UTILIZATION OF WET BREWERS GRAINS AS A REPLACEMENT FOR CORN SILAGE IN LACTATING DAIRY COW DIETS

by

CHRISTA LYNN MAHNKEN

B.S., Southern Illinois University, 2008

A THESIS

submitted in partial fulfillment of the requirements for the degree

MASTER OF SCIENCE

Department of Animal Science and Industry
College of Agriculture

KANSAS STATE UNIVERSITY
Manhattan, Kansas

2010

Approved by:

Major Professor
Dr. Micheal Brouk

Abstract

An evaluation of short-term replacement of corn silage (CS) and soybean meal with a blend of wet brewers grains (BG) and cracked corn on milk production and DMI was completed utilizing 8 primiparous (192 DIM) and 4 multiparous (191 DIM) mid-lactation Holstein cows. Milk production, composition, DMI, production efficiency, fatty acid composition and diet digestibility were evaluated. Cows were allotted to a 4 x 4 Latin Square with 3 replications blocked by parity, DIM and energy corrected milk (ECM). Crude protein and starch levels were balanced between diets by varying the levels of cracked corn and soybean meal in four diets; 0 BG (0% wet BG and 24% CS of diet DM), 12 BG (12% wet BG and 12% CS), 18 BG (18% wet BG and 6% CS), and 24 BG (24% wet BG and 0% CS). Fifteen day periods were used, d11-15 designated for collection. Orts were collected daily and TMRs were fed at 5 to 10% of previous day's intake. Cows were milked 3x/day and individual milk weights recorded at every milking. Milk samples, body weights and BCS were taken -2 and -1d pre-trial to obtain baseline data and d14 and 15 of each period. During collection, samples of TMR and orts were taken d1, 3 and 5. Fecal grab samples were taken d12-15 at 8 hr intervals and advanced 2 hrs every 24 hr period to account for diurnal variation.

Dry matter intake was similar (P=0.33) among treatments (20.3, 20.8, 20.9 and 21.2 kg/cow) for 0 BG, 12 BG, 18 BG AND 24 BG respectively, however CP intake of 24 BG tended to be greater (P=0.05) than 0 BG. NDF intake was lower for 0 BG compared to all other treatments and 24 BG was higher than 12 BG (P=0.0007). Dietary fat intake was different (P<0.001) across all treatments, increasing with greater BG inclusion. Inclusion of BG had no effect (P=0.37) on milk production (30.5, 31.5, 31.6 and 32.1 kg/cow), fat percent or amount, protein percent, SNF, lactose or SCC, but protein yield (P=0.04) was lower and MUN (P=0.05)

tended to be lower with 0 BG compared to 18 BG and 24 BG. Efficiency of milk production did not differ (P=0.93) among treatments. Milk fatty acid profiles were different among treatments, with general increases of individual fatty acids as BG inclusion increased. No differences were found in DM, CP or ADF digestibility across treatments. Results suggest wet BG fed simultaneously with grass hay can be utilized as a short-term replacement for CS in mid-lactation dairy cow diets.

Table of Contents

List of Tables

Acknowledgements

I would like to thank Tallgrass Brewing Company for donating the wet brewers grains for my study. Thanks also go to the great help from the KSU dairy farm crew and Mr. Mike Scheffel for his help, support and guidance through the study. My fellow graduate students also deserve great thanks for their support during collection periods, and distraction from getting too stressed. Many thanks to Cheryl Armendariz for her patience and guidance through my lab work. Finally, thank you Dr. Brouk for guiding me through the graduate school process. A lot has happened in the past two years and, despite the situation, you were understanding and supportive through it all.

Dedication

To the most amazing, supportive and loving family a daughter could ask for. When I was down and wanted to quit, you reminded me that God wouldn't give me any situation I couldn't handle or wouldn't learn from. You've given me my faith and the heart of gold to see the positive side of every situation and always wear a smile.

CHAPTER 1 - Review of Literature

Introduction

Finding cheaper and nutrient dense feeds is essential in any sector of animal agriculture, but in the past few years, this has become increasingly important for the dairy industry. A decrease in milk price and subsequent increase in feedstuff cost has resulted in the necessity of evaluating the feeding program and stretching the dollar as much as possible. In some cases, improper planning when harvesting or poor yields have forced producers to find alternate feedstuffs for dairy ration staples, such as corn silage and alfalfa hay. In many instances, by-product feeds like wet brewers grains (BG) are utilized. Wet BG are typically fed in locations close to the brewery, but with the increasing number of micro-breweries and their need to find use for their by-product, it has become more widely used. In longer distances from the brewery, it is typically fed in dry form. Quality will vary from brewery to brewery which prompts the need for nutrient profile testing prior to use. Regardless of the physical characteristics when fed, previous research has found BG to be successful in supplementing forage and concentrate (Firkins et al. 2002; Dhiman et al. 2003; Murdock et al. 1981; Armentano et al. 1986). The amount of diet DM substituted by wet BG varies by what was replaced, the quality of the BG and other ration ingredients. In situations of improper planning of stored forages such as corn silage, wet BG may be a potential short-term solution, but a proper evaluation of this feed is needed.

Roughage Requirements for a Lactating Dairy Cow

With the predominant move to use a total mixed ration (TMR) and more nutrient dense diets, meeting roughage requirements to maintain proper effective fiber and fermentation, as well as supplying substrates for utilization by rumen microorganisms in producing precursors for milk synthesis is warranted. The National Research Council (NRC) in 2001 outlined several items such as neutral detergent fiber (NDF), forage NDF, maintaining particle size, etc., as fundamental to rumen health and sustaining milk production. Studies done previous to 2001 contributed to the recommendations made in the 2001 publication of the Nutrient Requirements of Dairy Cattle. Authors suggest no less than 25% ration NDF with at least 19% forage NDF and a maximum non-fibrous carbohydrate (NFC) of 44% (Dairy NRC, 2001). The upper critical value for ration NDF is around 33% without negatively impacting digestibility and fermentation of the diet (NRC, 2001).

Maintaining effective fiber in the diet is a notable concern for dairy producers. Effective fiber is commonly defined as "the ability of a diet to stimulate chewing" (NRC, 2001). The capacity of a feedstuff to stimulate chewing and increase salivary buffers to the rumen is vital in maintaining appropriate rumen pH due to increased production of fermentative acids (Allen, 1997). If the buffering capacity is decreased, the pH will also remain low initiating digestive upsets, metabolic issues and decreased milk production. Sufficient effective fiber is also needed to retain scratch factor in the rumen. The scratch factor is imperative in successful perpetuation of ruminal papillae and increased surface area for absorption of nutrients into the blood stream. Systems developed to measure such things, such as peNDF (physically effective neutral

detergent fiber) and extensive use of the Penn State Particle Separator (Nasco, Fort Atkinson, WI) allow dairy nutritionists to more accurately balance rations for effective fiber.

Feeding roughage to dairy cows could increase fermentation, stimulate acetic acid production and maintain rumen health when fed at proper amounts. The NRC recommends no more than 33% of diet DM be NDF, and no less than 25% of the ration DM be NDF for a healthy rumen environment without detrimental effects on ruminal retention time, which subsequently reduces digestion and fermentation. If NDF is lower than 25% DDM, a decreased pH would be expected in addition to depressed milk fat percentage (Grant, 1997). A decrease in pH can depress appetite and ruminal motility which directly affects fiber digestion and the ability of microbes to yield fermentative end products, such as acetic acid needed for milk fatty acid production (Allen, 1997). On the other hand, over feeding forage can increase retention times, essentially decreasing digestion and absorption of necessary nutrients and increasing manure. With increased interest and use of by-product feeds, proper balancing of NDF sources is important in ration formulation.

Brewery By-products as Feed Ingredients in Lactating Dairy Rations

The brewing process yields three main products used as feedstuffs in the ruminant nutrition industry: brewers condensed solubles, brewers yeast and wet or dry BG (Westendorf et al., 2002). Brewers condensed solubles are removed from the process before the BG are dried. Following completion of fermentation, the beer is cooled and the yeast drops to the bottom of the fermentation vessel where it is drained from the beer (Rinkes, 2010). Wet and dried BG are removed from the brewing process before yeast is added and fermentation begins, therefore BG contain no brewers yeast. Brewers condensed soluble have been researched very little, but Bravo et al. (1978) found no effects on milk protein percent when cows were fed up to 2.27 kg/cow

daily. However, milk yield was significantly lower as brewers condensed soluble were included in the diet. In 1999, J. W. Schroeder from North Dakota State University Extension reviewed common by-products fed to dairy cattle in an extension publication. While brewers condensed solubles have similar feeding values to corn, it is an unstable feed with highly fermentable qualities (Schroeder, 1999). It is also extremely palatable to ruminants causing an over-consumption concern (Schroeder, 1999).

Feeding brewers yeast to ruminants, specifically dairy, as a feed additive is thought to have positive effects on milk fat and protein, but no differences in milk production (D.A. Roth-Maier, 1979). Research has also been conducted on the inclusion of brewers yeast in calf starters. Results showed a decreased need for antibiotic use and less fever in calves in the pre-weaning stage of life leading researchers to think it could diminish pre-weaning infections (Seymour et al., 1995). In lactating dairy cows, milk yield has not been significantly increased, but brewers yeast inclusion has increased milk fat percentages (Harris et al., 1990). When cows were fed 9 kg/d of liquid brewers yeast for 14 days and was compared to a control of soybean oil meal, cows increased both milk fat percentage (4 vs. 4.42%) and protein percentage (3.53 vs. 3.75%) (E. A. Gaede, 1979). Similar results were found with milk fat when 6 kg/d (as-fed) liquid brewers yeast was compared to the control (Petraitis et al., 1971). A study by West et al. (1994) found that feeding liquid brewers yeast along with 30% wet BG diet resulted in greater milk production and 4% FCM when compared with 30% wet BG and no liquid brewers yeast. Other studies found no significant differences in milk production, milk fat or milk protein percentage when feeding brewers yeast (Grieve et al. 1978, Dawkins et al. 1962). Regardless of the mixed results, utilizing brewery by-products such as brewers condensed solubles and brewers yeast can reduce brewery waste disposal costs and provide the dairy producer a usable feedstuff.

What are Wet Brewers Grains

Wet brewers grains (BG) are defined as a by-product of the brewing industry. The method of brewing beer is important in determining what nutrients of the grain are remaining in the by-product. Despite the process being similar across most breweries, an overview of beer production is necessary. Westendorf et al. (2002) describes it in several simple steps. Larger breweries begin by soaking the barley in warm water for malting. After malting, the soaked barley grain is dried and malt hulls, sprouts and cleanings are removed. In some microbreweries, the malted barley is brought into the system and not done at the brewery. Regardless of brewery size, dried grains are then crushed, added to water and heated, which activates enzymes to complete the starch to sugar conversion. During this step, referred to as mashing, rice and corn grits are added to the mixture. This continues until the largest part of the starch is converted to sugar. To disperse the liquid which contains sugar, also known as wort, from the spent grains, the mashed mixture is pressed and separated. The wort will continue on to make beer and the grains will become by-products that dairy producers could utilize as a feed source.

Wet BG are an unstable feed source and may spoil quickly, leaving most breweries only with local market opportunities (Johnson et al., 1987). Decreasing spoilage and increasing storage time though ensiling BG may work (Johnosn et al., 1987). Wet BG are not readily transported across the country, but are fed in the local area near large breweries or microbreweries. Most of these large breweries are found along the East Coast, New York, Texas, Colorado, Missouri and California, while microbreweries are becoming local staples across the United States. World-wide availability depends on accessibility to breweries. The majority of wet BG are sold to dairies and some to beef operations (Westendorf et al., 2002).

Brewers grains are commonly fed in two forms, wet or dried. Wet BG come directly from the brewery with no drying while the dried (BG) have continued processing including the separation of the brewers condensed solubles and drying (Westendorf et al., 2002). In general, wet BG are utilized by farms in proximity to the brewery while dried BG can be shipped farther away. Despite the reduced opportunity of wet BG to be distributed beyond the local market, it comprises most of the market for brewers grains (Westendorf et al., 2002). Wet BG have become more popular on dairy operations since the increase in the cost of drying and cost of transportation (Johnson et al., 1987). However, dried BG are still being utilized in other livestock such as beef cattle and horses as a protein or carbohydrate source. Chemically, wet and dried BG are similar. The National Research Council (NRC) 2001 states that the typical dried BG will have 90.7% dry matter while the wet BG will have 21.8%. Both have similar crude protein levels of 28-29% but vary on the percentage of crude protein within each nitrogen fraction. Dried BG have most of the protein in the B fraction which represents "potentially degradable true protein" (NRC, 2001). Wet BG have similar amounts of protein in both the A, representing soluble protein, and B fractions. Because of passage rate, dried BG have some amount of by-pass protein available for use and a lesser fraction for microbial protein production. Heating of dried BG may also decrease rumen degradability making the protein less available to the rumen microorganisms. Wet BG have the potential to supply rumen microorganisms with what is needed to make microbial CP and has a portion available for RUP, which makes brewers grains ideal for ruminant animals. Dhiman et al. (2003) compared dried to wet BG in diets of similar DM. Comparable feed intakes, milk yields, and milk composition were found when feeding either dried or wet BG at 15% diet DM showing that both could be supplemented in a lactating dairy cow diet.

Chemical Composition of Wet Brewers Grains

In ration balancing it is important to know the chemical composition of the feedstuff being utilized so that the diet being fed will be as nutritionally accurate as possible. The National Research Council (2001) chemically defined wet BG and the main nutrients of concern are NEL (Net energy of Lactation), DM (dry matter), CP (crude protein), NDF (neutral detergent fiber), ADF (acid detergent fiber) and EE (ether extract). An energy value used commonly in the dairy industry is the NE_L or net energy of lactation. This value is commonly identified as the amount of energy the feedstuff will supply to the animal for maintenance, fetal growth, weight gain and the act of lactation, or how much energy is in the milk. As stated in the NRC (2001) the NE_L requirements for dairy cows includes not only maintenance and lactation but also pregnancy and changes in body weight, suggesting that NE_L can be used as an overall measure of energy needed. The NRC (2001) NE_L value for wet BG is 1.71 Mcal/kg. The DM value tells the producers the portion of the feed that is not water. The NRC (2001) DM for wet BG is 21.8%. From this quantity an estimated weight of each nutrient can be determined from a total weight of the feedstuff being used. The DM is also a very powerful tool in balancing rations. If the DM of a feedstuff changes, the amount of DM and nutrients delivered in the ration will be influenced, which could impact milk production. The NRC (2001) CP value is 28.4% for wet BG which allows wet BG to be useful as a supplemental protein source (Murdock et al., 1981). The estimate for CP varies somewhat between breweries resulting in a nutritional hurdle for the industry. This has resulted in suppliers using a range for CP, or a commodity average. While the CP value is of use, separation of protein into nitrogen fractions may be more beneficial for more precise ration formulation. The NRC (2001) has taken CP and classified it into three fractions, A, B and C. Fraction A is composed of protein that is readily degraded in the rumen

for use in making microbial cell protein, such as amino acids and non-protein nitrogen sources including nucleic acids, ammonia, urea, etc. The B fraction is slowly degraded in the rumen, or, due to passage rate, passes to the intestine as rumen undegradable protein (RUP). The combination of digested RUP (around 80% of RUP) and digested microbial cell protein (around 64%) is metabolizable protein. Metabolizable protein is not all digested and absorbed in the small intestine and is passed to the lower gut where further microbial digestion takes place. This can be recycled in the urea cycle or excreted in the feces. The C fraction is that portion which will be entirely passed through the digestive tract without digestion. These numbers become of interest when balancing for protein and microbial cell protein.

Two related components of importance are NDF and ADF. The NDF is defined as the addition of the hemicellulose, cellulose and lignin, whereas ADF consists of just cellulose and lignin. Wet BG have an NDF of 47.1% and an ADF of 23.1% as listed in the 2001 NRC. Defining the fiber within a feedstuff becomes essential for rumen health, milk and milk fat production and DMI. Effective fiber will usually simulate salivary buffer production which is important in maintaining rumen pH and reducing the potential for rumen metabolic issues. Intake can be affected by the amount of fiber in the diet, as well as the type and digestibility of that fiber source (West et al., 1997). A fiber source with decreased digestibility and passage rate may decrease intake depending on what type of forage is being fed. Wet BG, despite small particle size, are considered a fiber source for ruminants. They have NDF and ADF values similar to that of corn silage and alfalfa hay.

The last dietary component of concern is ether extract (EE), commonly known as fat. Both wet and dried BG have EE values of 5.2% DM. Fat can provide added energy to the diet but can be overfed. If the diet contains over 5-6% and there are large amounts of unsaturated

fatty acids, increased biohydrogenation may occur leading to milk fat depression (Dhiman et al., 1999). Milk protein can also be reduced due to large amounts of fat in the diet. Large amounts of fat may decrease rumen pH and subsequently kill rumen microorganisms needed for microbial protein synthesis. If lower amounts of amino acids are available to make milk protein, then milk protein depression will occur.

WBG Affect on the Rumen

The rumen is a complex environment which must be sustained to maintain rumen health. Dairy cows are fed wide varieties and amounts of feedstuffs and by-products that are constantly changing due to changes in economics and availability. Evaluating the effects wet BG have on the rumen are vitally important in its nutritional evaluation. The small particle size of wet BG may result in detrimental effects to the rumen including decreased pH, as well as rapid fermentation and assimilation of carbohydrates (Aguilera-Soto et al., 2009). This, in turn, can lead to ruminal acidosis and laminitis (Aguilera-Soto et al., 2009). Determining the impact wet BG have on the rumen requires evaluation of several items including pH, protozoal numbers, ruminal ammonia-N values and volatile fatty acids (VFA).

The normal rumen pH of a lactating dairy cow is between 6.0 and 6.2 with daily fluctuations above and below the optimum levels. When the rumen drops below this value there is a chance for ruminal acidosis to occur. Sudden changes in diet, most commonly low fiber and highly fermentable or reduced particle size, is an explanation for acidosis when introducing new feeds. Wet BG have a small particle size and are highly fermentable, leading to some concern. Dhiman et al. (2003) reported no significant changes in rumen pH when feeding 15% dried BG. Aguilera-Soto et al. (2009) found similar results when they used wet BG as a source of concentrate in a study looking at feed additives and its concurrent influence on digestibility and

milk production. Time after feeding also has an effect on rumen fluid pH as Murdock et al. (1981) have reported. While the treatment rations had no effect on rumen pH, rumen fluid pH significantly ($P<0.001$) increased from 1000h and 1400h which was not disadvantageous to the rumen environment (Murdock et al., 1981). Previous research could lead one to assume introducing wet BG in the diet up to 30% diet DM would have no detrimental effects on the rumen.

Survival of microorganisms in the rumen environment is greatly impacted by ruminal pH. It's been stated that wet BG up to 30% diet DM had no effect on the pH, but what about protozoa numbers, VFA's and ruminal ammonia-N? Miyazawa et al. (2007) reported a numerical increase in protozoal numbers compared to the control when wet BG were fed at 9.3% diet DM, but this was not a significant increase. Total VFA quantities were not found to be impacted by feeding wet BG equal to 30% diet DM (Murdock et al. 1981, Dhiman et al. 2003, Miyazawa et al. 2007, Aguilera-Soto et al. 2009), but individual VFA's may be influenced. Acetic acid was increased to some extent in some studies, further establishing the thought that fibrous feeds will encourage cellulolytic bacterial growth, moreover increasing the amount of acetic acid in the rumen (Miyazawa et al., 2007). Ruminal ammonia-N was also not significantly affected by inclusion of wet BG further proving wet BG have minimal detrimental effects on the rumen environment when fed properly.

Wet Brewers Grain as a Concentrate Source

The versatility of wet BG has made it a probable candidate for supplementation or replacement of concentrate, more specifically protein, in a diet (Johnson et al., 1987). Most commonly, this substitution is for soybean meal (SBM) or corn. The animal agricultural industry

is always seeking newer, cheaper and nutritionally similar feedstuffs to replace corn or soybean meal. Wet BG have the potential to serve in this role.

As mentioned before, the NRC breaks protein into nitrogen fractions, or sub-groups, A, B and C. Comparing the fractions for SBM (A: 22.5%, B: 76.8%, C: 0.7%) to that of wet BG (A: 48.3%, B: 42.5%, C: 9.2%), one notices the dissimilar dispersion of constituents (NRC 2001). Soybean meal has more protein that is slowly degraded (B fraction) compared to that of wet BG, making it a source for rumen microbes as well as a sufficient source of undegradeable protein depending on passage rate. The rumen microbes are able to convert rapidly degraded dietary protein into microbial cell protein, giving it added value as it advances through the digestive tract. Wet BG provide a different scenario. About half of the protein is rapidly degraded in the rumen which provides amino acids or nitrogen for microbial cell protein synthesis, or is degraded into ammonia which will be absorbed into the blood stream and converted into urea in the liver. The urea can then be excreted in the urine or recycled by the animal in saliva or back in the rumen. The slower protein breakdown will follow suit, or will be pushed further down the digestive tract depending on retention time. The C fraction, or that which will be undegradable in the rumen, will continue to the duodenum for further breakdown. Although wet BG have a larger degradable fraction of protein, that protein is converted into microbial cell protein which is digested and absorbed in the duodenum. While both feedstuffs are providing the duodenum with protein differently, there seems to be a sufficient amount of amino acids being supplied for milk production (Murdock et al., 1981).

Wet BG as a supplement or complete replacement of other concentrate sources, have been tested at several different dietary levels. When researchers in Japan compared wet BG to a typical dairy diet of alfalfa hay, corn silage, sudangrass hay and a grain mixture, they found no

differences in DMI, crude protein intake and NDF intake, but ether extract increased in the wet BG diet (Miyazawa et al., 2007). Milk production and 4% fat corrected milk were also not significantly different. Wet BG were tested against dried BG, dried distillers grains with solubles and a combination of wheat bran and SBM with similar affects on milk production, but feed intake decreased with the wet BG, but digestibility was the highest (Porter et al., 1975). A decrease in DMI is a common occurrence in diets with wet BG. In most test diets containing wet BG, the average dry matter of the diet is less (around 45 to 50%) than that of a normal diet (around 60%). Having lower intakes at higher moisture contents has been attributed to many things including increased concentrations of fermentation end products, rumen fill due to bulkier feedstuffs and increased intake of water (Robinson et al., 1990). All of these conclusions could be possible reasons why there are generally decreased intakes in diets containing wet BG. Fresh wet BG, ensiled wet BG, fresh wet BG + urea and SBM were used as protein supplements in a 1987 trial (Johnson et al., 1987). The SBM diet (14% of diet DM) resulted in significantly higher intakes when compared to diets supplemented with fresh wet BG (25.6% diet DM), ensiled wet BG (26.26% diet DM) and fresh wet BG +urea (14.65% diet DM) (Johnson et al., 1987). This may be in part to lower digestible DM of fresh wet BG diet at 45% and the fermentation of ensiled wet BG. A tendency for decreased DMI was also found when 15 or 30% of the diet DM replaced corn and SBM with wet BG, although it was not significant (West et al., 1994). West et al. (1994) determined that wet BG could be used as a concentrate, and more particularly protein, supplement in lactating dairy cows up to 30% of the diet dry matter. Other studies (Murdock et al. 1981, Polan et al. 1985, Miyazawa et al. 2007) using wet BG as a concentrate supplement concur with West et al. and Johnson et al. Wet BG can be used effectively as a protein supplement in lactating dairy cow diets.

Wet Brewers Grain as a Forage Source

Despite the fact wet BG have been studied primarily as a supplement for concentrates, there has been some interest in its value as a forage NDF source. Because of the nature of the grains it's thought to maintain an effective chewing response with a range from 32 to 80% of alfalfa silage (Mertens, 1997). The large range is due to the particle size of the grain and its ability to maintain rumen fill (Firkins et al., 2002). Regardless of small particle size, Firkins et al. (2002) found wet BG could be an effective replacement of the forage NDF and total NFC as each decreased with increased inclusion rate. Rates of wet BG inclusion were low (8.65% diet DM), medium (17.29% diet DM) and high (25.94% diet DM) with decreasing amounts of alfalfa hay, corn silage and soybean meal. Dry matter intake as well as milk production were maintained in all three treatments. This trend was also seen in a study evaluating effectiveness of dried BG as a forage, concentrate or both a forage and concentrate replacement. There was a decrease in DMI when dried BG replaced concentrate but this response was not seen when it replaced forage (Younker et al., 1998). This is thought to be a result of gut fill which is why reducing the amount of forage NDF and total NFC has been considered (Firkins et al., 2002). Dhiman et al. (2003) further supported this theory when he and his colleagues compared wet BG to dried BG at 15% of diet DM and found no differences in DMI, milk yields or milk composition, further emphasizing no difference in nutritive value of either feedstuff. Overall, wet BG can be an effective replacement for a portion of forage NDF in a lactating cow's diet.

Affects on Milk Production

Milk production is driven by several things including dry matter intake as well as the quality of the feedstuffs used. Previous research has indicated that supplementing or completely replacing the protein source in the diet with wet BG will not significantly affect milk production

(Murdock et al., 1981, Armentano et al., 1986, Johnson et al., 1987, Hoffman et al., 1988). In the same way, West et al. (1994) replaced a portion of the ground corn/SBM concentrate mix and found similar milk production among all treatments. Replacing forage with wet BG also yielded no differences in milk production (West et al., 1994). The level at which wet BG are included in the diet could have an effect because of a possible decrease in DMI, but in studies conducted with inclusion of up to 30% of the diet DM there were no differences in milk production (West et al., 1994). However, in the same study when liquid brewers' yeast was added along with 30% wet BG inclusion, there was a significant ($P < 0.10$) increase in milk production when compared to 30% wet BG (West et al., 1994). This increase was attributed to the numerical increase in DMI and possibly due to an enhanced ruminal environment from the yeast (West et al., 1994).

While there were no significant differences in milk production, in some research there were differences in milk protein or fat produced for cows supplemented with wet BG. It's been shown that wet BG and dried BG diets resulted in more milk protein (kg) compared to soybean meal (Polan et al., 1985). This may be due to an increased intake of protein over the SBM diet, which lead to greater milk production in wet BG and dried BG fed cows. However, in a study conducted by West et al. (1994) in heat stressed cows, milk protein percentage decreased in cows receiving wet BG at either 15 or 30%. Dietary ether extract in the 15% and 30% diets were 3.5% and 4.2%, respectively, compared to 3.2% for the 0% wet BG (West et al., 1994). Increased dietary fat content of wet BG diets may be the attributing factor to decreased milk protein percentage. Similar results were found when pressed brewers grains were fed at 40% and then compared to the control diet, 0% pressed BG (Davis et al., 1983). There are also mixed reviews when percent and amount of fat were compared. Polan et al. (1985) found no significant differences when comparing milk fat percent, but yield of milk fat (kg) produced was

significantly higher when wet BG was compared to the basal diet. Comparing levels of inclusion and protein type, there was an overall interaction in milk fat percent and a tendency in fat yield for the high protein level (Polan et al., 1985). Miyazawa et al. (2007) results were in disagreement. They found a tendency for 9.3% of diet DM as wet BG to have higher milk fat percentages but not milk fat quantity. In two trials with pressed brewers grains, researchers reported higher milk fat percents in diets up to 40% inclusion compared to the control diet (Davis et al., 1983). As one can see from mixed results of studies, including wet BG in a lactating diet could have a positive effect on milk production and components of milk.

Changes in Long Chain Fatty Acid Profiles

Humans have become more concerned with health and how the food they eat affects their health. Milk is a nutritious, widely-consumed food that has potential to become more healthful if saturated fat can be decreased.

Conjugated linoleic acid (CLA) has been shown to have anticancer and anti-obesity properties warranting the pressure for increased research in this area. One way to potentially alter fatty acid profiles of milk is by feeding by-products that have highly digestible fiber which may modify the rumen through biohydrogenation (Miyazawa et al., 2007). AbuGhazaleh et al. (2003) also noted increased CLA in milk fat when diets high in linoleic acid were fed. Studies with wet BG have been inconclusive. There was a tendency for CLA to be increased when cows were fed 9.3% wet BG (Miyazawa et al., 2007), but when Dhiman et al. (2003) measured CLA in milk from cows fed either 15% wet BG or 15% dried BG, a numerical decline in CLA was reported.

Other LCFA, most notably C18:0, C18:1, C18:2 and C18:3, have been altered when wet BG were fed. In the same Miyazawa et al. (2007) study they saw a significant increase in C18:0 and C18:1 from the control diet. An explanation of their findings wasn't thoroughly given.

Dhiman et al. (2003) found differing results. C18:0 and C18:1 were not different but C18:2 and C18:3 were significantly lower when wet BG were compared to dried BG (Dhiman et al., 2003). The researchers again gave no explanation for the reduction.

Negative Metabolic Effects

When most by-products are fed improperly there are potentially negative effects. Wet BG are no different, but there are few observations in literature in which metabolic problems have been cited. In a 1959 study done in New Zealand studying the toxicity of BG, it was determined that when grains were allowed to spoil, there were more incidences of lactic acid poisoning which decreased the rumen pH below acceptable levels (Owens, 1959). This was only found when grains were heaped into piles for storage instead of spread across a surface. Claw lesions and lameness have also been observed in cattle in Uganda who were fed wet BG at 57% of the diet and were not allowed to graze (Okwee-Acai et al., 2005). The authors note that this high incidence of lameness is most likely due to wet BG being widely unregulated when fed and lack of experience in intensively managing dairy cattle (Okwee-Acai et al., 2005). Other research with wet BG suggests the most common issue becomes decreased dry matter intake (DMI) when they are fed at greater than 20% of the diet DM, but the majority of those studies saw no differences in milk production (Porter et al. 1975, Johnson et al. 1987). Positive results were found by Preston et al. (1973) in growing and finish cattle fed dried BG at three levels, 0%, 25% or 50% of the ration compared to a high corn ration. They saw a decrease in rumen keratosis and liver abscesses even in the high dried BG diet. As time and research has progressed and producers have become more educated on intensively managed dairy cattle, the potential metabolic issues have decreased greatly.

Conclusion

A review of the literature has explored wet BG in detail but has left some questions unanswered. Wet BG are becoming more widely available, but each brewery uses different grains and therefore produces a different end product. Nutritional evaluation of wet BG produced at individual breweries will become increasingly important. This evaluation will impact how the grains are fed. Previous research recommends not exceeding 30% of diet DM in prevention of acidosis, milk fat depression and changes in milk yield. Those studies evaluated wet BG effectiveness when fed with alfalfa hay, but doesn't address replacing corn silage. In times of feedstuff shortage corn silage and alfalfa hay may not always be available to buy and a short-term replacement must be used. Due to increased cost and feedstuff availability, research should be conducted using wet BG replacing a common feedstuff, corn silage.

References

Abughazaleh, A.A., D.J. Schingoethe, A.R. Hippen and K.F. Kalscheur. 2003. Conjugated linoleic acid and vaccenic acid in rumen, plasma, and milk of cows fed fish oil and fats differing in saturation of 18 carbon fatty acids. J. Dairy Sci. 86:3648-3660.

Aguilera-Soto, J.I., R.G. Ramirez, C.F. Arechiga, F. Mendez-Llorene, M.A. Lopez-Carlos, J.A. Pina-Flores, C.A. Medina-Flores, H. Rodriguez-Frausto, D. Rodriguez-Tenorio and H. Gutierrez-Banuelos. 2009. Effect of feed additives on digestibility and milk yield of Holstein cows fed wet brewer grains. J. Appl. Anim. Res. 36:227-230.

Allen, M.S. 1997. Relationship between fermentation acid production in the rumen and the requirement for physically effective fiber. J. Dairy Sci. 80:1447-1462.

Armentano, L.E., T.A. Herrington, C.E. Polan, A.J. Moe, J.H. Herbein and P. Umstadt. 1986. Ruminal Degredation of dried brewers grains, wet brewers grains, and soybean meal. J. Dairy Sci. 69:2124-2133.

Bravo, R.P., J.E. Tomlinson, D.E. Pogue and B.L. Arnold. 1978. Brewers condensed soluble vs. corn as an energy source for lactating dairy cows. J. Dairy Sci. 61(Suppl. 1):169-170.

Davis, C.L., D.A. Greenwalt and G.C. McCoy. 1983. Feeding value of pressed brewers grains for lactating dairy cows. J. Dairy Sci. 66:73-79.

Dawkins, C.W.C., and S.C. Meadowcroft. 1962. Feeding of brewers yeast to dairy cows. Exp. Husbandry. 8:49-55.

Dhiman, T.R., E.D. Helmink, D.J. McMahon, R.L. Fife and M.W. Pariza. 1999. Conjugated linoleic acid content of milk and cheese from cows fed extruded oilseeds. J. Dairy Sci. 82:412-419.

Dhiman, T.R., H.R. Bingham, and H.D. Radloff. 2003. Production response of lactating cows fed dried versus wet brewers' grain in diets with similar dry matter content. J. Dairy Sci. 86:2914-2921.

Firkins, J.L., D.I. Haratine, J.T. Sylvester, and M.L. Eastridge. 2002. Lactation performance by dairy cows fed wet brewers grains or whole cottonseed to replace forage. J. Dairy Sci. 85:2662-2668.

Gaede, E.A. 1979. Brewers' yeast can replace soya bean oilmeal. Tierzuchter. 31:283-285. Web of Knowledge.

Grant, R.J. 1997. Interactions among forages and nonforage fiber sources. J. Dairy Sci. 80:1438-1446.

Grieve, D.G. and J.D. Steckley. 1978. Utilization of liquid brewers yeast as a protein source by lactating cows. Dairy Ind. Res. Rep. 1978. 37-40.

Harris, B., Jr., and D.W. Webb. 1990. The effect of feeding a concentrated yeast culture product to lactating dairy cows. J. Dairy Sci. 73(Suppl 1):266.

Hoffman, P.C. and L. E. Armentano. 1988. Comparison of brewers wet and dried grains and soybean meal as supplements for dairy cattle. Nutritional Reports International. 38:655-663.

Johnson, C.O.L.E., J.T. Huber, and K.J. King. 1987. Storage and utilization of brewers wet grains in diets for lactating dairy cows. J. Dairy Sci. 70:98-107.

Mertens, D.R. 1997. Creating a system for meeting the fiber requirements of dairy cows. J. Dairy Sci. 80:1463-1481.

Miyazawa, K., H. Sultana, T. Hirata, S. Kanda, and H. Itabashi. 2007. Effect of brewers grain on rumen fermentation, milk production and milk composition in lactating dairy cows. An. Sci. Journal. 78:519-526.

Murdock, F.R., A.S. Hodgson, and R.E. Riley, Jr. 1981. Nutritive value of wet brewers grains for lactating dairy cows. J. Dairy Sci. 64:1826-1832.

National Research Council (NRC). 2001 Nutrient requirements of dairy cattle. 7th revised edition. Washington, DC: National Academy Press:

Okwee-Acai, J. and J. Acon. 2005. Claw lesions and lameness in zero-grazed cattle fed on brewers grain in Uganda. Bull Anim. Hlth. Prod. Afr. 53:107-112.

Owens, E.L. 1959. Observations on the toxicity of brewers' grain for dairy cows. New Zealand Vet. Journal. 7:43-46.

Petraitis, I., and S. Baranauskas. 1971. Effect of liquid brewers yeast on milk yield and milk quality. Proceedings of Inter-University Dairy Conference. 119-123.

Polan, C.E., T.A. Herrington, W.A. Wark and L.E. Armentano. 1985. Milk production responses to diets supplemented with dried brewers grains, wet brewers grains, or soybean meal. J. Dairy Sci. 68:2016-2026.

Porter, R.M. and H.R. Conrad. 1975. Comparative nutritive value of wet and dried brewers grains for dairy cattle. J. Dairy Sci (Abstr) 58:747-748.

Preston, R.L., R.D. Vance, and V.R. Cahill. 1973. Energy evaluation of brewers grains for growing and finishing cattle. J. Anim. Sci. 37:174-178.

Robinson, P.H., P.L. Burgess, and R.E. McQueen. 1990. Influence of moisture content of mixed rations on feed intake and milk production of dairy cows. J. Dairy Sci. 73:2916-2921.

Roth-Maier, D.A. 1979. Use of brewers' yeast for animal feeding has become more versatile. Tierzuchter. 31:159-160.

Schroeder, J.W. 1999. By-products and regionally available alternative feedstuffs for dairy cattle. AS-1180. http://www.ag.ndsu.edu/pubs/ansci/dairy/as1180w.htm. May 3, 2010.

Seymour, W.M., J.E. Nocek, and J. Siciliano-Jones. 1995. Effects of a colostrums substitute and of dietary brewers yeast on the health and performance of dairy calves. J. Dairy Sci. 78:412-420.

West, J.W., L.O. Ely and S.A. Martin. 1994. Wet brewers grains for lactating dairy cows during hot, humid weather. J. Dairy Sci. 77:196-204.

Westendorf, M.L. and J.E. Wohlt. 2002. Brewing by-products: their use as animal feeds. Vet. Clin. Food Anim. 18:233-252.

Younker, R.S., S.D. Winland, J.L. Firkins, and B.L. Hull. 1998. Effects of replacing forage fiber or nonfiber carbohydrates with dried brewers grains. J. Dairy Sci. 81:2645-2656.

CHAPTER 2 - Utilization of wet brewers grains as a replacement for corn silage in lactating dairy cow diets

C.L. Mahnken, B.J. Bradford, T.G. Rozell, and M.J. Brouk

Kansas State University
Department of Animal Sciences and Industry
Manhattan, KS 66506-1600

Abstract

Four diets varying in the amount of wet brewers grains (BG) inclusion; 0 BG (0% BG and 24% corn silage (CS) of diet DM), 12 BG (12% BG and 12% CS), 18 BG (18% BG and 6% CS), and 24 BG (24% BG and 0% CS) were evaluated using 8 primiparous (192 DIM) and 4 multiparous (191 DIM) mid-lactation Holstein cows to evaluate replacing CS and soybean meal on a short-term basis with a blend of wet BG and cracked corn by varying the levels of cracked corn and SBM. Milk production (MP), milk composition, DMI, production efficiency, body weights, body condition scores (BCS) and ration digestibility were evaluated. Cows were allotted to a 4 x 4 Latin Square with 3 replications blocked by parity, days in milk (DIM) and energy corrected milk (ECM). Crude protein (CP) and starch levels were balanced between diets by varying the levels of cracked corn and soybean meal. Fifteen day periods were used, d11-15 were designated for collection. Orts were collected daily and TMR were fed at 5 to 10% of previous day's intake. Cows were milked 3x/day and individual milk weights recorded at every milking. Milk samples, body weights (BW) and BCS were taken -2 and -1d pre-trial to obtain baseline data and d14 and 15 of each trial feeding period. During collection, samples of TMR and orts were taken on d1, 3 and 5. Fecal grab samples were taken d12-15 at 8 hr intervals and advanced 2 hrs every 24 hr period to account for diurnal variation.

Dry matter intake was similar (P=0.33) among treatments (20.3, 20.8, 20.9 and 21.2 kg/cow) for 0 BG, 12 BG, 18 BG AND 24 BG, respectively; however CP intake of 24 BG tended to be greater while 0 BG was lowest. Intake of NDF was lower for 0 BG compared to all other treatments and 24 BG was higher than 12 BG (P=0.0007). Dietary fat intake was different (P<0.001) across all treatments, increasing with greater BG inclusion. Inclusion of BG had no effect (P=0.37) on milk production (30.5, 31.5, 31.6 and 32.1 kg/cow), fat percent or amount, protein percent, SNF, lactose or SCC, but protein yield (P=0.04) and MUN (P=0.05) were lower

with 0 BG compared to 18 BG and 24 BG. Efficiency of production did not differ (P=0.93) among treatments.

Diet had an effect on milk fatty acid composition profiles across treatments. Short and medium chain fatty acids were higher (P=0.002) when feeding 0 BG vs. 12 BG, 18 BG or 24 BG diets. Total long chain fatty acids, *trans*-18:1 and total unsaturated fatty acids were significantly higher (P<0.01) with increasing wet BG inclusion. No differences were noted in odd-chained, polyunsaturated fatty acids or Δ^9-desaturase index. Digestibility of DM, CP and ADF were not different (P>0.05) among diet. For a short-term period, results suggest wet BG fed in conjunction with grass hay can replace CS in lactating cow diets.

Introduction

With the increasing cost of feedstuffs, dairy expansion and, unfortunately, improper nutritional planning, the need to find alternate feedstuffs has become a great necessity in the dairy industry. By-product feeds, specifically brewery by-products, have become an option to dairy managers looking for alternative feedstuffs. Brewery by-products are defined by Dhiman et al. (2003) as the residues of the grains used to manufacture beer. The products used most readily in the livestock industry include dried and wet BG. The increased cost of drying has caused wet BG to encompass the majority of the brewers grains sold, however the high cost of transportation and the delicate nature of the grains has made it a locally fed feedstuff (Murdock et al., 1981).

Wet BG are a versatile feedstuff utilized as a protein, concentrate or forage supplement. The CP content of wet BG are variable by brewery but averages 28-29%, making it a suitable replacement for soybean meal in diets of lactating cows in mid-lactation (Johnson et al., 1987). In 1981 Murdock et al. showed that cows fed wet BG to replace concentrate up to 30% of DM

and as a protein supplement achieved similar levels of milk production in early and mid-lactation. Wet BG were also effective as a concentrate during hot, humid weather with no decrease in dry matter intake (DMI) or milk yield when fed at 30% DM (J. W. West, 1994). In the same study, West (1994) found that wet BG plus liquid brewers yeast increased milk yield. When wet BG replaced the forage NDF while decreasing the non fiber carbohydrate (NFC), it was found that cows had similar milk production (Firkins et al., 2002). While research has been done replacing forage in the diet with wet BG, there is no research comparing it to CS. The objective of this study was to analyze the effects of wet BG when replacing corn silage at four levels in the diet on milk production and composition in lactating dairy cows.

Materials and Methods

Cows, Diets and Sampling

Twelve lactating Holstein cows were fed one of four diets with varying amounts of wet BG in a 4 x 4 Latin square design with three replications. The treatment periods were 15 days in length, the first 10 days for adaptation to the diet and the last 5 days designated for collection. Wet BG were added to the diet as a replacement for the dry matter (DM) of corn silage (CS) at four different levels. 0 BG had 24% CS and 0% BG of dietary DM, 12 BG: 12% CS and 12% BG, 18 BG: 6% CS and 18% BG and 24 BG: 0% CS and 24% BG. Diet compositions were adjusted as needed by decreasing SBM and increasing ground corn to maintain similar dietary levels of starch and crude protein.

Cows were housed in a tie-stall facility at the Kansas State University Dairy Teaching and Research Center. All procedures were performed with the approval of the Kansas State University Institutional Animal Care and Use Committee. A total mixed ration (TMR) was fed

to each cow at 630 and 1500 h with feed and orts weighed on a daily basis to provide additional feed at 5 to 10% of intake from the previous day. Feed ingredients, TMR and orts were sampled on days 1, 3 and 5 of each collection period, frozen and composited by treatment and period. Body weights and body condition scores (using the 1-5 scale) were collected on the first day of the study and day14 and 15 of each treatment period following the noon milking.

Cows were milked three times daily with individual milk weights being recorded at every milking. Two milk samples were taken at each milking on day 14 and 15 of each period providing six samples for each cow per period. One sample was taken in a vial with a preservative, potassium dichromate, and sent to DHIA; the other in a vial without which was then composited by cow, day, and period, and frozen for later analysis. Fecal grab samples were taken every 8 hours starting on d 12 and ending on d 15. The sampling time was moved ahead by 2 hours every day to account for diurnal variation (Knowlton et al., 2007). Fecal samples for every cow were frozen and later composited by cow and period.

Laboratory Analysis

Ingredient and ort samples were analyzed by Dairy One Forage Laboratory (Ithaca, NY). The samples were analyzed using wet chemistry for dry matter, crude protein (AOAC 989.03), acid detergent fiber (ADF) (AOAC 973.18C), neutral detergent fiber (NDF) (adapted from Van Soest et al., 1991), lignin (AOAC 973.18D), and ash (AOAC 942.05). Crude fat was evaluated using the Soxtec HT6 System (Eden Prairie, MN) (AOAC 2003.05) while starch was measured using AOAC 989.03 (YSI 2700 SELECT Biochemistry Analyzer, Application note number 319, Yellow Springs, OH). Calcium, phosphorus, magnesium, potassium, sodium, iron, zinc, copper, manganese, molybdenum and sulfur were analyzed using a Thermo IRIS Advantage HX or

Intrepid Inductively Coupled Plasma (ICP) Radial Spectrometer (Waltham, MA), while chloride ions were analyzed from a method similar to Cantliffe, 1970 (Brinkmann Metrohm 716 Titrino Titration Unit, Riverview. FL) (AOAC 989.03). Volatile fatty acids were measured using gas chromatography (Perkin Elmer Autosystem XL Gas Chromatograph, Waltham, MA) via Supelco (Sigma Aldrich, St. Louis, MO) packed column and biochemistry analyzer methods (YSI 2700 SELECT Biochemistry Analyzer, YSI User's Manual, page 4-7, Yellow Springs, OH).

Milk samples with preservatives (potassium dichromate) were sent to an external laboratory, the Heart of America DHIA Laboratory (Manhattan, KS). These samples were analyzed using near infrared spectroscopy (Bentley 2000 Infrared Milk Analyzer, Bentley Instruments, Inc.) for fat, protein, and lactose determination. Somatic cell count (SCC) was determined by flow cytometer laser (Somacount 500, Bentley Instruments, Inc.) and milk urea nitrogen (MUN) was determined by a modified Berthelot reaction in which the milk is enzymatically split into carbon dioxide and ammonia and the ammonia is analyzed colorimetrically (Chemspec 150 Analyzer, Bentley Instruments, Inc.).

In the laboratory at Kansas State University several analyses were done. Sample preparation is as follows: Fecal samples (composited by wet weight after thawing), feed ingredient and ort samples were dried in a forced air oven at 55^{o}C and then ground through a Wiley mill (Thomas Scientific, Swedesboro, NJ) with a 1 mm screen. A subsample was then taken from each composite and dried in the 105^{o}C oven for true DM and sequentially ashed. Acid detergent insoluble ash (ADIA) analysis was determined on the fecal samples, feed ingredient and ort samples in duplicate. Samples were first analyzed for ADF by the ANKOM Technology Corp. system (Fairport, NY). For feed ingredients containing more than 5% fat, the fat was extracted from the samples using acetone prior to ADF analysis. After ADF analysis,

duplicate samples were immersed in acetone for 3 minutes, the acetone allowed to evaporate, dried in the 105^{o}C oven for 2 hours and allowed to cool to room temperature. Following this process, the samples were put into a 450^{o}C oven for 8 hours for combustion. ADIA values were determined as (ash content – bag weight) / original sample at laboratory DM weight x 100 (Cochran et al., 1986). Fecal samples were also analyzed for nitrogen through combustion, and crude protein was calculated as nitrogen x 6.25 (Nitrogen Analyzer Model FP-2000, Leco Corporation St. Joseph, MI).

Fatty acid analysis was conducted on the milk by gas liquid chromatography (GLC) in the following manner. Milk samples were thawed using a water bath until cow body temperature (38.5°C) was reached and then composited by cow and period on a volume basis. Milk samples were freeze dried and 1 ml of benzene, including an internal standard (1000 μg/ml methyl-C13), were added to the tubes and vortexed. Four ml of BF_3-Methanol was used to rinse the sample to the bottom of the tube, the tube was gassed with N_2 and gently mixed again so as to not disturb the sample. Tubes were incubated for 1h at 60^{o}C. After cooling, 4 ml of water and 1 ml of hexane were added, tubes were vortexed and then centrifuged for 5 minutes at 1000 x g. The upper layer was retained for observation using a GLC (model 5890, Hewlett Packard, Palo-Alto, CA) with a 100m x .25mm capillary column with a column film thickness of .20μ (SP2560, Supelco, Inc., Bellefonte, PA). The injector split ratio was 1:100 with a temperature of 250^{o}C and a flow rate of 1 ml/min. The detector was a flame ionization detector with a temperature of 250^{o}C. The final oven temperature was 245^{o}C which was met by increasing the temperature by 2^{o}C/min to 200^{o}C and by 4^{o}C/min to 245^{o}C from the initial temperature of 140^{o}C. The final temp of 245^{o}C was held for 17 minutes.

Feeds and fecal samples were also subjected to fatty acid analysis by a similar procedure to that of the milk samples. After the samples were added to the tubes, 2 ml of internal standard in benzene and 3 ml of methanolic-HCl were included, and then the tubes were gassed with N_2 and gently mixed. The tubes were then heated for 2h in 70^{o}C water, removed and cooled. Five ml of 6% K_2CO_3 and 2 ml of benzene were added to the tubes, vortexed and then centrifuged at 500 x g for 5 minutes. The upper layer was once again transferred to a GC vial for analysis on the GLC (model 5890, Hewlett Packard, Palo-Alto, CA). The GC used a 2 mm x 2 M glass column (#1-1851 Supelco, Inc., Bellefonte, PA) with N_2 as the carrier gas at 20 ml/min. The inlet temperature was 225^{o}C and the flame ionization detector temperature was 250^{o}C. The oven had a final temperature of 210^{o}C which was reached by increasing the temperature by 3.5^{o}C/min from an initial temperature of 130^{o}C.

Statistical Analysis

The MIXED Procedure of SAS version 9.1 (SAS Institute Inc., Cary, NC) was used. Milk weights, DHIA milk samples and feed intake data from the collection period were averaged by cow and period. Feed and ort samples were composited by period and individual feed values were used to calculate diet nutrient concentrations. Feed fatty acids were averaged by period and diet. Milk and fecal fatty acids were averaged by cow, period and diet. Fixed effects in the model statement were diet, replication and diet x replication interaction, while random effects were period and cow within replication. Significance was established at $P < 0.05$.

Results and Discussion

Feed Intake

Wet BG and corn silage differ nutritionally, as shown in Table 1. Wet BG are a considerably wetter product (23.60% DM) than CS (35.48%). Other notable differences between feedstuffs include CP (26.93% DM BG vs. 8.38% DM CS), fat (8.58% DM BG vs. 3.35% DM CS) and starch (13.03% DM BG vs. 40.30% DM CS). These differences were accounted for when formulating the rations by increasing ground corn as wet BG increased in the rations to balance the lost starch, and decreasing soybean meal to account for increased protein in the BG. There was also diversity among feedstuffs when evaluating minerals. Phosphorus (P) was higher in wet BG (0.62% DM BG vs. 0.27% DM CS), and potassium (K) (0.07% DM BG vs. 1.10% DM CS) was much higher in corn silage.

The formula of experimental diets is listed in Table 2. Cracked corn was increased, accounting for lost starch, and SBM decreased, in an effort to keep protein levels balanced, as the amount of BG was increased from 0 to 24% BG. All diets were formulated to be similar in all nutrients except DM, which decreased as inclusion of BG increased (Table 3).

Dry matter intake was not different (P=0.33) across treatments (Table 4). Similar results were seen when wet BG replaced forage up to 25% DM (Firkins et al. 2002; Hoffman and Armentano 1988) and concentrate at 9.3% DM (Miyazawa et al., 2007). West et al. (1994) fed up to 30% BG and saw no differences among diets. Decreases in DMI were noted by Davis et al. (1983) when 30 and 40% pressed brewers grains were fed. Decreased diet DM, such as 24 BG, could depress DMI because of increased water intake from the diet. This was not the case for the current study. Intakes of ADF (P=0.16), starch (P=0.52), nonfibrous carbohydrates (NFC) (P=0.96) and net energy of lactation (NE_L) (P=0.25) were similar across treatments.

Crude protein intake tended to be higher (P=0.05) for 24 BG compared to 0 BG. There was also a tendency for 0 BG to be lower than 18 BG and 12 BG to be lower than 24 BG. This may be due to higher CP levels of BG fed than that which was tested when rations were balanced, resulting in greater intakes of protein in those diets of higher BG inclusion. Previous research by Miyazawa et al. (2007) did not see differences in CP intake. Murdock noted a significant increase when 3.04 kg/d DM was compared to 6.57 kg/d DM of BG was fed, agreeing with the results of this study. Neutral detergent fiber (NDF) intake increased from 0 BG to 24 BG as seen in Table 4. Corn silage had a 9.20% lower NDF value than BG which accounts for the significantly lower NDF intake (P=0.0007) for 0 BG compared to all other diets, as well as lower NDF intake for 12 BG compared to 24 BG. Despite the reported increases, other research shows no differences in NDF intake at 9% DM inclusion (Miyazawa et al., 2007). Fat intake had a significant (P=<0.0001) increase as BG inclusion increased from 0 to 24% DM. Once again, this is because of the higher fat content of BG compared to that of CS. Ash intake was significantly higher for 24 BG as compared to all other diets. This may be due to a higher NDF and lignin value in 24 BG.

Including BG in the diet had no effect on the body condition scores (BCS) (P=0.32) or average body weight (P=0.74), but significant differences were seen with body weight changes (Table 5). When fed 0 BG cows lost significantly (P=0.04) more weight than either 18 or 24 BG, while 12, 18 and 24 BG were similar. A study comparing fresh and ensiled BG as well as SBM noted the numerically higher body weight gains were likely due to higher protein intakes (Johnson et al., 1987). Other studies involving BG reported no affect on weight differences (West et al., 1994; Murdock et al., 1981). In the current study, the increased weight gain on 18 and 24 BG compared to that of 0 BG could be due to increased intake of fat. Dry matter intake,

milk yields and efficiencies were similar among diets despite the weight changes. Dissimilarity in BCS and average body weight may have been more apparent if the trial were over a longer period of time.

Milk Production

There were no differences (P=0.37) in milk production, which is consistent to the findings of West et al. (1994) and Firkins et al. (2002) who replaced forage in the diet up to 30% DM and 26% DM respectively. However, when Polan et al. (1985) tested three different levels of wet BG inclusion (13.0 %, 20.6% and 29.0% DM) and compared them to the basal diet, the cows fed BG produced more milk. In the current study, replacing corn silage up to 24% DM with BG maintained milk production. All other components except protein yield and milk urea nitrogen (MUN) were not different across treatments. Yield of protein tended to be higher for the 18 BG and 24 BG diets compared to the 0 WBG. Milk urea nitrogen followed that of protein yield with 18 and 24 BG being higher (P=0.05) than 0 BG. Previously it was noted that CP intake tended to be higher in both of these diets compared to 0 BG, which could have impacted both protein production and MUN values. Conversely, other studies using BG had varying results to that of the current study in regards to milk protein. West et al. (1994) actually saw a decrease in milk protein percentage with increasing BG inclusion up to 30%, which one could assume meant a decrease in milk protein production even though the authors failed to report those values. They noted that milk protein usually decreases with increasing fat content of the diet, and BG has a large amount of fat (8.58% DM), leading one to believe that BG inclusion may have lead to the decrease. No differences were found in fat corrected milk (FCM), solids corrected milk (SCM), or energy corrected milk (ECM). Moreover, efficiencies of milk production (milk yield/DMI), FCM (FCM/DMI), SCM (SCM/DMI), and ECM (ECM/DMI)

were similar (P>0.05) across treatments (Table 6). The findings in the current study are consistent with that of Dhiman et al. (2003) who replaced 15% DM with BG and with that of West et al. (1994) and Polan et al. (1985) stating that BG can replace the forage portion of the diet and still maintain milk production and efficiencies of production.

Somatic cell count (SCC) was also measured and analyzed as somatic cells x 1,000 cells/ml, as well as the negative log transformed value. Diet did not have an effect on SCC (P=0.17) or Log SCC (P=0.09).

Fatty Acid Profiles

While there were no differences in the amount of fat produced in the milk, there were significant differences associated with the fatty acid profiles of the feed (table 7 and 8), milk produced (table 9 and 10), and feces (table 11). There were significant decreases in the short and medium-chained fatty acids of milk as the level of BG increased from 0 BG to 12, 18 and 24 BG. When diets contained either 15% wet or dried brewers grains there were no significant differences in short and medium chain fatty acids, but BG had numerically higher values (Dhiman et al., 2003). However, when Miyazawa et al. (2007) compared using 9.3% wet BG to the control, they saw numerical decreases in the wet BG diet, but not significant. In the current study, the significant decreases from 0 BG to other treatments may be due to higher fiber intake of cows on the wet BG diet. Short and medium chain fatty acids are synthesized de novo in the alveoli of the udder. Increased amounts of long chain fatty acids supplied in the diet can inhibit de novo synthesis. As a consequence decreased quantities of short and medium chain fatty acids may be the outcome.

There were no significant differences (P=0.50) in odd-chained fatty acids suggesting proper amounts of fiber in the diet to produce acetate, a precursor to fatty acid production. Also

no differences were seen in polyunsaturated fatty acids or the Δ^9 desaturase index which represents no Δ^9 desaturase activity in the udder (Mullins and Bradford, 2010). Significant differences were noted in total LCFA, total *trans*-18:1 and total unsaturated fatty acids (UFA) (table 10) Total LCFA were lowest in 0 BG while highest in 24 BG. These increases were likely due to increased amounts supplied by the wet BG (table 10). A study using 9.3% wet BG saw a similar increase in C18:1 and noted diet as the source of variation (Miyazawa et al., 2007). While there were decreases of some unsaturated LCFA, significant increases in *trans*-18:1 and total UFA were reported. Similar studies conducted using wet BG reported significant increases in C18:1, C18:2 and C18:3 (Dhiman et al. (2003) and Miyazawa et al. (2007)). Both research groups cited diet as being the possible contributor to higher amounts of these LCFA. Dhiman et al. (1999) found that high amounts of digestible fiber increased cis-9, trans-11 CLA, which is an intermediate in the biohydrogenation process of the rumen. Another report show that cows that were consuming grazed grass compared to TMR with conserved forages had considerably more CLA and other unsaturated fatty acids in milk (Rego, et al., 2009). When cows were fed diets with wet BG they were getting both a digestible fiber in wet BG, but also grass hay, which is atypical of a normal lactating diet with alfalfa hay. This may contribute to the increases in some of the LCFA. Significant differences were also seen in total saturated fatty acids (SFA) and total CLA (table 8). Decreases in SFA from 0 BG to 24 BG were noted (P=0.02). Previously it was stated that there were decreases in almost all short and medium chain fatty acids as the amount of BG increased, which contribute approximately 30% to the total SFA value. SFA profiles from the fecal samples show a significant increase (P=0.02) from 0 to 24 BG (table 11). Total fecal CLA showed an increase from 0 BG to 24 BG. This increase may be related to the diet or to the extent of biohydrogenation in the rumen (Dhiman et al., 1999). In the current study, there were

no significant differences (P=0.94) in proportion supplied by the diet (table 8), but there were numerical increases in amounts of cis-9, trans-11 CLA supplied (table 7). This increase of the biohydrogenation intermediate due to less time in the rumen for complete biohydrogenation could explain higher CLA in the milk when cows were fed 24 WBG.

Digestibility

To determine digestibility of DM, CP and ADF, acid detergent insoluble ash (ADIA) was used as an internal marker (table 12). Diet ADIA percent was higher (P=0.004) for 0 BG, while percent ADIA in manure and ADIA intake weren't different from 0 BG to 24 BG. Similar digestible DM and ADF intake were reported, but digestible CP intake had a trend to increase with wet BG inclusion. This is similar to diet CP intake in which a trend was also noted. Feces DM (P=0.29), CP (P=0.40) and ADF (P=0.41) and the percent DM (P=0.62), CP (P=0.81) and ADF (P=0.78) digestibility did not differ significantly among diets and are similar to digestibility values reported by others (Polan et al. 1985, Armentano et al. 1986, Hoffman and Armentano 1988). Hoffman and Armentano (1988) compared wet BG, dried BG and SBM as protein supplements at three different inclusion levels (13, 20.6 and 29% DM) and saw no digestibility differences among diet type. Two levels of dried BG, low (24.8% DM) and high (43.8% DM), were tested against low levels of SBM (15.8 % DM), and similar to the recent study, no differences were noted between high and low levels of dried BG (Polan et al, 1985).

Conclusion

No differences were found in DMI, milk yield, production efficiencies or digestibility of DM, CP and ADF when lactating dairy cows were fed wet BG up to 24 % diet DM. Despite

MUN levels being adequate, the relatively high levels may indicate excessive protein being fed for cows in mid to late lactation. Excessive protein paired with increased fat intake possibly causing increased weight gain may make it difficult for mid to late lactation cows to maintain current weight going into the dry period. While there are differences in fatty acid profiles, an increase in CLA's produced in milk of cows fed wet BG could be important in later years as the concern for healthy products for human consumption continue to increase. Utilizing wet BG as a replacement for corn silage up to 24 % of diet DM in lactating dairy diets during times of shortage can be done over short periods without negatively affecting production.

In the future, research could be done in several areas. This study shows no differences in mid to late lactation cows fed wet BG, but a different response might be found in early lactation cows. With the numbers of microbreweries across the country increasing, more research should be done to ensure consistency when utilizing these by-products. While this research showed positive short-term attributes from feeding wet BG, additional research should examine the longer term affects on milk yield, milk components, rumen function and digestibility.

Bibliography

Armentano, L.E., T.A. Herrington, C.E. Polan, A.J. Moe, J.H. Herbein and P. Umstadt. 1986. Ruminal Degredation of dried brewers grains, wet brewers grains, and soybean meal. J. Dairy Sci. 69:2124-2133.

Cochran, R.C., D.C. Adams, J.D. Wallace, and M.L. Galyean. 1986. Predicting digestibility of difference diets with internal markers: evaluation of four potential markers. J. Anim. Sci. 63:1476-1483.

Dhiman, T.R., G.R. Anand, L.D. Satter, and M.W. Pariza. 1999. Conjugated linoleic acid content of milk from cows fed different diets. J. Dairy Sci. 82:2146-2156.

Dhiman, T.R., H.R. Bingham, and H.D. Radloff. 2003. Production response of lactating cows fed dried versus wet brewers' grain in diets with similar dry matter content. J. Dairy Sci. 86:2914-2921.

Firkins, J.L., D.I. Haratine, J.T. Sylvester, and M.L. Eastridge. 2002. Lactation performance by dairy cows fed wet brewers grains or whole cottonseed to replace forage. J. Dairy Sci. 85:2662-2668.

Hoffman, P.C. and L. E. Armentano. 1988. Comparison of brewers wet and dried grains and soybean meal as supplements for dairy cattle. Nutritional Reports International. 38:655-663.

Johnson, C.O.L.E., J.T. Huber, and K.J. King. 1987. Storage and utilization of brewers wet grains in diets for lactating dairy cows. J. Dairy Sci. 70:98-107.

Knowlton, K.F., M.S. Taylor, S.R. Hill, C. Cobb and K.F. Wilson. 2007. Manure nutrient excretion by lactating cows fed exogenous phytase and cellulose. J. Dairy Sci. 90:4356-4360.

Miyazawa, K., H. Sultana, T. Hirata, S. Kanda, and H. Itabashi. 2007. Effect of brewers grain on rumen fermentation, milk production and milk composition in lactating dairy cows. An. Sci. Journal. 78:519-526.

Mullins, C.R. and B.J. Bradford. 2010. Effects of a molasses-coated cottonseed product on diet digestibility, performance, and milk fatty acid profiles of lactating dairy cattle. J. Dairy Sci. 93:3128-3135.

Murdock, F.R., A.S. Hodgson, and R.E. Riley, Jr. 1981. Nutritive value of wet brewers grains for lactating dairy cows. J. Dairy Sci. 64:1826-1832.

National Research Council (NRC). 2001 Nutrient requirements of dairy cattle. 7th revised edition. Washington, DC: National Academy Press.

Polan, C.E., T.A. Herrington, W.A. Wark and L.E. Armentano. 1985. Milk production responses to diets supplemented with dried brewers grains, wet brewers grains, or soybean meal. J. Dairy Sci. 68:2016-2026.

Rego, O.A., S.P. Alves, L.M.S. Antunes, H.J.D. Rosa, C.F.M. Alfaia, J.A.M. Prates, A.R.J. Cabrita, A.J.M. Fonseca, and R.J.B. Bessa. 2009. Rumen biohydrogenation-derived fatty acids in milk fat from grazing dairy cows supplemented with rapeseed, sunflower or linseed oil. J. Dairy Sci. 92:4530-4540.

Rinkes, B. 2010. Brewing process specifics. Personal communication. June 21, 2010.

Van Soest, P.J., J. B. Robertson, and B. A. Lewis. 1991. Methods for dietary fiber, neutral detergent fiber, and nonstarch polysaccharides in relation to animal nutrition. J. Dairy Sci. 74:3583-3597.

West, J.W., L.O. Ely and S.A. Martin. 1994. Wet brewers grains for lactating dairy cows during hot, humid weather. J. Dairy Sci. 77:196-204.

Table 1. Nutrient differences between corn silage and wet brewers grains

Item	CS[1]	BG[2]
	% DM	
DM,%	35.48	23.60
CP,%	8.38	26.93
ADF,%	20.40	21.90
NDF,%	35.93	45.13
Lignin,%	2.53	7.05
Fat,%	3.35	8.58
Starch,%	40.30	13.03
NE_L[3], Mcal/kg	0.79	0.81
Ash,%	4.33	4.23
Ca,%	0.19	0.23
P,%	0.27	0.62
Mg,%	0.13	0.23
K,%	1.10	0.07
Na,%	0.02	0.02
Cl,%	0.29	0.00
S,%	0.12	0.30
Fe, mg/kg	117.50	181.00
Mn, mg/kg	17.80	39.00
Zn, mg/kg	18.30	76.30
Cu, mg/kg	6.50	11.50

[1] CS = corn silage.
[2] BG = brewers grain.
[3] NE_L = net energy of lactation.

Table 2. Ingredient composition of experimental diets

Ingredient	Treatments[1]			
	0 BG	12 BG	18 BG	24 BG
	% of DM			
Corn Silage	24.03	12.03	6.04	-
Wet Brewers Grains (WBG)	-	12.03	18.01	24.06
Grass Hay	22.02	22.04	22.04	22.04
Whole Cotton Seed	6.61	6.62	6.62	6.62
Cracked Corn	23.12	27.73	29.93	32.32
SoyBest™ (Grain States Soya, West Point, NE)	9.17	9.18	9.18	9.18
Soybean Meal Solv., 48%	10.55	5.88	3.67	1.29
Ground Limestone	1.46	1.46	1.46	1.46
Salt	0.17	0.17	0.17	0.17
Sodium Bicarbonate	0.91	0.91	0.91	0.91
Magnesium Oxide	0.09	0.09	0.09	0.09
Zinpro4-Plex™ (Zinpro Corp., Eden Prairie, MN)	0.05	0.05	0.05	0.05
Selenium premix, 0.06%	0.04	0.04	0.04	0.04
Vitamin A premix, 30,000 IU/g	0.01	0.01	0.01	0.01
Vitamin D premix, 30,000 IU/g	0.01	0.01	0.01	0.01
Vitamin E premix, 20,000 IU/g	0.18	0.18	0.18	0.18
Rumensin 80™ (Elanco, Greenfield, IN)	0.01	0.01	0.01	0.01
Cane Molasses	0.47	0.47	0.47	0.47
XP Yeast™ (Diamond V Mills, Inc., Cedar Rapids, IA)	0.21	0.21	0.21	0.21
MegalacR™ (Arm & Hammer, Princeton, NJ)	0.89	0.89	0.89	0.89

[1] 0 BG: 0% DM WBG and 24% DM CS, 12 BG: 12% DM WBG and 12% DM CS, 18 BG: 18% DM WBG and 6% DM CS, 24 BG: 24% DM WBG and 0% DM CS.

Table 3. Nutrient composition of experimental diets containing either CS or BG

	Treatments[1]			
Nutrient	0 BG	12 BG	18 BG	24 BG
	% DM			
DM, %	65.46	59.36	56.50	54.09
CP, %	17.45	17.64	17.67	17.98
ADF, %	18.97	19.16	19.08	19.29
NDF, %	32.34	33.64	34.29	34.32
Lignin, %	2.68	3.24	3.60	3.80
Fat, %	4.51	5.29	5.61	5.86
Starch, %	26.38	26.01	26.78	25.54
NE_L[2], Mcal/kg	0.77	0.77	0.77	0.77
Ash, %	7.86	7.48	7.24	8.09
Ca, %	1.03	1.02	0.93	1.16
P, %	0.41	0.43	0.44	0.46
Mg, %	0.25	0.28	0.26	0.27
K, %	1.54	1.33	1.23	1.14
Na, %	0.32	0.33	0.31	0.40
S, %	0.19	0.20	0.20	0.21
Fe, mg/kg	182.17	183.48	178.24	196.03
Mn, mg/kg	38.16	41.85	43.30	47.96
Zn, mg/kg	53.74	52.91	58.75	64.55
Cu, mg/kg	12.23	11.65	11.71	13.54
Mo, mg/kg	1.92	1.66	1.86	1.68

[1] 0 BG: 0% DM WBG and 24% DM CS, 12 BG: 12% DM WBG and 12% DM CS, 18 BG: 18% DM WBG and 6% DM CS, 24 BG: 24% DM WBG and 0% DM CS.
[2] NE_L=net energy of lactation

.

Table 4. Effects of WBG supplementation on nutrient intake in lactating dairy cows

Item	Treatments[1]				SE	P
	0 BG	12 BG	18 BG	24 BG		
	Intake, kg					
DMI[2]	20.33	20.78	20.87	21.23	0.68	0.33
CP	3.55	3.67	3.69	3.81	0.11	0.05
ADF	3.87	3.99	3.98	4.09	0.15	0.16
NDF	6.58[a]	6.99[b]	7.16[bc]	7.26[c]	0.22	0.0007
NFC[3]	8.27	8.30	8.31	8.21	0.33	0.96
Fat	0.92[a]	1.10[b]	1.17[c]	1.24[d]	0.04	<0.0001
Starch	5.35	5.41	5.59	5.44	0.25	0.52
Ash	1.60[a]	1.55[a]	1.51[a]	1.71[b]	0.06	0.003
NE_L, Mcal/d	34.28	35.30	35.66	35.83	1.22	0.25

[a-d] Means in the same row with unlike superscripts differ ($P < 0.05$)

[1] 0 BG: 0% DM WBG and 24% DM CS, 12 BG: 12% DM WBG and 12% DM CS, 18 BG: 18% DM WBG and 6% DM CS, 24 BG: 24% DM WBG and 0% DM CS.

[2] Dry Matter Intake

[3] Non-fibrous carbohydrate

Table 5. Effects of WBG inclusion on performance of lactating dairy cows

	Treatments					
Item	0 BG	12 BG	18 BG	24 BG	SE	P
Milk, kg/d	30.45	31.43	31.62	32.01	1.50	0.37
Milk fat, %	3.51	3.53	3.52	3.55	0.15	0.98
Milk protein, %	3.01	3.05	3.10	3.05	0.08	0.15
Milk fat, kg/d	1.06	1.10	1.11	1.14	0.06	0.20
Milk protein, kg/d	0.91[a]	0.95[ab]	0.97[b]	0.97[b]	0.04	0.04
Milk lactose, %	4.82	4.81	4.87	4.85	0.04	0.05
Milk lactose, kg/d	1.47	1.51	1.54	1.55	0.07	0.32
SNF[2], kg/d	2.65	2.75	2.81	2.82	0.12	0.17
SCC, x 1,000 cell/ml	197.17	497.67	250.63	312.96	164.30	0.17
Log SCC	1.90	1.98	2.03	2.18	0.18	0.09
MUN	14.93[a]	15.27[ab]	16.12[b]	16.15[b]	0.79	0.04
ECM[3], kg/d	30.24	31.33	31.67	32.20	1.43	0.14
FCM[4], kg/d	28.13	29.03	29.24	29.87	1.41	0.20
SCM[5], kg/d	32.78	33.93	34.41	34.92	1.54	0.15
Avg. BCS[6]	3.10	3.08	3.11	3.15	0.06	0.32
Avg. weight, kg	622.02	624.39	623.58	624.95	12.87	0.74
BCS change	-0.09	-0.04	-0.10	-0.06	0.05	0.23
Weight change, kg	-4.63[a]	-1.80[ab]	8.13[b]	6.14[b]	3.47	0.04

[a-d] Means in the same row with unlike superscripts differ ($P < 0.05$)

[1] 0 BG: 0% DM WBG and 24% DM CS, 12 BG: 12% DM WBG and 12% DM CS, 18 BG: 18% DM WBG and 6% DM CS, 24 BG: 24% DM WBG and 0% DM CS.

[2] Solids Non-Fat.

[3] Energy Corrected Milk = (0.327 x kg of milk) + (12.95 x kg of milk fat) + (7.2 x kg of milk protein).

[4] Fat Corrected Milk = (0.4 x kg of milk) + (15 x kg of milk fat).

[5]Solids Corrected Milk = (0.0752 x kg of milk) + (12.3 x kg of milk fat) + (6.56 x kg of SNF).

[6] BCS = body condition score.

Table 6. Effect of WET BG supplementation on efficiencies of production in lactating dairy cows

	Treatment[1]					
Item	0 BG	12 BG	18 BG	24 BG	SE	P
Milk efficiency[2]	1.49	1.51	1.51	1.51	0.06	0.93
ECM efficiency[3]	1.48	1.51	1.51	1.52	0.06	0.76
FCM efficiency[4]	1.38	1.40	1.40	1.41	0.06	0.84
SCM efficiency[5]	1.61	1.63	1.64	1.65	0.06	0.73

[a-d] Means in the same row with unlike superscripts differ ($P < 0.05$)

[1] 0 BG: 0% DM WBG and 24% DM CS, 12 BG: 12% DM WBG and 12% DM CS, 18 BG: 18% DM WBG and 6% DM CS, 24 BG: 24% DM WBG and 0% DM CS.

[2] Milk efficiency = milk yield kg/ DMI kg.

[3] Energy corrected milk efficiency = ECM kg / DMI kg.

[4] Fat corrected milk efficiency = FCM kg / DMI kg.

[5]Solids corrected milk efficiency = SCM kg / DMI kg.

Table 7. Diet long chain fatty acid profiles

Fatty Acid	Treatments[1]				SE	P
	0 BG	12 BG	18 BG	24 BG		
	g/100 g					
C6:0	0.10	0.13	0.08	0.09	0.06	0.93
C8:0	0.10	0.11	0.10	0.11	0.007	0.59
C10:0	0.003[a]	0.008[b]	0.009[b]	0.008[b]	0.001	0.05
C11:0	0.002	0.001	0.006	0.0008	0.003	0.61
C12:0	0.10	0.11	0.09	0.08	0.01	0.44
C14:0	0.19	0.22	0.22	0.23	0.01	0.14
C14:1	0.002	0.002	0.002	0.001	0.0005	0.47
C15:0	0.02[a]	0.04[b]	0.04[b]	0.05[c]	0.002	<0.0001
C16:0	6.33	7.58	7.21	7.33	0.41	0.21
C16:1	0.08	0.09	0.09	0.10	0.005	0.09
C17:0	0.06	0.06	0.05	0.05	0.003	0.44
C17:1	0.004	0.004	0.003	0.003	0.0007	0.29
C18:0	1.11	1.20	1.09	1.06	0.08	0.67
C18:1n9t	0.01	0.01	0.01	0.01	0.003	0.89
C18:1n10t	0.01	0.02	0.02	0.01	0.002	0.56
C18:1n11t	0.007	0.008	0.007	0.006	0.002	0.86
C18:1n9c	5.76	6.65	6.17	6.28	0.39	0.47
C18:1n11c	0.31	0.34	0.32	0.32	0.01	0.65
C18:2n6t	0.008	0.007	0.006	0.008	0.003	0.97
C18:2n6c	13.16	14.88	14.83	15.47	1.02	0.45
C18:3n6	0.00007	0.005	0.0008	0.001	0.003	0.54
C18:3n3	1.70	1.70	1.68	1.68	0.13	0.99
C20:0	0.15	0.16	0.15	0.15	0.007	0.45
C20:1	0.06[a]	0.10[b]	0.11[b]	0.12[c]	0.005	<0.0001
C20:2	0.02	0.02	0.02	0.03	0.003	0.15
C20:3n3	0.004	0.003	0.004	0.005	0.002	0.97
C20:3n6	0.002	0.002	0.003	0.003	0.0008	0.79
C20:4n6	0.009	0.008	0.006	0.005	0.003	0.66
C20:5n3	0.01	0.01	0.01	0.01	0.002	0.77
C21:0	0.01	0.01	0.01	0.01	0.0007	0.30
C22:0	0.13	0.14	0.13	0.13	0.007	0.77
C22:1n9	0.01	0.02	0.02	0.02	0.003	0.11
C22:2	0.001	0.002	0.002	0.002	0.001	0.84
C22:5n3	0.0001	0.0001	0.0008	0.0001	0.0004	0.42
C22:6n3	0.003	0.001	0.001	0.001	0.001	0.89
C23:0	0.04	0.04	0.04	0.04	0.001	0.28
C24:0	0.13	0.14	0.13	0.13	0.005	0.60
C24:1	0.04	0.05	0.05	0.06	0.007	0.42
CLA[2] 9c, 11t	0.01	0.01	0.009	0.008	0.004	0.85
CLA 9c, 11c	0.002	0.002	0.002	0.001	0.0009	0.98
CLA 9t, 11t	0.05	0.06	0.04	0.04	0.03	0.95

[a-d] Means in the same row with unlike superscripts differ ($P < 0.05$)

[1] 0 BG: 0% DM WBG and 24% DM CS, 12 BG: 12% DM WBG and 12% DM CS, 18 BG: 18% DM WBG and 6% DM CS, 24 BG: 24% DM WBG and 0% DM CS.

[2] CLA = conjugated linoleic acid.

Table 8. Diet total saturated (SFA), unsaturated (UFA) and CLA long chain fatty acid profiles

	Treatment[1]					
Fatty Acid	0 BG	12 BG	18 BG	24 BG	SE	P
	g/ 100g					
SFA[2]	28.61	29.39	28.60	28.18	1.61	0.96
UFA[3]	71.39	70.61	71.40	71.82	1.61	0.96
CLA[4]	0.21	0.23	0.17	0.16	0.10	0.94

[a-d] Means in the same row with unlike superscripts differ ($P < 0.05$)

[1] 0 BG: 0% DM WBG and 24% DM CS, 12 BG: 12% DM WBG and 12% DM CS, 18 BG: 18% DM WBG and 6% DM CS, 24 BG: 24% DM WBG and 0% DM CS.

[2] Saturated fatty acids, sum of $C_{4:0}$, $C_{6:0}$, $C_{8:0}$, $C_{10:0}$, $C_{11:0}$, $C_{12:0}$, $C_{14:0}$, $C_{15:0}$, $C_{16:0}$, $C_{17:0}$, $C_{18:0}$, $C_{20:0}$, $C_{21:0}$, $C_{22:0}$, $C_{23:0}$, $C_{24:0}$.

[3] Unsaturated fatty acids, sum of $C_{14:1}$, $C_{16:1}$, $C_{18:1n9t}$, $C_{18:1n10t}$, $C_{18:1n11t}$, $C_{18:1n9c}$, $C_{18:1n11c}$, $C_{18:2n6t}$, $C_{18:2n6c}$, $C_{18:3n6}$, $C_{18:3n3}$, $C_{20:1}$, $C_{20:2}$, $C_{20:3n6}$, $C_{20:4n6}$, $C_{20:5n3,}$ $C_{22:5n3,}$ $C_{22:6n3}$.

[4] Conjugated linoleic acids, sum of $C_{CLA9c11t,}$ $C_{CLA9c11c,}$. $C_{CLA9t11t,}$ $C_{CLA10t12c.}$

Table 9. Effects of feeding wet BG on milk fatty acids profiles

Fatty Acid	Treatments[1]				SE	P
	0 BG	12 BG	18 BG	24 BG		
	g/100 g					
C4:0	3.19	3.14	3.13	3.03	0.13	0.14
C6:0	2.06[a]	1.94[b]	1.93[b]	1.82[c]	0.07	0.0001
C8:0	1.08[a]	1.01[b]	1.01[b]	0.94[c]	0.03	0.001
C10:0	2.22[a]	2.05[b]	2.07[ab]	1.92[b]	0.07	0.006
C11:0	0.18	0.18	0.18	0.17	0.01	0.87
C12:0	2.50[a]	2.30[ab]	2.36[ab]	2.17[b]	0.09	0.02
C14:0	9.68[a]	8.92[b]	8.97[b]	8.48[b]	0.25	0.0006
C14:1	0.73	0.69	0.70	0.66	0.06	0.28
C15:0	0.86	0.85	0.89	0.91	0.03	0.24
C16:0	27.91	27.93	27.80	27.76	0.49	0.95
C16:1	1.49	1.43	1.33	1.36	0.10	0.06
C17:0	0.70[a]	0.66[b]	0.6 [b]	0.6 [b]	0.02	0.004
C18:0	13.53	14.06	14.32	14.28	0.49	0.45
C18:1n9t	0.37[a]	0.40[b]	0.42[c]	0.44[c]	0.01	<0.0001
C18:1n10t	0.92	0.98	0.98	0.90	0.13	0.76
C18:1n11t	1.8 [a]	2.2 [b]	2.52[b]	2.88[c]	0.14	<0.0001
C18:1n9c	23.45	23.78	23.26	24.09	0.76	0.33
C18:1n11c	0.68[a]	0.61[b]	0.59[b]	0.59[b]	0.04	0.02
C18:2n6t	0.01	0.01	0.01	0.01	0.0008	0.07
C18:2n6c	4.20	4.30	4.32	4.26	0.10	0.73
C18:3n6	0.06	0.05	0.05	0.06	0.002	0.19
C18:3n3	0.48	0.48	0.47	0.45	0.01	0.21
C20:0	0.16[a]	0.17[b]	0.18[b]	0.18[b]	0.006	0.007
C20:1	0.05[a]	0.07[b]	0.07[b]	0.07[b]	0.005	0.01
C20:2	0.05	0.05	0.05	0.05	0.002	0.73
C20:3n6	0.20	0.18	0.19	0.18	0.01	0.10
C20:4n6	0.21[a]	0.18[b]	0.19[b]	0.18[bc]	0.006	<0.0001
C20:5n3	0.04[a]	0.03[b]	0.03[b]	0.03[b]	0.0009	0.0007
C21:0	0.03	0.03	0.03	0.03	0.002	0.56
C22:0	0.06	0.06	0.06	0.06	0.004	0.51
C22:5n3	0.08[a]	0.07[b]	0.07[b]	0.07[b]	0.002	0.0005
C22:6n3	0.006	0.006	0.004	0.003	0.001	0.07
C23:0	0.03	0.02	0.02	0.02	0.002	0.51
C24:0	0.03	0.03	0.03	0.03	0.003	0.95
CLA[2] 9c, 11t	0.81[a]	0.95[b]	1.04[b]	1.19[c]	0.05	<0.0001
CLA 9c, 11c	0.01[a]	0.009[a]	0.01[ab]	0.01[b]	0.001	0.02
CLA 9t, 11t	0.05[a]	0.05[b]	0.06[b]	0.06[bc]	0.002	<0.0001
CLA 10t, 12c	0.013	0.016	0.014	0.015	0.002	0.56

[a-d] Means in the same row with unlike superscripts differ (P < 0.05)

[1] 0 BG: 0% DM WBG and 24% DM CS, 12 BG: 12% DM WBG and 12% DM CS, 18 BG: 18% DM WBG and 6% DM CS, 24 BG: 24% DM WBG and 0% DM CS.

[2] CLA = conjugated linoleic acid.

Table 10. Effects of wet BG on classes of milk fatty acids

	Treatment[1]					
Fatty Acid	0 BG	12 BG	18 BG	24 BG	SE	P
	g/ 100g					
Short- and medium-chain FA[2]	22.51[a]	21.07[b]	21.24[b]	20.10[b]	0.57	0.002
Long chain FA[3]	48.09[a]	49.57[ab]	49.64[ab]	50.78[b]	0.92	0.01
Odd-Chain FA	1.74	1.69	1.72	1.71	0.04	0.50
Total t*rans*-C18:1[4]	3.17[a]	3.67[b]	3.93[b]	4.21[c]	0.18	<0.0001
Polyunsaturated FA	6.19	6.37	6.49	6.55	0.15	0.08
Δ^9 Desaturase Index[5]	7.03	7.14	7.11	7.17	0.40	0.91
Total UFA[6]	35.78[a]	36.65[ab]	36.36[a]	37.55[b]	0.83	0.02
SFA[7]	64.22[a]	63.35[ab]	63.64[a]	62.45[b]	0.83	0.02
CLA[8]	0.88[a]	1.03[b]	1.12[b]	1.27[c]	0.06	<0.0001

[a-d] Means in the same row with unlike superscripts differ (P < 0.05)

[1] 0 BG: 0% DM WBG and 24% DM CS, 12 BG: 12% DM WBG and 12% DM CS, 18 BG: 18% DM WBG and 6% DM CS, 24 BG: 24% DM WBG and 0% DM CS.

[2] Fatty acids < C16:0.

[3] Fatty acids > C16:0.

[4] Includes *trans*-9, *trans*-10, and *trans*-11 C18:1.

[5] Calculated as C14:1/(C14:0 + C14:1).

[6] Unsaturated fatty acids, sum of $C_{14:1}$, $C_{16:1}$, $C_{18:1n9t}$, $C_{18:1n10t}$, $C_{18:1n11t}$, $C_{18:1n9c}$, $C_{18:1n11c}$, $C_{18:2n6t}$, $C_{18:2n6c}$, $C_{18:3n6}$, $C_{18:3n3}$, $C_{20:1}$, $C_{20:2}$, $C_{20:3n6}$, $C_{20:4n6}$, $C_{20:5n3}$, $C_{22:5n3}$, $C_{22:6n3}$.

[7] Saturated fatty acids, sum of $C_{4:0}$, $C_{6:0}$, $C_{8:0}$, $C_{10:0}$, $C_{11:0}$, $C_{12:0}$, $C_{14:0}$, $C_{15:0}$, $C_{16:0}$, $C_{17:0}$, $C_{18:0}$, $C_{20:0}$, $C_{21:0}$, $C_{22:0}$, $C_{23:0}$, $C_{24:0}$.

[8] Conjugated linoleic acids, sum of $C_{CLA9c11t}$, $C_{CLA9c11c}$,. $C_{CLA9t11t}$, $C_{CLA10t12c}$.

Table 11. Long chain fatty acid profiles of fecal samples

	Treatments[1]					
Fatty Acid	0 BG	12 BG	18 BG	24 BG	SE	P
	g/100 g					
C6:0	0.45[a]	0.29[b]	0.50[a]	0.42[a]	0.05	0.0004
C8:0	0.04	0.03	0.04	0.04	0.004	0.10
C10:0	0.01	0.02	0.02	0.01	0.002	0.37
C11:0	0.0004	0.002	0.005	0.001	0.002	0.22
C12:0	0.15[a]	0.13[b]	0.12[b]	0.13[b]	0.005	0.002
C14:0	0.35	0.32	0.32	0.36	0.02	0.05
C15:0	0.28	0.30	0.28	0.29	0.02	0.52
C16:0	8.12[a]	8.42[a]	8.14[a]	9.80[b]	0.40	0.01
C16:1	0.25	0.27	0.24	0.25	0.01	0.22
C17:0	0.32	0.34	0.31	0.35	0.03	0.07
C18:0	25.43[a]	27.45[ab]	25.48[a]	31.32[b]	1.68	0.02
C18:1n9t	0.08	0.08	0.07	0.08	0.007	0.52
C18:1n10t	0.24	0.33	0.27	0.25	0.06	0.47
C18:1n11t	1.16[a]	1.20[a]	1.21[a]	1.49[b]	0.08	0.010
C18:1n9c	1.81	1.66	1.64	1.85	0.010	0.10
C18:1n11c	0.23[a]	0.20[b]	0.19[b]	0.22[ab]	0.010	0.01
C18:2n6t	0.02[a]	0.03[b]	0.03[b]	0.03[b]	0.001	0.0007
C18:2n6c	2.26[a]	1.98[b]	2.10[b]	2.46[a]	0.16	0.03
C18:3n6	0.007	0.005	0.003	0.005	0.001	0.23
C18:3n3	0.21	0.19	0.19	0.22	0.01	0.14
C20:0	0.35[a]	0.40[a]	0.38[a]	0.47[b]	0.02	0.0002
C20:1	0.03[a]	0.03[b]	0.04[b]	0.05[c]	0.002	<0.0001
C20:2	0.01	0.01	0.01	0.01	0.001	0.51
C20:3n6	0.01	0.01	0.01	0.01	0.001	0.08
C20:4n6	0.02	0.02	0.02	0.02	0.002	0.35
C20:5n3	0.007	0.004	0.005	0.005	0.0009	0.19
C21:0	0.03[a]	0.03[a]	0.03[a]	0.04[b]	0.002	0.001
C22:0	0.29	0.30	0.27	0.31	0.01	0.10
C22:1n9	0.01	0.01	0.01	0.02	0.0009	0.25
C23:0	0.08	0.09	0.08	0.09	0.004	0.15
C24:0	0.31	0.31	0.30	0.34	0.01	0.20
C24:1	0.03[a]	0.03[a]	0.03[ab]	0.03[b]	0.002	0.05
CLA[2] 9c, 11t	0.08[a]	0.06[b]	0.06[bc]	0.07[c]	0.005	0.0002
CLA 9t, 11t	0.07	0.07	0.07	0.08	0.004	0.25
SFA[3]	36.24[a]	38.42[a]	36.28[a]	44.00[b]	2.15	0.02
UFA[4]	6.40	6.09	6.09	7.00	0.33	0.06
CLA[5]	0.15[a]	0.13[b]	0.14[bc]	0.15[ac]	0.008	0.03

[a-d] Means in the same row with unlike superscripts differ ($P < 0.05$)

[1] 0 BG: 0% DM WBG and 24% DM CS, 12 BG: 12% DM WBG and 12% DM CS, 18 BG: 18% DM WBG and 6% DM CS, 24 BG: 24% DM WBG and 0% DM CS.

[2] CLA = conjugated linoleic acid.

[3] Saturated fatty acids, sum of $C_{4:0}$, $C_{6:0}$, $C_{8:0}$, $C_{10:0}$, $C_{11:0}$, $C_{12:0}$, $C_{14:0}$, $C_{15:0}$, $C_{16:0}$, $C_{17:0}$, $C_{18:0}$, $C_{20:0}$, $C_{21:0}$, $C_{22:0}$, $C_{23:0}$, $C_{24:0}$.

[4] Unsaturated fatty acids, sum of $C_{14:1}$, $C_{16:1}$, $C_{18:1n9t}$, $C_{18:1n10t}$, $C_{18:1n11t}$, $C_{18:1n9c}$, $C_{18:1n11c}$, $C_{18:2n6t}$, $C_{18:2n6c}$, $C_{18:3n6}$, $C_{18:3n3}$, $C_{20:1}$, $C_{20:2}$, $C_{20:3n6}$, $C_{20:4n6}$, $C_{20:5n3}$, $C_{22:5n3}$, $C_{22:6n3}$.

[5] Conjugated linoleic acids, sum of $C_{CLA9c11t}$, $C_{CLA9c11c}$, $C_{CLA9t11t}$, $C_{CLA10t12c}$.

Table 12. Effects of feeding WBG on apparent digestibility

	Treatment[1]					
Item	0 BG	12 BG	18 BG	24 BG	SE	P
Diet ADIA, %	1.56[a]	1.53[b]	1.53[b]	1.52[b]	0.02	0.004
Feces ADIA, %	5.27	5.11	4.95	4.91	0.21	0.24
ADIA[2] intake, kg/d	0.32	0.32	0.32	0.32	0.01	0.86
DDM[3] intake, kg/d	14.25	14.49	14.34	14.59	0.65	0.75
Feces, DM[4], kg/d	6.09	6.30	6.53	6.64	0.32	0.38
DM digestibility, %	69.97	69.83	68.76	68.52	1.55	0.57
CP[5] intake, kg/d	2.58	2.67	2.65	2.78	0.11	0.07
Feces CP, kg/d	0.97	0.99	1.04	1.03	0.05	0.49
CP digestibility, %	72.60	73.08	71.89	72.75	1.58	0.79
ADF[6] intake, kg/d	2.05	2.05	2.05	2.00	0.22	0.96
Feces ADF, kg/d	1.82	1.93	1.93	2.09	0.14	0.20
ADF digestibility, %	51.78	51.64	51.32	48.70	4.33	0.64

[1] 0 BG: 0% DM WBG and 24% DM CS, 12 BG: 12% DM WBG and 12% DM CS, 18 BG: 18% DM WBG and 6% DM CS, 24 BG: 24% DM WBG and 0% DM CS.
[2]ADIA=acid detergent insoluble ash.
[3]DDM=digestible dry matter.
[4]DM=dry matter.
[5]CP=crude protein.
[6]ADF=acid detergent fiber.