41). Total mixed rations, refused feed, and fecal samples for each cow were composited for 4 d in each collection period. Fecal samples were collected at 0000, 0800, and 1600 h (d 1), 0200, 1000, and 1800 h (d 2), 0400, 1200, and 2000 h (d 3), and 0600, 1400, and 2200 h (d 4). The collection schedule remained the same but not all cows were collected at the same week on the project in order to minimize the number of separate collection periods. Fecal grab samples were taken by the "tickle" technique into 120 ml plastic cups. Samples were stored at 38^{o}C until all samples for the period were taken then composited for each cow and subsampled.

After diets were subsampled, samples were dried in at 60^{o}C in a forced air oven, equilibrated with atmospheric moisture for determination of air DM, and ground through a Wiley mill with a 1 mm screen. Total DM and CP (4) were determined on all samples. Samples

TABLE 3. Collection schedule for cows in experiment two.

Group Number	1	2	3	4	5	6	7	8
Number of Cows	6	9	3	9	9	6	3	3
1st Collection	7	5	5	4	8	6	9	8
2nd Collection	15	13	15	14	16	14	13	16
3rd Collection	23	22	23	22	23	21	22	21

were analyzed for ADF and NDF (19). To estimate the amount of protein that was available to the animal wet and dry CGF were analyzed for acid detergent insoluble nitrogen (ADIN) content (19). Indigestible ADF (IADF) following in vitro digestion (41) was determined on all samples. Each sample was randomly allotted into two of five runs being careful not to have the same sample in one run twice. Preparation of inoculum and the incubation procedure was similar to that described by Waller et al. (44) but with subsamples increased to .5 g and the incubation of feed samples in acid pepsin solution was eliminated. Acid detergent fiber in digested samples was analyzed by the method described by Goering and Van Soest (19).

Calculating Digestibilities

Digestibilities of DM, CP, ADF, and NDF were calculated for each of the three treatments in each period using indigestible ADF as an internal marker. Calculations for nutrient digestibilities were made by using the following equation (30).

Digestibility = 100 - (100 (% indicator in feed/% indicator in feces) * (% nutrient in feces/ % nutrient in feed)

Statistical Analysis

Diet composition data were tested for differences due to treatment using the least squares method (35). Animal production data were tested for the main effects and the residual was used to test for significance of each main effect. Response variables (milk, fat, and 4% FCM) were averaged by week and treatment and subjected to analysis of covariance using SAS (35). The average of each response variable for each treatment during the preliminary was the covariate in experiment two with previous lactation serving as a covariate in experiment one. In the case of production of primiparous cows no covariate was used. Where differences were determined, least square means were separated using the Student Neuman-Keuls multiple range test (37).

CHAPTER 4

RESULTS

Experiment One

The average nutrient content, standard deviation of the mean, and minimum and maximum values of WCGF is presented in Table 4. Dry matter content ranged from 32 to almost 56% in the 22 samples analyzed. The CP, CF, ADF, and NDF content of WCGF also varied with the average of each being 20.6%, 17.7%, 12.5%, and 42.0%, respectively. The chemical analysis of individual feedstuffs are presented in Table 5 with the average analysis of the total diet in Table 6.

Replacement of a portion of the dietary DM with WCGF did not result in statistically significant changes in milk, fat, protein and 4% FCM in multiparous cows (Table 7). Throughout the trial, 4% FCM plotted bimonthly was similar for multiparous cows fed both diets (Figure 2) and followed typical lactation curves. However primiparous cows fed the WCG diet produced greater ($P<.01$) amounts of actual and 4% FCM (Table 7). Differences in FCM were evident after wk 9 (Figure 3) and remained higher throughout the remainder of the trial. Percentage milk fat, and protein (Table 7) were not different due to treatment.

Experiment Two

Wet CGF (Table 8) varied the greatest in its ADF content ranging from 7.1 to 36.3% with an average of 12.4% and a SD of 5.91

TABLE 4. Analysis of wet corn gluten feed during the 26 wk trial in experiment one.

Nutrient	N	Mean	SD	Minimum	Maximum	C.V.
DM	22	44.2	6.40	32.1	55.9	14.47
CP	23	20.6	1.71	16.6	23.3	8.32
ADF	22	12.5	5.60	5.9	28.5	44.66
NDF	23	42.00	7.12	29.3	52.8	16.96

TABLE 5. Chemical analysis of individual ingredients in diets fed to lactating cows in experiment one.

		Diet Component Analysis			
Ingredients	N	DM (%)	CP	ADF	NDF
			---------(% of DM)---------		
WCGF	22	44.2	20.6	12.5	42.0
Concentrate	13	87.4	22.2	9.2	25.4
Corn Silage	13	37.8	7.1	38.2	63.5
Wheatlage	9	25.9	9.4	43.9	71.5
Sudan Hay	13	78.2	10.8	46.8	75.3
Wheat Hay	13	84.0	7.9	40.3	65.6

TABLE 6. Average chemical analysis of diets fed to lactating cows over the 26 wk experimental period in experiment one.

Treatment	DM (%)	CP	ADF	NDF
		------------(% of DM)------------		
Control	46.9	14.3	24.4	47.3
Wet Corn Gluten	40.4	13.9	21.8	53.0
SE	1.55	.53	1.80	.93
P>F	.01	.62	.31	.01

TABLE 7. Effects of addition of wet corn gluten feed to the diet of multiparous and primiparous cows on milk production and composition in experiment one.

	Treatment			
	Control	WCGF	SE	P>F
Multiparous cows				
Milk, kg/d	26.4	26.7	.61	.83
Fat, %	3.28	3.40	.06	.13
4% FCM, kg/d	23.6	24.3	.50	.33
Protein, %	3.00	3.05	.03	.14
Primiparous heifers				
Milk, kg/d	20.7	23.5	.68	.005
Fat, %	3.32	3.42	.06	.23
4% FCM, kg/d	18.5	21.4	.63	.002
Protein, %	3.04	3.04	.64	.95

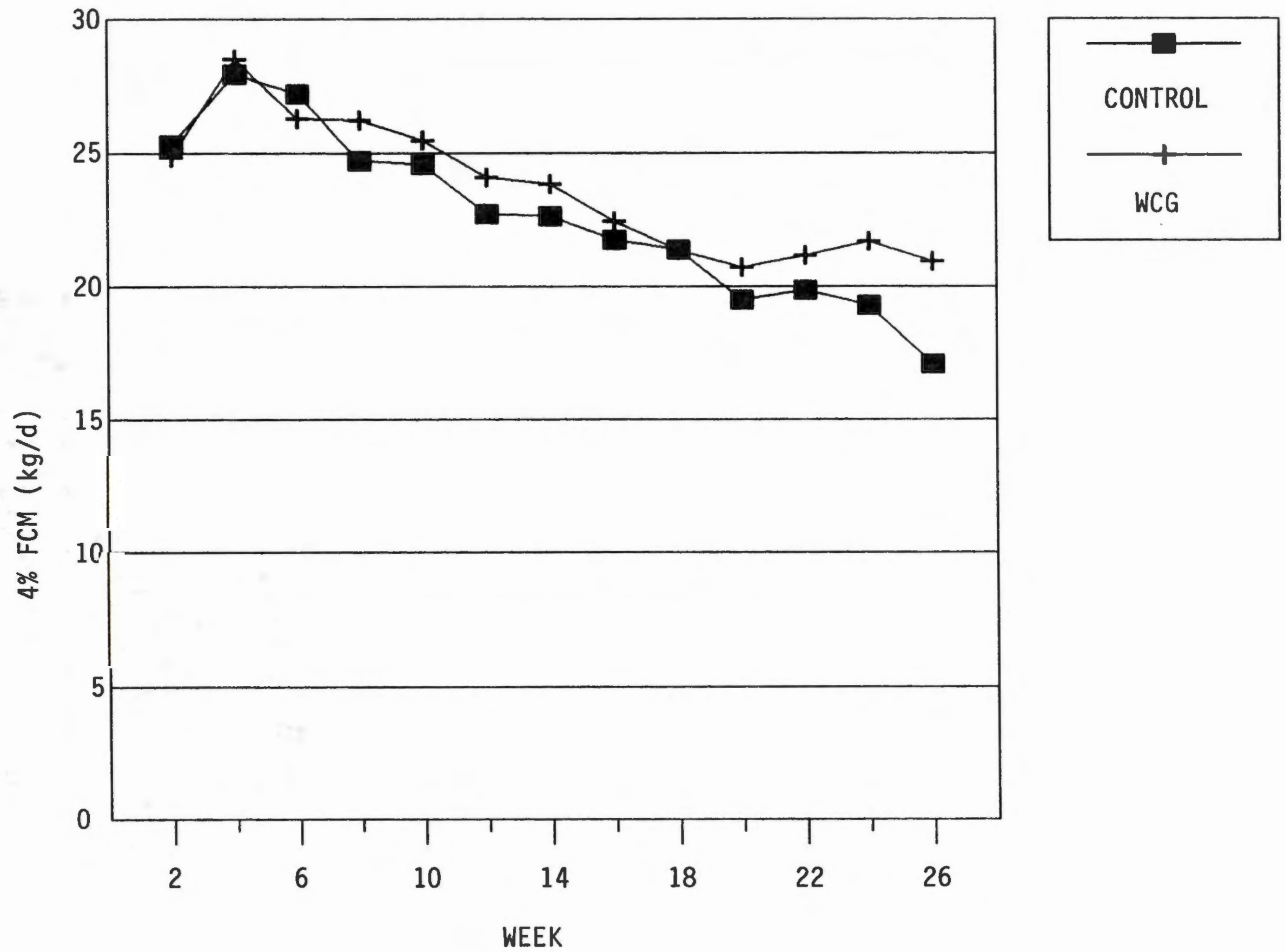

FIGURE 2. Biweekly milk production of multiparous cows by treatment in experiment one.

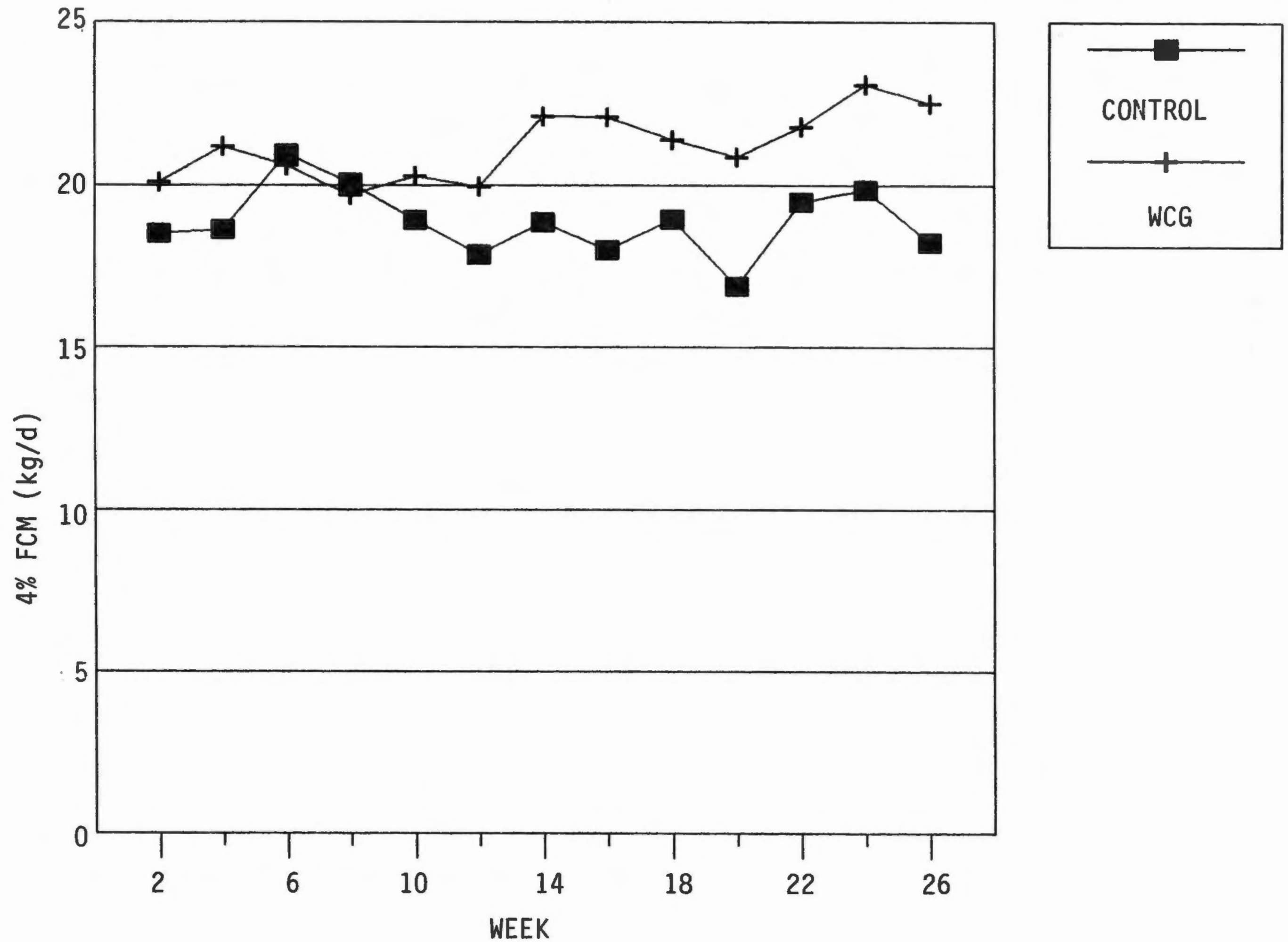

FIGURE 3. Biweekly milk production of primiparous heifers by treatment in experiment one.

TABLE 8. Analysis of wet and dry corn gluten feed during the 20 wk experimental period in experiment two.

Nutrient	N	Mean	SD	Minimum	Maximum	C.V.
Wet Corn Gluten Feed						
DM	31	47.3	5.03	38.4	57.1	10.63
CP	31	20.5	2.18	14.2	25.1	10.65
ADF	31	12.4	5.91	7.1	36.3	47.54
NDF	31	39.3	7.97	25.3	55.5	20.27
ADIN	26	4.9	3.21	2.6	14.9	65.38
Dry Corn Gluten Feed						
DM	20	86.7	1.37	82.4	88.9	1.58
CP	20	18.1	3.43	14.2	23.9	18.97
ADF	20	13.0	2.84	9.4	16.2	21.91
NDF	20	49.1	10.16	35.9	62.2	20.70
ADIN	16	7.4	6.14	2.3	29.6	82.97

over 31 samples. Crude protein and NDF also varied and are shown in Table 8. Averages for ADIN were higher for DCGF (7.4%) than of WCGF (4.9%). Dry CGF also varied considerably in nutrient contents but as expected was very constant in is DM content (Table 8). Nutrient content averages for CP, ADF, and NDF were 18.1%, 13.00%, and 49.1%. Individual feedstuff chemical analysis along with the analysis of the TMR are presented in Tables 9 and 10.

Cows fed the WCGF or DCGF diets produced similar amounts of milk (Table 11) compared to cows fed the control ration. Cows fed the DCGF diet produced milk with a lower ($P<.03$) fat percentage than cows fed either the WCGF or control diets. Thus, there was a trend for animals fed the DCGF diet to produce less 4% FCM than cows fed the WCGF diet, though no significant differences were detected. The trend with increased production from the CGF diets was consistent based on biweekly 4% FCM (Figure 4). Cows fed the DCGF diet produced milk with a lower ($P<.03$) fat percentage than cows fed either the WCGF or control diets. Efficiency of milk production, calculated by dividing 4% FCM production by DMI, both in kg/d, was highest for the WCGF diet (1.45) and lowest for the DCGF diet (1.37), with the control diet (1.41) intermediate between the other two.

Intakes of DM, CP, ADF and NDF were higher ($P<.01$) for lactating cows fed the DCGF diet than cows fed control (Table 11). Apparent digestibility of the DCGF diet were higher for DM ($P<.01$), CP ($P<.04$), NDF ($P<.02$), and ADF ($P<.03$). Intake of NDF was highest for cows consuming the DCGF diet, intermediate for WCGF, and lowest by the control group ($P<.01$).

TABLE 9. Chemical analyses of individual ingredients in diets fed to lactating cows in experiment two.

		Diet Component Analysis			
Ingredients	N	DM (%)	CP	ADF (% of DM)	NDF
Wet Corn Gluten	31	47.5	20.4	12.6	39.3
Dry Corn Gluten	20	84.8	18.3	12.8	48.5
Concentrate	41	87.2	28.1	5.0	14.5
Corn Silage	24	28.5	9.6	35.2	57.7
Corn	14	87.7	10.7	4.1	17.2
Alfalfa Hay	7	87.8	14.2	39.5	50.7

TABLE 10. Average chemical analysis of diets fed to lactating cows over the 20 wk period in experiment two.

Treatment	DM (%)	CP	NDF	ADF
		------------(% of DM)	--------------	
Control	41.9^{B}	14.1^{B}	41.0^{B}	20.6
Wet Corn Gluten	39.6^{C}	15.1^{A}	43.5^{A}	20.9
Dry Corn Gluten	45.6^{A}	14.8^{A}	44.9^{A}	20.4
SE	.15	.08	.38	.17
P>F	.0001	.0001	.0002	.42

^{A,B,C}Nutrients, within columns, with different superscripts differ at levels of probability shown.

TABLE 11. Effects of addition of wet or dry corn gluten feed to the diet of lactating cows on milk production, intake, digestibility, and body weight change in experiment two.

	Control	WCG	DCG	SE	P>F
<u>Milk Production</u>					
Milk, kg/d	28.74	30.82	30.85	.51	.16
Fat, %	3.70^{A}	3.73^{A}	3.48^{B}	.04	.025
FCM, kg/d	27.59	29.60	28.28	.45	.33
<u>Intake, kg/d</u>					
DM	19.7^{B}	19.8^{AB}	21.2^{A}	.72	.01
CP	2.8^{B}	3.0^{AB}	3.2^{A}	.13	.01
NDF	8.0^{C}	8.6^{B}	9.5^{A}	.38	.01
ADF	4.1^{B}	4.3^{AB}	4.4^{A}	.16	.01
<u>Apparnet Digestibility, %</u>					
DM	73.5^{B}	75.1^{AB}	76.4^{A}	.69	.01
CP	72.4^{B}	74.2^{AB}	75.5^{A}	.85	.04
NDF	65.3^{B}	66.9^{AB}	68.6^{A}	.82	.02
ADF	61.9^{B}	63.4^{AB}	65.3^{A}	.88	.03
<u>Body Weight, kg/d</u>					
Increase	1.6	2.4	2.4	.25	.35

^{A,B,C}Treatments, within lines, with different superscripts differ at levels of probability shown.

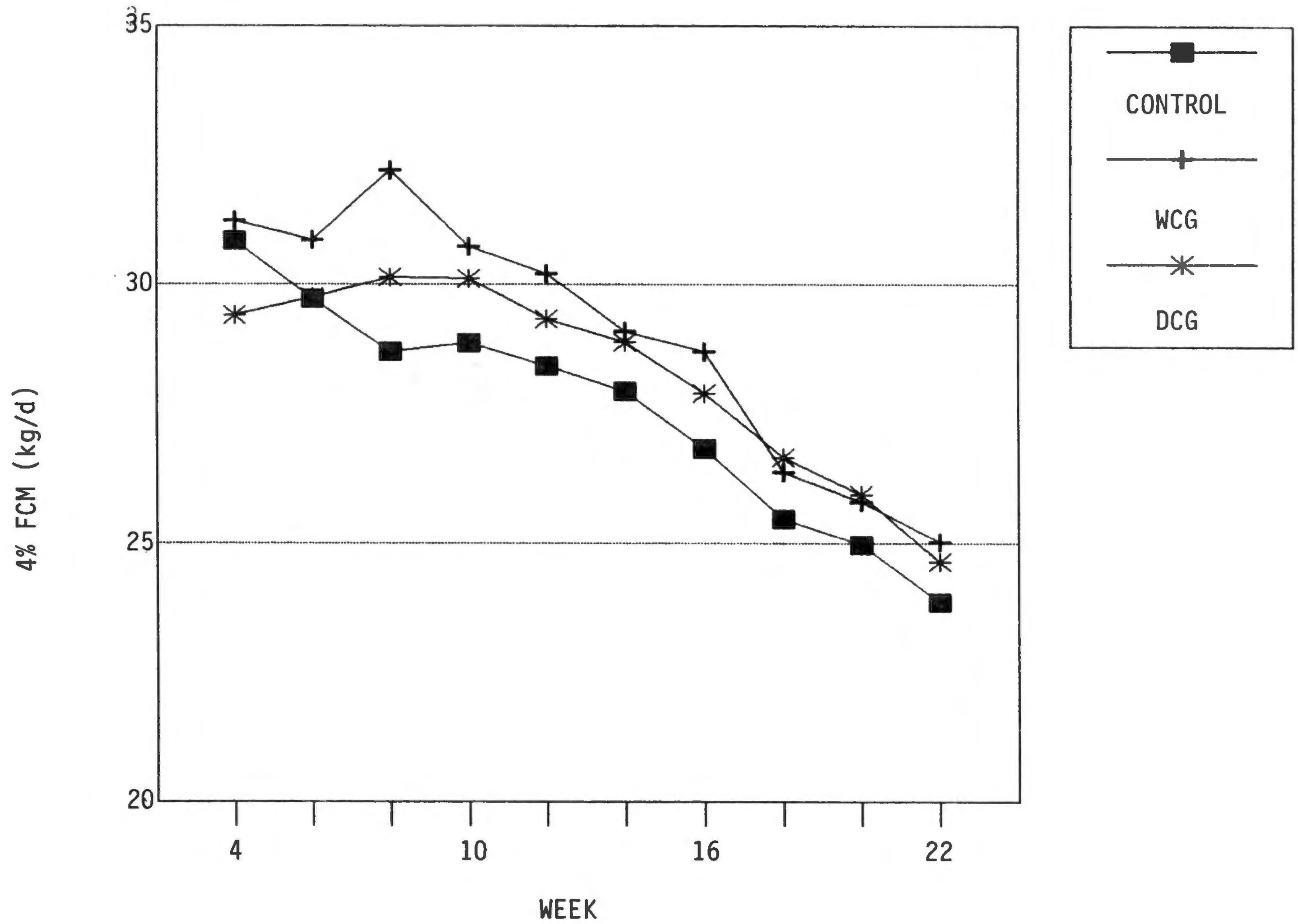

FIGURE 4. Biweekly milk production of cows by treatment in experiment two.

Intakes and digestibility of dietary components can also be viewed across periods without regard to treatment to compare effects of stage of lactation (Table 12). Dry matter and NDF intakes were higher in period two (peak lactation) than in period 1 (early lactation) or period 3 (late lactation). Two exceptions for intake were period 2 did not differ from period 1 for CP or from period 3 for ADF. Digestibilities of DM, CP, ADF, and NDF across all diets decreased ($P<.01$) from the first to the second period and again from the second to the third period.

All cows gained weight regardless of treatment (Table 11) although those fed gluten diets gained an average of .8 kg/wk more than cows fed the control diet. However, differences between treatments in body weight changes were not significant due to treatment and follow the same trend throughout the study (Figure 5).

TABLE 12. Effects of experimental period in lactating cows on intake and digestibility in experiment two.

Period	1	2	3	SE	P>F
Intake (kg/d)					
DM	19.8^{B}	21.4^{A}	19.4^{B}	.72	.01
CP	3.0^{AB}	3.2^{A}	2.8^{B}	.13	.01
NDF	8.6^{B}	9.3^{A}	8.3^{B}	.38	.01
ADF	3.9^{B}	4.5^{A}	4.4^{AB}	.16	.01
Apparent Digestibility (%)					
DM	78.1^{A}	75.6^{B}	71.1^{C}	.69	.01
CP	78.3^{A}	74.9^{B}	68.9^{C}	.85	.01
NDF	70.9^{A}	68.4^{B}	61.4^{C}	.82	.01
ADF	66.8^{A}	64.2^{B}	59.7^{C}	.88	.01

^{A,B,C}Periods, within lines, with different superscripts differ at levels of probability shown.

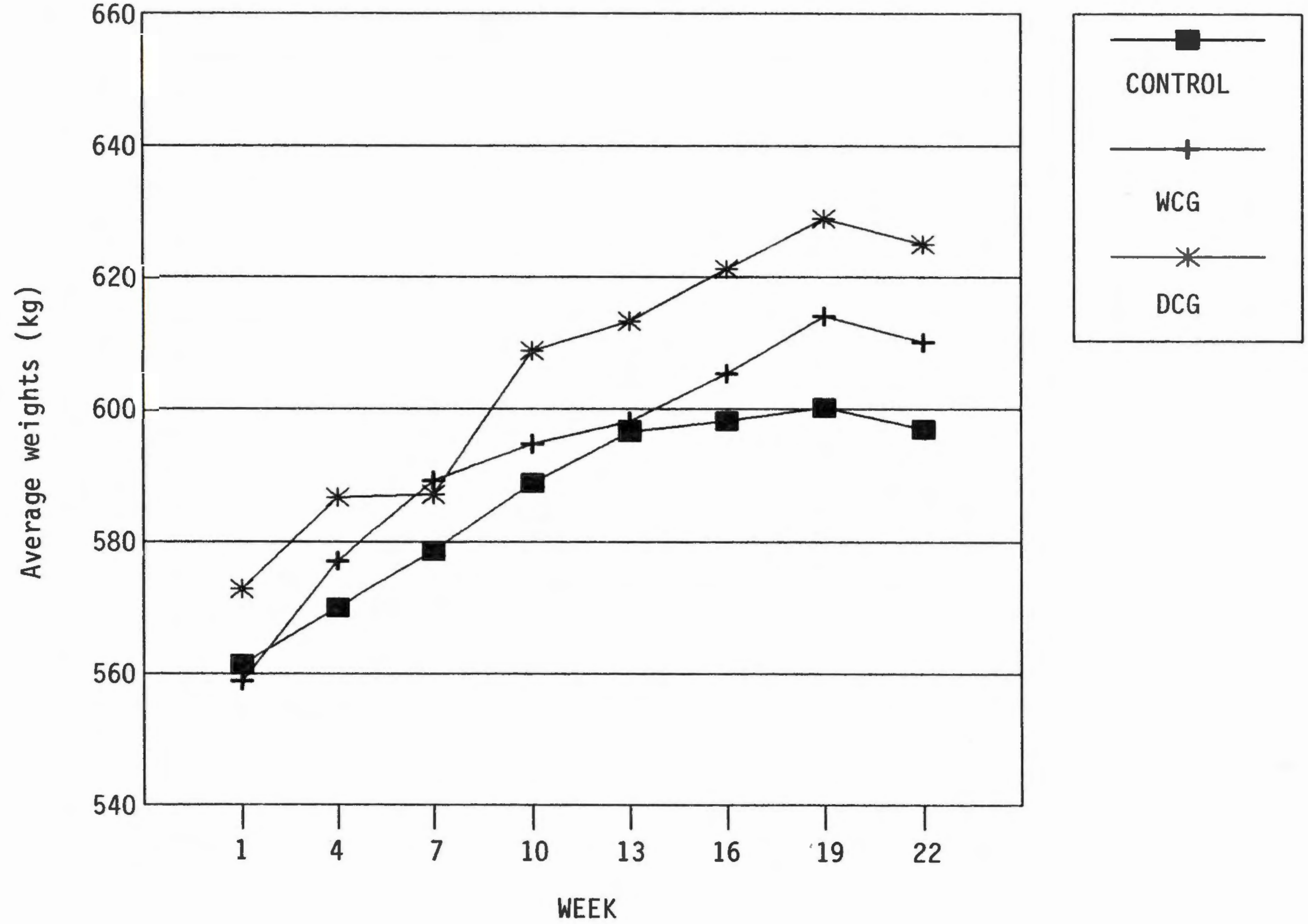

FIGURE 5. Weight change of cows by treatment in experiment two.

CHAPTER 5

DISCUSSION

DM Consumption

Dry matter consumption was 1.52 kg/d higher ($P<.01$) for cows consuming the DCGF diet when compared to cows fed the control diet. Macleod et al. (28) found corresponding results with lactating dairy cows fed diets in which DCGF replaced 26% of the DM. Dry matter intake increased 2.2 kg/d over a corn and SBM based control diet. Intake of DCGF at 29% of a SBM and corn silage diet by lambs was comparable to intake of corn and SBM alone (16). Differences in intakes may be explained by the N composition of the SBM and DCGF. The total N as soluble N is higher in DCGF than in SBM (24, 28) and is also more degradable in the rumen (15) which may explain the higher intake by cows fed DCGF based diets due to an increased rate of passage.

When compared to cows fed the DCGF diet, cows fed the WCGF diet had intakes slightly but nonsignificantly lower. Similar results (16, 20, 38) reveal the same statistically insignificant trend between DM intakes of diets containing wet or dry CGF. Significant differences in DM intake were reported by Macleod et al. (28) who compared wet or dry CGF at 26% of dietary DM and found lactating cows consumed 3.1 kg/d less of the WCGF diet. The difference in results may easily be explained by total DM of the rations. The DM of the DCGF diet was reported as 57.3% as compared to only 47.6% for the WCGF diet. Hutjens (22) recommended 50% DM as a minimum to maintain maximum DM intake, and intake may be depressed

complete diets has also been depressed when DM content was below 60 to 65% (26).

Cows fed WCGF at 25% of dietary DM consumed slightly more DM than cows fed the control diet. This is in contrast to similar comparisons which found no difference in DM consumption (16, 20, 38) but agrees with Macleod et al. (28) who showed a slight increase in DM intake by cows fed WCGF at 25% of dietary DM.

Intake of CP and ADF follow the same trend as did DM intake. Since rations were balanced on the basis of CP and ADF, intakes of these components would be expected to be closely related to DM intake. The difference in NDF intakes between treatments may also be easily explained by the average composition of each diet (Table 10). The diet with 25% of its DM replaced with DCGF had the highest % NDF followed by the WCGF diet with the control diet having the lowest % of NDF. Thus, intake of NDF was determined by both dietary NDF content and DM intake.

Apparent Digestibilities

The DCGF based diet had significantly higher digestibilities for DM, CP, NDF, and ADF when compared to the control diet (Table 11). In a similar experiment with lambs, Firkens et al. (16) reported no difference in digestibility of DM or NDF when comparing corn silage plus SBM with a similar diet in which DCGF replaced 29% of DM. Lambs fed the DCGF diet had lower intakes and digestibilities of ADF and higher intakes of N with no difference in N digestibility when compared to lambs fed the control diet. Firkens et al. (16) explained the difference in digestion of ADF due to changes in its cellulosedue to drying. Dry corn gluten feed's cellulose structure becomes more rigid and crystalline, when dried, differing from its amorphous original state.

The change in cellulose was noted by Firkens et al. (16) to explain a lower digestibility of ADF when the DCGF diet is compared to a WCGF diet. Similar results were obtained by Bowman and Paterson (6) who fed diets containing either wet or dry CGF replacing 50% of DM to wether lambs and found ADF digestibility was significantly lower in the DCGF diet. These results are in contrast to experiment two in ADF digestibility between diets containing dry or wet CGF as 25% of DM (Table 11). Njoya and Trenkle (32) agreed with our results reporting digestibilities of diets containing wet or dry CGF were similar, however, their diets were composed of 95.5% of wet or dry CGF (DM basis). Unlike ADF digestibilities both reports (6, 32) agreed with NDF and DM digestibilities observed in experiment two (Table 11) with no difference between diets containing WCGF or DCGF. Firkens et al. (16) and Njoya and Trenkle (32) reported NDF and DM digestibilities slightly higher for the WCGF as compared to the DCGF diet, the opposite trend of what we found. In agreement with our results, Bowman and Paterson (6) also reported slightly higher digestibility of WCGF compared to DCGF fed to wether lambs at 50% of dietary DM. Crude protein was also observed to be slightly more digestible in the DCGF diet than in the WCGF diet. Digestibility of

N in a similar experiment with WCGF or DCGF replacing 29% of a diets DM was slightly higher for the WCGF diet (6, 16).

In contrast to the comparison with DCGF, digestibilities of DM, CP, NDF, and ADF fractions were slightly higher in the WCGF diet than in a SBM and corn silage control diet. Firkens et al. (16) found similar results when WCGF replaced 29 instead of 25% of the diets DM. Staples et al. (28) also reported complementing results when WCGF replaced 20% of the DM in diets for lactating dairy cows.

When all cows are considered as one group within periods and each period is compared with the other periods for intake and digestibility a surprising result appears (Table 12): apparent digestibility decreased rather than increased with decreased DM intake. This decrease could be explained by an increase in the ADIN portion of ADF. The remaining results are as one would expect. Dry matter intake increased ($P<.01$) during the second period then decreased ($P<.01$) in the third period, common for a DM curve. As DM intake increased during the second period apparent digestibility significantly decreased. However, there was no increase in digestibility during the final period as expected. The decrease of digestibility may be explained by a increase ($P<.01$) of ADIN content of the diet which would decrease digestible intake.

Milk Production

Cows consuming the DCGF diet produced 2.11 kg/d more milk than cows fed the control diet in experiment two (Table 11). Macleod et al. (28) reported a .8 kg/d increase in milk yield when 26% of the control diet was replaced with DCGF. The increase in milk production was explained by a 20% increase in CP intake by cows fed the DCGF diet compared to the control cows. Higher CP intakes have been reported to increase the DE intake (43), thus increasing milk yield and protein levels (28). Our results show a significantly higher intake and digestibility of CP for the DCGF treatment. Although cows fed DCGF produced milk with a lower ($P<.03$) fat percentage than control cows, the higher milk yield of cows fed DCGF resulted in slightly higher 4% FCM production. The decrease in milk fat may be explained by a shift in the acetate to propionate ratio. An increase in propionate and a decrease in acetate has been reported when CGF was introduced into the diet (16). Other reports have also shown the increase in propionate concentration which also influences milk fat (5, 21). The shift in the acetate to propionate ratio has been attributed to the hemicellulose digestion of CGF (23). Macleod et al. (28) reported a significant increase in 4% FCM when DCGF was fed at 26% of the control rations DM. The difference in 4% FCM production was achieved from an increase in milk fat percentage over the control ration. The differences in milk fat reported by Macleod et al. (28) may have resulted from a lower ADF content in the diet than recommended by the National Research Council. Much of the differences in results can be explained by alterations of processing to produce the DCGF.

Cows that ingested the WCGF diet showed slightly elevated level of 4% milk production and a higher ($P>.03$) milk fat percentage over those cows fed the DCGF diet. Our results agree with Macleod et al. (28) and Macleod and Grieve (29) in reporting no difference in 4% FCM production between cows fed wet or dry CGF diets. Macleod and Grieve (29) did find a slight nonsignificant increase in 4% FCM yield with the cows fed the DCGF diet. Our findings disagree from both of Macleod's reports (28, 29) in that we found no difference in actual milk yield when DCGF was added to the diet. We also disagreed with Macleod et al. (28) by detecting a lower milk fat (P<.025) for cows fed the DCGF diet. An increase in DM intake with DCGF added to the diet was noted to be responsible the difference in milk production. The increase observed in milk fat percentage has been reported to be caused by higher digestibility of ADF and NDF in wet when compared to the dried CGF (17,28). The same increase in ADF and NDF digestibilities can also be found in results of our digestibility trial (Table 11).

When 26% of the control rations DM was replaced with WCGF, the resulting diet showed a slight advantage in milk and 4% FCM production with all cows in experiment two (Table 14) and with multiparous cows in experiment one (Table 10). However, primiparous cows in experiment one increased milk and 4% FCM by 3 kg/cow/d when WCGF was added to the control diet. Our results agree with Gunderson et al. (20), and Armentano and Dentine (3) who reported no effect of WCGF on milk or FCM yield, though they did find a trend for an increase of both. The differences in milk and FCM in various reports may be explained by differing DM intakes reported when WCGF was fed.

Although intake was not measured in experiment one, differences in milking order may have contributed to treatment differences in DM intake by primiparous cows which could have influenced milk and FCM yield. Under parlor milking conditions, it is normal for older, more aggressive cows to enter the parlor first whereas younger cows tend to stand back. Thus, there was a tendency to milk most of the multiparous cows toward the beginning and the primiparous cows toward the end of each group. Since feed was placed in feed bunks while cows were in the parlor holding lot, the first cows through the parlor would have first access to the feed. The total amount of mixed diet offered was consumed by each group before the next milking although both groups had access to wheat or sudex hay with a lower feed value.

The dairymen observed that cows fed the WCGF diet appeared satisfied sooner than cows receiving the control diet. This is reasonable because the higher NDF content of WCGF diet undoubtedly increased the amount of digestible fiber which in turn would increase the DE content of the diet and caused the cows to reach satiety sooner. Thus, older cows fed the WCGF diet did not consume as much of the mixed diet immediately following each milking so more was left for the younger cows which arrived later. On the other hand, older cows fed the control diet left less of the mixed diet for the younger cows, forcing them to consume more of the lower quality hay to meet their DM requirements. Since the mixed diet would benefit milk production more than hay, this would could have contributed to higher milk production by primiparous cows fed the WCGF diet.

Milk fat increased slightly when WCGF was fed in both experiments (Tables 7 and 11). Similarly, other reports (12, 20, 28, 29, 38) have shown a tendency for milk fat content to increase as WCGF was introduced into the diet. The increase in the milk fat test has been attributed to a increase in fiber intake which altered rumen fermentation to produce a larger acetate:propionate ratio (12). Protein content of milk in experiment one did not differ between treatments with or without WCGF feed, which agrees with Macleod et al. (28). Other reports (20, 38) show a slight but insignificant decrease in protein content of milk.

Efficiency of Production

The efficiency of milk production was increased from 1.40 to 1.50 kg 4% FCM/kg DM intake by addition of WCGF to the control diet. Two other studies find the same trend (20, 38). Both reports show the efficiency of production increasing as larger amounts of WCGF are incorporated into the diet. Staples et al. (38) noticed a quite different trend when the efficiency of productions were corrected for milk production that could be from change in body weight. Efficiencies corrected for body weight changes were most favorable for cows consuming the control ration and decreased as WCGF was added to the ration. This is opposite to what we would find if we corrected efficiencies of our cows for body weight changes since cows fed the WCGF diet gained more weight than the control cows.

When the efficiency of production by our cows receiving the wet or dry CGF treatments are compared the cows fed the WCGF diet still have the highest (1.50 vs. 1.33). The same results may be calculated from data from another study (28) although the efficiency of production was not reported. The efficiencies are as one might expect since the cows fed the DCGF diet did consume an increased amount of DM in both our (Table 11) and Macleod et al. (28) experiments without significantly increasing FCM production to the same extent. The same explanation is helpful when comparing the efficiencies for the control and DCGF treatments. Those cows fed the DCGF treatment had a lower efficiency in experiment two and one other report (28) when compared to the control treatment.

Weight Change

Adding CGF to the diet, whether in the wet or dry form, tends to increase weight gain of lactating dairy cattle. Those cows fed a diet in which 25% on the control treatments DM was replaced with wet or dry CGF showed a insignificant increase in weight change of .8kg more per week (Table 11). All cows regardless of treatment gained weight during the 22 wk experiment. Staples et al. (38) found similar results when a diet containing 20 or 30% of WCGF (DM basis) was compared to a similar control diet. A lower increase in body weight change was reported (28) when a control diet was compared to a diet with 26% of its DM as WCGF. The same study also reported a significant increase in weight gain in cows fed a diet in which 25% of the control rations DM was replaced with DCGF in comparison to the control diet. The significant increase in weight gain from cows fed the DCGF diet over the other treatments is possibly due to having the lowest efficiency of production.

Economic Analysis

Perhaps the most useful way to evaluate results from both experiments is by economic comparisons between treatments. The cost of each ration can be calculated based on current market prices of each ingredient to reflect the cost of all diets on a DM and as-fed basis. The total cost per ton of those diets formulated with CGF is consistently cheaper. Adding DCGF instead of WCGF increases the cost of the diet but the cost still remains slightly less than the control diet.

The income from milk production must also be calculated before making any conclusions. Value of milk produced is figured on milk at $26.63 per 100 kg weight with a 15 cent bonus for every tenth increase in milk fat over 3.5%. The advantage of feeding wet or dry CGF can best be evaluated by subtracting feed cost from milk income. Based on milk production, DM intake, and diet composition WCGF was found to be feasible in the diet. Also built into our calculation was 4% expected waste of WCG due to storing losses (Hutjens, University of Illinois, Personal Communication) and a $7.50 charge per ton for hauling both the wet and dry CGF (Johnson, University of Tennessee, Personal Communication). Due to the possible differences in herd size, labor potential and cost, and machinery needs between dairy farms these variables were not estimated in our cost efficiency of CGF's but should be considered before incorporating CGF's into the diet.

CHAPTER 6

SUMMARY

Two studies were conducted with lactating dairy cows to determine the possible effects of feeding corn gluten feed on milk production, weight change, feed intake and digestibility, and economic parameters. In the first experiment WCGF was evaluated in a commercial dairy herd. The second was a more controlled study using the University of Tennessee's dairy herd at Knoxville. In both experiments CGF replaced 25% of the control diets DM to create the experimental diets.

Adding WCGF to the diet had no effect on milk, fat, protein or 4% FCM production. Dry CGF added to the diet additionally increased milk production, but significantly lowered milk fat ($P<.025$), with no decrease in 4% FCM yield. Dry CGF also increased DM, CP, NDF, and ADF intakes ($P<.01$), while enhancing DM ($P<.01$), CP ($P<.04$), NDF ($P<.02$), and ADF ($P<.03$) digestibilities when compared to the control diet. Intakes and digestibilities of the WCGF diet tended to be similar to those of the other two treatments. However, NDF intakes of cows fed WCGF were significantly lower than those of cows fed DCGF but higher than those of cows fed the control.

Efficiency of production tended to be highest for cows fed WCGF (1.50kg 4% FCM/kg DM intake), intermediate for controls (1.40), and lowest for cows fed DCGF (1.33). Weight change was not significantly different between treatments, though cows fed the CGF diets tended to gain .8 kg more weight per week than cows fed the control diet.

Milk production and feed intake was valued with feed waste and trucking also included to evaluate cost efficiencies of the diets. The diets ranked in the same order as they did for efficiencies of production. Wet CGF produced the largest return above feed and DCGF the lowest. The evaluation of CGF in diets of lactating dairy cows was of importance due the availability of CGF's in the South and the lack of published reports on using CGF's from universities other than northern. Replacement of 25% dietary DM by the by-products wet or dry CGF maintained or possibly increased performance of lactating dairy cows. Therefore, corn gluten feeds should be considered as alternative feed sources at dairy farms within economical hauling distance of wet corn milling plants.

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