PRODUCTION RESPONSE TO CORN SILAGE PRODUCED FROM NORMAL, BROWN MIDRIB, OR WAXY CORN HYBRIDS

by

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(Under the Direction of John K. Bernard)

ABSTRACT

The starch in waxy corn hybrids is 100% amylopectin which is more digestible than that of normal corn hybrids; the production response to feeding silage produced from these hybrids has been inconsistent. Brown midrib corn varieties have lower lignin concentrations and have been shown to support higher DMI and milk yield. The objective of this study was to evaluate the nutrient intake and milk production response of lactating dairy cows fed diets based on corn silage from a normal, brown midrib, or waxy corn hybrid. No difference was observed in DMI among treatments. Milk yield was highest for cows fed BMR compared with WAXY but similar to CONTROL. Milk fat percentage tended to be lower for cows fed CONTROL compared with BMR or WAXY. Milk protein percentage tended to be lower for cows fed CONTROL compared with WAXY but similar to BMR.

INDEX WORDS: BMR, Waxy, Corn Silage

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DEDICATION

I dedicate this work to my family for instilling in me the core values of honesty, integrity, and hard work and teaching me that those qualities will get you far in life. I especially want to thank my wife who was willing to move halfway across the country and support me while I pursued one of my goals in life.

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CHAPTER 1

INTRODUCTION

Corn (Zea mays L.) silage makes up the largest forage portion of today's lactating dairy cattle (Bos taurus) diets (Akay and Jackson, 2001). Corn silage is favored over other forages because of its good agronomic traits, high yield of digestible nutrients, ease of ensiling, and ease of integration into total mixed rations (Neylon and Kung, 2003). Corn silage provides valuable energy to diets through readily available starch and also provides fiber to the diet which help maintain rumen health.

Traditionally, corn hybrid variety selection for silage production was based on grain production. However, Coors et al. (1994) reported that hybrids chosen for high grain production might not be the highest producing varieties for corn silage. The selection of hybrids based on grain yield also neglects to include the genetic influence on nutritive value (Bal et al., 2000). The best management practices used in the selection of corn hybrids involves evaluating many different aspects of the resulting forage. Besides grain, traits of DM yield, energy concentration, and fiber concentrations and digestibility, and fermentation characteristics when stored at the proper moisture content (Carter et al., 1991). As the cost of corn grain increases, the economic role of whole plant corn silage in dairy rations is becoming more important.

Corn silage has been utilized in dairy diets for decades, originally as supplemental forage when primary forage yields were deficient. Traditionally, corn was planted as a grain crop; however, harvesting the whole plant for the production of silage allows for more digestible nutrients to be produced per acre than any other forage. The production of corn silage is simple in terms of management and production, as it is an annual crop only needing to be harvested once and requires little management for survivability, when comparing to a perennial forage crop. When properly harvested and ensiled, corn silage can provide a palatable and vital nutritional component to dairy rations.

The goal of modern dairy farms is to maximize milk production while trying to reduce input costs, over half of which is feed costs. As annual milk production increases, there is also a need to produce improved feedstuffs in order to meet their genetic potential of the herd. VandeHaar and St-Pierre (2006) determined that over the last 100 years that annual milk production has more than quadrupled. Dairy producers are constantly searching for more economical means to provide nutrients to lactating dairy cattle, usually through selection of improved corn varieties to plant for silage production.

There are many types of corn hybrids to choose from including, tropical, leafy, brown midrib, waxy, and high oil. The most recent research on all of these corn hybrid varieties will be covered in the review of literature as it pertains to the DMI, milk production and agronomic traits observed when using these hybrid types.

CHAPTER 2

REVIEW OF LITUREATURE: Corn Hybrid Types Effect on DMI, Milk Yield and Agronomic Characteristics

High Oil Corn Hybrids

High oil corn varieties have increased concentrations of oil and lower starch concentrations in the grain. This additional oil allows higher crude protein levels than conventional dent corn varieties (Akay and Jackson, 2001). These varieties of corn also have a larger germ where the oil is concentrated within the kernel than is observed in conventional dent corn (Parsons et al., 1998). When used as whole plant corn silage, the increased oil content of the grain is diluted by the addition of the plant stalks. Several studies have evaluated the utilization of either high oil corn grain or high oil corn silage fed to lactating dairy cattle; however, the results have been inconclusive. Weiss and Wyatt (2000) reported that unprocessed high oil corn silage contained 8.2% more TDN than unprocessed conventional silage. When conventional corn silage was processed it increased TDN concentrations similar to unprocessed high oil silage. There was no difference in DMI of cows fed diets based on high oil corn compared with conventional corn silage, although cows fed high oil silages tended to produce 1 kg/d more milk and 1.3 kg/d more FCM. Similar numeric differences in milk yield and FCM when feeding high oil corn silage were observed by Atwell et al. (1988). LaCount et al. (1995) fed high oil corn silage for an entire lactation at 25% of the dietary DM and did not observe any differences in DMI or milk yield. However when high oil corn grain was fed there was an increase of 2.2 kg/d in DMI.

Dhiman et al. (1999) reported no differences in milk yield or DMI when high oil corn silage was fed at 22.5% of dietary DM compared with normal corn silage. No differences in milk yield or DMI was observed by Moreira et al. (2000) when high oil corn silage provided 37.5 % of the dietary DM was fed to lactating dairy cows for 28 days.

Nutridense (BASF, Florham Park, NJ) variety of high oil corn hybrids, has been a subject of more recent high oil corn hybrid research. This corn hybrid contains a minimum of 1% unit more oil and 1 to 2% units more protein than conventional corn hybrids (Akay and Jackson, 2001). Benefield et al. (2006) evaluated the potential of Nutridense corn grain and leafy Nutridense corn silage on animal performance. No differences were observed in DMI or milk yield for diets containing 30.6% corn silage and 27.7% corn grain provided from Nutridense corn grain, leafy Nutridense corn silage or a conventional yellow dent corn grain or silage. This data is similar to that of Akay and Jackson (2001), who found no difference in DMI and milk yield when early lactation dairy cows were fed diets containing 33% corn silage and 28% corn grain, produced from Nutridense or yellow dent corn. Chase (2010) also reported similar DMI (23.5 vs. 24.2 kg/d, respectively) and milk yield (43.5 vs. 43.6 kg/d, respectively) when feeding diets based on 59% corn silage from either Nutridense or yellow dent corn.

Although feeding Nutridense or high oil corn silage did not improve DMI, feeding high oil corn grain can improve DMI (Atwell et al., 1988; LaCount et al., 1995). With increasing costs of feedstuffs, more producers are turning to feed efficiency to improve economic returns as part of their selection criteria when selecting corn hybrids. Weiss and Wyatt (2000) did not include efficiency in the statistical analysis of the data, but calculations made from their data indicate that efficiency (FCM/DMI) was higher for the processed high oil silage than the processed conventional yellow dent corn silage (1.32 and 1.22, respectively). Increased efficiency using

Nutridense corn silage compared with a conventional hybrid was also been observed by Chase (2010) and Akay and Jackson (2001).

The use of high oil corn hybrids either as silage or as grain can be useful to increase the energy of diet. However, one must watch the amount of total dietary fat as fats reduce the amounts of fermentable carbohydrate available for microbial growth. Polyunsaturated fats, like those found in corn oil, can also contribute to milk fat depression if not closely monitored (Hartnell et al. 2005).

Leafy Corn Hybrids

Leafy corn silage hybrids simply have additional leaves above the last ear on the plant. These varieties were developed in the 1970s. The addition of the extra leaves often increases the leaf to stem ratio which helps to increase the digestibility of the silage (Hartnell et al., 2005). Increased digestibility has been documented though small in most cases (Thomas et al., 2001; Nennich et al., 2003; Kuehn et al., 1999; Ballard et al., 2001). Although improved fiber digestibility has been observed, most studies have failed to observe any improvement in milk yield (Thomas et al., 2001; Clark et al., 2002). Clark et al. (2002) observed that when leafy silage was fed at 42% of the diet DM, there was an increase of 0.9 kg/d in DMI of mid lactation cows compared with the control silage. This is in agreement with Ballard et al. (2001) who reported 0.5 kg/d higher DMI when feeding diets based on leafy corn silage to Holstein heifers at 79% of the dietary DM compared with a dual hybrid. Thomas et al. (2001) also reported higher milk yield when feeding leafy corn silage compared to a dual hybrid corn silage, at 26% DM of the ration. However, DMI was not analyzed in their study as cows were group fed.

Although some studies have reported increased milk yield when feeding leafy hybrid silage, the majority of the research does not support any improvement in milk yield for leafy hybrids compared with conventional corn hybrids (Kuehn et al., 1999; Bal et al., 2000; Moreira et al., 2000; Ballard et al., 2001; Nennich et al., 2003). In all the above mentioned trials, the diets contained between 31 to 40% corn silage on a DM basis. Grain to stover ratio is a measure some producers use to measure the value of a silage crop. Thomas et al. (2001), Kuehn et al. (1999) and Nennich et al. (2003) all reported that leafy silage lowered this ratio compared to conventional hybrids. Kuehn et al. (1999) also stated that silage yields were greater for the leafy hybrids compared with grain or blend hybrids (14.9, 13.8, 14.5 tonnes of DM/ha, respectively).

Waxy Hybrids

The waxy trait was first observed in 1908 in China; however, hybrids weren't initially developed until 1936 at Iowa State University (Harnell et al. 2005). Waxy corn hybrids were originally used by the textile and adhesive industries and for human consumption, rather than for animal feed (Hawton et al., 1996). The composition of the starch in grain from waxy corn hybrids is different from conventional corn grain. The starch of waxy hybrids is nearly 100% amylopectin while conventional corn is approximately 25% amylose and 75% amylopectin. Mohd and Wootton (1984) reported that amylopectin is highly digestible in the rumen. This could allow for more ruminal available starch which can be used for increased microbial protein synthesis (Sniffen and Robinson, 1987). The increase in microbial synthesis would allow for additional amino acid flow to the duodenum, provided that rumen pH remains sufficient (Poore et al., 1993a). Poore et al. (1993b) reported that this would result in increased milk yield.

Waxy corn hybrids were initially used as a grain substitute for conventional dent corn. However, data using waxy corn hybrids as either a grain or as silage is quite limited. Waxy corn grain utilization in beef cattle rations is rather inconclusive. Johnston and Anderson (1993) observed increased average daily gain and DMI when waxy corn grain was fed to newly received calves in a feedlot compared to feeding a non-waxy corn. Several other studies observed no improvements in the performance of finishing cattle (Farlin and McCormick, 1975; Brady and Farlin, 1977; Johnston and Anderson, 1992).

Information on the use of waxy corn grain in dairy rations is also very limited. Schroeder et al. (1996) reported a 4% increase in milk yield when waxy corn grain composed 100% of the grain mix in the diet fed to lactating cows. In contrast, Schroeder et al. (1998) did not observe any difference in milk yield or FCM when feeding waxy corn grain to lactating cows, though there was an increase of 0.78 kg/d in DMI feeding waxy corn grain compared with dent corn grain and an improvement in DMI of 0.96 kg/d when feeding 100% waxy corn grain compared with feeding a blend of 50% dent and 50% waxy corn grain.

Feeding waxy corn silage has been reported to increase milk yield and FCM compared with normal control silage (Moreira et al., 2000; Akay and Jackon, 2001). Moreira et al. (2000) fed diets containing 37.5% corn silage (DM basis) and did not observe any difference in DMI among the treatments. In their trial, the waxy hybrid did produce more silage than the control (23.9 vs. 21.7 tonne/ha, respectively). Akay and Jackson (2001) fed diets consisting of 32% corn silage and 27% corn grain produced from the same variety. No differences in DMI were observed between waxy vs. control silage. However, efficiency of FCM was higher for the waxy corn silage than the control silage (1.49 vs. 1.43, respectively); milk yield also increased (1.9 kg/d) along with FCM yield (2.2 kg/d) when feeding waxy corn silage compared with the control silage. As previously discussed dairy efficiency can be used as a measure of economic value of a feedstuff. There is not enough data to show the economic benefit or increased value of feeding waxy corn silage at this time.

BMR Corn Hybrids

Brown midrib (BMR) corn is a mutant genotype trait which was identified in 1924 at the University of Minnesota (Jorgenson, 1931). This trait is so named because of the reddish-orange coloration that forms in the midrib of the leaf when at the 4 to 6 leaf stage of maturity (Hartnell et al., 2005). The BMR trait is a natural mutation which essentially knocks out a portion of the lignin biosynthetic pathway, through a reduction in O-methyltranserase enzyme activity (Barriere and Argillier, 1993), there by reducing the lignin concentration in the plant and increasing in vitro NDF digestibility (Cherney et al., 1991; Oba and Allen, 1999).

The use of BMR corn silage in dairy cattle rations has frequently been reported to increase DMI (Oba and Allen, 1999; Bal et al., 2000; Moreira et al., 2000; Ballard et al., 2001; Castro et al., 2010). A few studies have not found any differences in DMI (Bal et al., 2000; Tine et al., 2001; Kung et al., 2008). Oba and Allen (1999) fed diets consisting of approximately 44% corn silage (DM basis) to evaluate the efficacy of the increase in NDF digestibility of BMR. Milk yield and DMI were higher for cows fed BMR compared with an iso-genetic control (2.8 kg/d and 2.1 kg/d, respectively). In a recent study of BMR corn silage, Castro et al. (2010) examined the effect of BMR corn silage compared to normal corn silage with and without the inclusion of Tifton 85 on the performance of early-lactating cows. Corn silage made up 40% of the dietary DM when Tifton 85 was not included and 34% when Tifton 85 was used in the diet. Higher DMI was observed in the diets containing the BMR corn silage. However, no differences were reported in milk yield between corn silage types. An increase in DMI and the rate of passage of BMR corn silages support increased milk yield by improving microbial N production efficiency (Oba and Allen, 2000b).

The effect of BMR corn silage on milk yield is not as consistent its effects on DMI. Several studies have reported increased milk yield when feeding BMR silage at varying percents in the diet (Oba and Allen, 1999; Moreira et al., 2000; Oba and Allen, 2000a; Ballard et al., 2001; Ebling and Kung, 2004; Kung et al., 2008) while Bal et al. (2000), Tine et al. (2001) and Castro et al. (2010) did not observe any differences in milk yield. Ebling and Kung (2004) reported the greatest improvement in milk production (2.9 kg/d) when feeding processed BMR corn silage at 42% of the diet (DM basis) compared to processed conventional corn silage. The preponderance of the data suggest that when lactating cows are fed BMR corn silage they will have a higher DMI and milk yield than cows fed conventional corn silage.

Although BMR corn silage has shown promise in increasing DMI and milk yield compared to normal corn silage, there are questions about its economic feeding value. Eastridge (1999) reported a reduction in DM yields of 10.4% when examining several studies. Allen et al. (1999) also reported an average loss in DM yield of 8.8 %. This reduction in yield is often what deters many producers from using this variety. The feed efficiency of utilizing BMR corn silage compared to other silages has not differed (Oba and Allen, 2000a; Ebling and Kung, 2004; Kung et al., 2008; Castro et al., 2010). The utilization of BMR corn silage in dairy rations can be beneficial when management and economic considerations are used.

Tropical Corn Hybrids

In the Southeastern USA, the shorter milder winter results in a longer growing season which offers dairy producers the ability to use double or even triple cropping systems. Tropical corn has been identified as having the potential to increase production in late season plantings and increase resistance to pests in the Coastal Plain region (Widstrom et al., 1980). Johnston et al. (1997) reported that a triple cropping system using rye in the winter, temperate corn in the spring, and a tropical corn in summer in the Coastal Plain of Georgia can produces 33 tonnes DM/ha forage per year. Of this total 35% was tropical corn silage. Tropical corn silage has been reported to have improved yields compared to a late season crop of temperate corn silage (Johnson et al., 1997; Utley et al., 1997). Utley et al. (1997) reported a 14% increase in DM yield in tropical corn silage relative to temperate corn.

Only a few studies have examined the effects of feeding tropical corn silage to lactating dairy cows. Nichols et al. (1998) compared the effects of feeding tropical corn silage and forage sorghum silage at different fibers levels and reported no differences in DMI or milk yield between forage types. Rakes et al. (1992) did not observe any differences in DMI and FCM yield when dairy cows were fed either tropical corn silage or temperate corn silage.

Research Objective

The goal of this research project was to evaluate silage produced from either waxy or brown midrib corn hybrids compared to a normal corn hybrid as the primary forage source in rations fed to lactating dairy cows by evaluating the nutrient production and intake of each hybrid and the lactational performance.

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CHAPTER 3

PRODUCTION RESPONSE TO CORN SILAGE PRODUCED FROM NORMAL, BROWN MIDRIB, OR WAXY CORN HYBRIDS [1]

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Abstract

The starch in waxy corn hybrids is 100% amlyopectin which has been suggested to be more digestible than that of normal corn hybrids, but the production response when feeding silage produced from these hybrids has been inconsistent. In contrast, brown midrib (BMR) corn varieties have lower lignin concentrations and have been shown to support higher DMI and milk yield. The objective of this study was to evaluate the nutrient intake and milk production response of lactating dairy cows to diets based on corn silage produced from three different types of corn hybrids. Thirty six multiparous and primiparous Holstein cows (66 ± 22 DIM, 41± 8 kg/d of milk) were used in an 11 wk trial using a completely randomized design during the fall of 2009. Experimental diets contained 36.4% of the dietary DM from corn silage from either a normal (Agratech 1021), BMR (Mycogen F2F797), or waxy (Master's Choice 590) hybrid. All cows were fed the diet containing normal corn silage during the first 2 wk of the trial before being assigned to one of three treatments for the following 9 wk. Data collected during the first 2 wk were used as a covariate in the statistical analysis. No difference (P= 0.81) was observed in DMI among treatments which averaged 22.6 kg/d. Milk yield was highest (P= 0.03) for cows fed BMR (37.6 kg/d) compared with WAXY (35.2 kg/d) but similar to control (36.2 kg/d). Milk fat percentage tended to be lower (P= 0.10) for cows fed control (3.28%) compared with BMR (3.60%) or WAXY (3.55%) corn silage. Milk protein percentage (P= 0.07) tended to be lower for cows fed normal (2.79%) compared with WAXY (2.89%) but similar to BMR (2.85%). No differences were observed in yield of milk components. Energy-corrected-milk (ECM) yield, dairy efficiency (ECM/DMI), and BW change did not differ among treatments. Results of this trial are consistent with previous reports in which cows fed diets based on corn silage produced

from BMR hybrids have higher milk yield compared with other hybrids. Corn silage produced from the waxy hybrid supported similar yield of ECM because of higher milk components, but milk yield was not improved compared to the normal.

INDEX WORDS: BMR, Waxy, Corn Silage

Introduction

Corn silage accounts for the largest portion of forage fed to lactating dairy cows on most dairy farms. Numerous corn hybrid varieties on the market today focus on silage production. Selecting the "best" hybrid for corn silage in the past was based on corn grain yields (Bal et al., 2000). Coors et al. (1994) reported that high yielding grain hybrids are not always the ideal choice for silage production. The nutritive value is known to vary between hybrids (Johnson et al., 1985; Coors et al., 1996), but it is also usually not taken in to consideration when hybrid selection is based solely on grain yield.

Brown midrib (BMR) corn hybrids have lower lignin concentrations, and have been reported to improve DMI and increase milk yields compared with their isogenic control (Oba and Allen, 1999). However, there are some agronomic concerns with BMR corn silage because of lower DM yields and an increased susceptibility for lodging (Cherney et al., 1991). In a review of literature, Eastridge (1999) reported an average of 10.4% lower DM yields of BMR silage compared with controls. It is thought that an increase in the rate of passage of BMR silage supports improved DMI. Oba and Allen (2000a, b) concluded that increasing post-ruminal starch digestion and efficiency of microbial N production along with greater DMI and an increased rate of passage might be responsible for higher milk yields when feeding BMR corn silage.

The effect of waxy corn silage on milk production his been evaluated in only a limited number of studies. Akay and Jackson (2001) evaluated the effects of feeding a waxy corn hybrid at 32.8% of the dietary DM in diets fed to early lactating dairy cows. Dry matter intake tended to be higher for cows fed diets based on waxy corn silage compared with that of cows fed the control diet. Milk and FCM yields were also higher for cows fed diets based on waxy corn silage (1.9 kg/d and 2.2 kg/d, respectively). Feeding waxy corn silage to lactating cows had previously been shown to increase yields of milk and FCM when compared with conventional corn silage (Moreira et al., 2000). Nearly 100% of the starch in waxy corn hybrids are composed of amylopectin were as the starch in conventional corn is approximately 75% amylopectin and 25% amylose. Amylopectin is highly digestible in the rumen (Mohd and Wootton, 1984). It is this composition of the starch in waxy corn hybrids that is thought to make waxy corn more beneficial than normal corn hybrids to ruminants.

The objective of this research was to evaluate the nutritive value and digestibility of corn silage produced from normal, brown midrib or waxy corn hybrids and the production response of lactating dairy cows when fed diets containing 36.4% of the dietary DM as one of these hybrids.

Materials and Methods

Silage Production

Three corn silage hybrid varieties were planted in the spring of 2009: normal corn hybrid ([CONTROL] AgraTech 1021, AgraTech Seeds, Inc., Atlanta, GA), BMR type ([BMR] Mycogen F2F797, Mycogen Seeds, Indianapolis, IN), and a waxy type ([WAXY] MC590, Masters Choice Hybrids, Ullin, IL) were planted in Tifton sandy loam soil at a seeding rate of 70,000 plants/ha using strip-tillage methods and corn was irrigated using dairy waste effluent.

Fertilizer and nutrients were applied based on soil tests and recommendations of the University of Georgia. Corn was harvested at 1/2 milk line and chopped to a theoretical chop length of 1.9 cm, with a conventional pull-type two row harvester without kernel processing. The forages were inoculated (Biotal 40788, Lallemand Animal Nutrition, Milwaukee,WI) and ensiled separately in 2.4 m silage bags for fermentation for approximately 90 d prior to the beginning of the trial.

Lactation Trial

Thirty-six primaparous and multiparous early lactation Holstein cows (66 ± 22 DIM, 41± 8 kg/d of milk) were used in a completely randomized design experiment. Cows were trained to eat behind Calan doors (American Calan Inc., Northwood, NH) prior to the beginning of the trial. The 11 wk trial included a 2 wk preliminary period during which all cows were fed the control diet and a 9 wk experimental period. Treatments consisted of the inclusion of corn silage produced from a normal corn hybrid (CONTROL), a brown midrib (BMR) or a waxy corn hybrid (WAXY) in the daily rations at a rate of 36.4% of the dietary DM (Table 1). During the pretrial period cows were fed diets using normal corn silage diet.

Data collected during the preliminary period was used as a covariate in the statistical analysis. All protocols used during this trial were approved by the University of Georgia Institute of Animal Care and Use Committee.

Experimental diets were feed once daily at approximately 110% of the previous daily intake to ensure ad libitum intake. The amounts of each diet offered and refused were recorded daily for each cow. Samples of experimental diets, orts, and dietary ingredients were collected three times each week. Samples were dried in a forced air oven at 60° C for 72 to determine DM. Samples were ground to pass through a 1-mm screen using a Wiley Mill (Arthur B. Thomas, Philadelphia, PA) and composited by week. Composite samples underwent analysis of

DM, ash (AOAC, 2000), CP (Leco FP-528 Nitrogen Analyzer, St. Joseph, MO), ADF (AOAC, 2000), NDF (Van Soest et al., 1991), starch (Hall, 2009), sugar (Dubois et. al., 1956), ether extract (AOAC, 1990) and minerals (AOAC, 2000).

Fermentation end product concentrations of the experimental silages were determined using the filtrate of a 25g wet sample blended with 200mL of distilled water. Sample pH was determined using 30 mL of the extract introduced to a Mettler DL12 Titrator (Mettler-Toledo, Inc., Columbus, OH) and titrated with 0.1 *N* NaOH to a pH of 6.5. Ammonia concentrations were determined by introducing a dilute sample (25 mL of extract and 75 mL of deionized water) to a Labconco Rapidstill II model 65200 analyzer (Labconco, Kansas City, MO) and titrating with 0.1 *N* HCl.

Table 1. Ingredient composition of experimental diets containing corn silage produced from normal (CONTROL) brown midrib (BMR) or waxy (WAXY) corn hybrids.

Ingredient	CONTROL	BMR	WAXY
Normal corn silage	36.39		
BMR corn silage		36.39	
Waxy corn silage			36.39
Ryegrass silage	7.87	7.87	7.87
Alfalfa hay	7.87	7.87	7.87
Brewers grain wet	12.78	12.78	12.78
Ground corn	17.70	17.70	17.70
Soybean hulls, pelleted	5.51	5.51	5.51
Megalac[1]	1.00	1.00	1.00
Soybean meal 47.5% CP	4.54	4.54	4.54
Prolak[2]	3.62	3.62	3.62
Potassium-magnesium-sulfate	0.20	0.20	0.20
Limestone	0.43	0.43	0.43
Dicalcium phosphate	0.20	0.20	0.20
Sodium bicarbionate	0.59	0.59	0.59
Magnesium oxide	0.22	0.22	0.22
Availa-4[3]	0.04	0.04	0.04
Salt	0.22	0.22	0.22
Potassium carbonate	0.20	0.20	0.20
Diamond V XP yeast culture[4]	0.25	0.25	0.25
Trace mineral-vitamin premix[5]	0.16	0.16	0.16
Rumensin 3%[6]	0.24	0.24	0.24

[1] Calcium salts of long-chain fatty acids (Church & Dwight Co., Inc., Princeton, NJ).

[2] Animal-marine protein blend (H. J. Baker & Bro., Inc. Stamford CT).

[3] Zinpro Corp., Eden Prairie, MN.

[4] Diamond V Mills, Cedar Rapids, IA.

[5] Minerial-Vitamin premix contianed (DM basis): 26.1% Ca; 0.38% Mg; 1.76% S; 144 ppm Co; 9,523 ppm Cu; 1,465 ppm Fe; 842 ppm I; 28,617 ppm Mn; 220 ppm Se; 25,343 ppm Zn; 4,210,830 IU/kg Vitamin A; 1,684,330 IU/kg Vitamin D; 21,045 IU/kg Vitamin E.

[6] Elanco Animal Health, Indianpolis, IN.

Lactic acid concentrations were determined using YSI 2700 Select Biochemistry Analyzer (YSI, Inc., Yellow Springs, OH) on a sample of equal parts extract and deionized water. Concentrations of acetic, propionic, butyric, and iso-butyric acids were determined using a 3 mL sample of extract filtered through a 0.2 µm PVDF GD/X Whatman filter membrane a 0.1 µL subsample was then injected into a Perkin Elmer AutoSystem gas chromatograph (Perkin Elmer, Shelton, CT) using a Restek column packed with Stabilwax-DA.

Cows were milked twice daily at 0400 and 1600h. Daily milk yields for each cow were recorded electronically (Alpro, DeLaval, Kansas City, MO). Milk samples were collected from consecutive p.m. and a.m. milking once per week throughout the trial and analyzed for milk fat, protein, and somatic cell concentrations (Southeast Milk Inc., Belleview, FL). Individual BW was recorded following the p.m. milking on three consecutive days at the end of the pretrial period and at the end of the data collection. To minimize variation, BW was recorded after the p.m. milking before allowing access to feed or water.

Fecal grab samples were collected to determine nutrient digestibility, from all cows during the last 4 d during wk 9. Samples were collected every 12 h on each day with the collection time advanced each day by 4 h. Fecal samples were dried in a forced air oven at 55° C, then ground to pass through a 1-mm screen using a Wiley Mill and composited by cow. Samples were analyzed for DM, ash NDF, ADF, CP, and EE as described previously. Indigestible ADF was utilized as a marker for determination of apparent digestibility and determined according to procedures outlined by Cochran et al. (1986). Nutrient concentrations of the treatments were calculated using chemical analysis results of ingredients in CPM, and wk 9 intake was used to calculate digestibility coefficients.

Statistical analysis

Weekly DMI, milk yield, and composition data were subjected to analysis of covariance using PROC MIXED procedures of SAS (SAS Institute, Cary, NC). Data collected during the 2 wk pretrial period was used as a covariate for statistical analysis. The model included the effects of covariate, wk, treatment, interaction of treatment by wk and error. Cow within treatment was included as a random effect and week as a repeated effect. When significance was observed ($P < 0.10$), the PDIFF option was used for mean separation.

Nutrient intake and digestibility data measured in wk 9 were subjected to ANOVA using PROC GLM procedures of SAS (SAS Institute, 2001). The model included the effects of cow, treatment, and error. When significance was observed ($P < 0.10$), the PDIFF option was used for mean separation.

Results and Discussion

Nutrient composition of silages and TMR

The nutrient composition of each of the experimental silages is presented in Table 2. The waxy corn silage contained lower concentrations of NDF and ADF than the BMR or the control silages. Akay and Jackson (2001) also reported lower concentrations of NDF and ADF in waxy corn silage compared with conventional corn silage. Starch concentration was higher in the waxy corn silage (35.06%) relative to the brown midrib and control silages (27.78%,and 29.29%, respectively). Brown midrib corn silage has been shown to have lower levels of starch (Bal et al., 2000; Ballard et al., 2001; Kung et al., 2008).

Table 2. Chemical composition of corn silage harvested from normal (CONTROL) brown midrib (BMR) or waxy (WAXY) corn hybrids.(mean ± SD)[1]

	CONTROL	BMR	WAXY
DM %	30.88 ± 1.36	29.22 ± 2.09	31.09 ± 1.66
CP	8.71 ± 0.15	9.02 ± 0.25	8.52 ± 0.42
ADF	27.09 ± 2.47	26.02 ± 1.75	24.36 ± 1.60
NDF	42.81 ± 3.26	43.38 ± 2.39	38.58 ± 2.08
Lignin	3.37 ± 0.42	2.04 ± 0.29	2.97 ± 0.25
Ether extract	3.59 ± 0.65	3.06 ± 0.31	3.34 ± 0.31
Ash	4.67 ± 0.25	4.68 ± 0.25	4.13 ± 0.26
Starch	29.29 ± 2.65	27.78 ± 2.44	35.06 ± 3.30
Sugar	1.29 ± 0.26	1.44 ± 0.30	1.24 ± 0.19
Calcium	0.21 ± 0.01	0.22 ± 0.01	0.19 ± 0.01
Phosphorus	0.27 ± 0.01	0.27 ± 0.01	0.27 ± 0.02
Magnesium	0.16 ± 0.01	0.17 ± 0.01	0.14 ± 0.01
Potassium	1.47 ± 0.04	1.53 ± 0.09	1.39 ± 0.10
pH	3.90 ± 0.10	3.86 ± 0.10	4.02 ± 0.07
Lactic Acid	3.23 ± 0.83	4.99 ± 1.13	2.89 ± 0.62
Acetic Acid	4.84 ± 0.83	3.06 ± 0.90	3.97 ± 1.66
Propionic Acid	0.93 ± 0.55	0.33 ± 0.18	1.03 ± 0.68
Iso-butyric Acid	0.01 ± 0.00	0.01 ± 0.00	0.01 ± 0.00
Total VFA	9.02 ± 0.71	8.37 ± 1.72	7.89 ± 1.94
Ammonia	0.99 ± 0.11	1.00 ± 0.14	1.02 ± 0.16

[1] All values except DM (%) given as percentage of DM.

Chemical composition of the experimental diets is presented in Table 3. Dry matter, CP and ADF concentrations were similar for all treatments the treatments. Numerically NDF was lower for the WAXY diet compared with CONTROL and BMR diets. Starch was higher in WAXY diet, and similar to the waxy diet fed by Akay and Jackson (2001).

Table 3. Chemical composition of experimental diets[1]

	CONTROL	BMR	WAXY
DM %	40.87	40.00	40.60
CP	17.20	17.33	17.58
ADF	20.74	20.06	19.27
NDF	40.71	39.80	38.14
Ash	6.97	6.97	6.83
Starch[2]	25.85	25.30	27.95
EE	4.76	4.57	4.67
NE_L(mCal/kg)[2]	1.76	1.76	1.79

[1] All values except DM (%) and NE_L(mCal/kg) given as percentage of DM.
[2] Calculated using ingredient analysis in CPM

Dry Matter Intake, Milk yield, and Composition

Table 4 shows the DMI, milk yield, and milk composition of each treatment. There were no differences in DMI between any of the treatments. Cows have been shown to have greater DMI in previous reports (Eastridge, 1999). The NDF fraction in BMR corn silage is more readily digestible in the rumen (Oba and Allen, 1999). Thus it is this thought that an increase in the rate of passage of BMR corn silage that allows for greater DMI compared to conventional corn silage. A reduced rumen fill likely due to a faster turnover rate of NDF allows for greater DMI when feeding BMR corn silage (Oba and Allen, 2000b).

Table 4. Dry matter intake, milk yield and composition of lactating cows fed diets based on corn silage from normal (CONTROL), brown midrib (BMR) or waxy (WAXY) hybrids.

	Control	BMR	Waxy	SE	P
DMI, kg/d	22.4	23.0	22.6	0.7	0.84
Milk, kg/d	36.2^{ab}	37.6^{a}	35.1^{b}	0.6	0.03
Fat, %	3.28^{c}	3.60^{d}	3.55^{d}	0.05	0.10
Fat, kg/d	1.19	1.35	1.25	0.05	0.23
Protein, %	2.79^{c}	2.85^{cd}	2.89^{d}	0.01	0.07
Protein, kg/d	1.01	1.07	1.02	0.03	0.15
ECM, kg/d	30.7	32.4	30.7	0.82	0.17
Efficiency[1]	1.35	1.43	1.38	0.02	0.46
Initial BW, kg	617.0	616.1	628.2	21.7	<0.0001
Change in BW, kg	21.0	36.9	24.4	5.2	0.14

^{a,b} Means with different superscripts in the same row differ (P < 0.05).

^{c,d} Means with different superscripts in the same row differ (P < 0.10).

[1] ECM/DMI.

Milk yield was higher (P < 0.05) for cows fed diets based on BMR compared with WAXY. The lack of difference in milk yield between the BMR fed cows and CONTROL fed cows, shows further inconsistency in the effect of feeding BMR corn silage and its effect on milk production. Castro et al. (2010) also reported no differences in milk yield in response to feeding BMR corn silage. The absence of a difference in milk yield between the WAXY and CONTROL contradicts the reported improvements reported by Akay and Jackson (2001) and Moreira et al. (2000) when feeding waxy corn silage. Milk yield was higher for cows fed the BMR compared with those fed WAXY (2.5 kg/d). This is likely due to the numerical differences in DMI between the BMR and WAXY diets.

Milk fat percentage tended to be higher (*P* = 0.10) for cows fed either the BMR or WAXY compared with CONTROL. Milk protein percent (P = 0.07) tended to be higher for cows fed WAXY compared with CONTROL. This is in contrast to previous trials in which no difference was observed in milk fat and protein percentage (Akay and Jackson, 2001; Moreira et al., 2000).

Nutrient Digestibility

Nutrient intake and digestibility during wk 9 is presented in Table 5. Intake of all the nutrients were similar for all three corn silage hybrids except the amount of EE that was consumed by the cows fed WAXY was lower ($P < 0.0001$) than those fed BMR or CONTROL. Total tract NDF and ADF digestibility were higher ($P = 0.05$, and $P = 0.03$, respectively) with BMR compared with either WAXY or CONTROL. Oba and Allen (1999) also reported marginal improvements in total tract digestibility of NDF and ADF when feeding BMR corn silage compared to the control. It is hypnotized that the NDF fraction of BMR corn silage undergoes hydrolysis more rapidly, thus reducing rumen fill and allowing greater DMI. However, an increased rate of passage is often observed with higher DMI, which could reduce the digestibility of NDF (Allen and Mertens, 1988).

Table 5. Nutrient intake and digestibility of cows fed diets based on corn silage produced from normal (CONTROL), brown midrib (BMR) or waxy (WAXY) hybrids.

	CONTROL	BMR	WAXY	SE	P
Intake, kg/d					
DM	23.86	23.52	21.76	0.97	0.2654
CP	4.2	4.13	3.94	0.17	0.5102
NDF	8.32	8.38	7.34	0.35	0.0766
ADF	5.16	5.09	4.57	0.21	0.1112
Starch	6.4	6.08	6.13	0.25	0.6173
EE	1.23^{a}	1.22^{a}	0.94^{b}	0.05	<0.0001
Digestibility, %					
DM	67.04	68.2	66.1	1.46	0.6195
CP	70.56	70.43	70.16	1.6	0.9833
NDF	47.5^{b}	52.71^{a}	46.04^{b}	1.86	0.0465
ADF	54.98^{b}	58.6^{a}	53.52^{b}	1.28	0.0278
Starch	96.36	94.8	94.78	0.77	0.2536
EE	84.39^{a}	86.25^{a}	79.66^{b}	1.27	0.0029

^{a,b} Means with different superscripts in the same row differ ($P < 0.05$)

When feeding waxy corn silage, Akay and Jackson (2001) also reported no improvements in NDF or ADF digestibility. This is in agreement with our findings, as there was no observed difference in NDF and ADF digestibility when feeding waxy corn silage compared to feeding the control corn silage. It has been shown that microorganisms will digest starch prior to digesting fiber (El-Shazly et al., 1961). McCarthy et al. (1989) reported that increasing the proportion of ruminally available starch in the diet has negative impacts on the digestibility of NDF and ADF. This would explain the reduced fiber digestion seen when feeding waxy corn silage, which contained high levels of starch.

Conclusions

The fiber faction contained in the BMR based diets was more comprehensively digested allowing for higher milk yield and DMI compared with the WAXY. Feeding WAXY did not improve milk yield, but tended to support higher concentrations of milk fat and protein. The results are consistent with other studies comparing BMR corn silage with normal temperate corn hybrids. The utilization of waxy corn hybrids for whole plant corn silage has been shown based on the results of this trial, although milk yield was not improved waxy corn silage did tend to produce higher concentrations' of fat and protein compared with the control corn silage.

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CHAPTER 4

CONCLUSION

Corn silage will continue to be a popular forage choice among dairy producers for many years to come, to provide effective fiber and high levels of energy to the diet. The genetics in corn seed is ever changing and although it is difficult for research to keep pace with new varieties it is a necessity, in order to provide sufficient accurate information.

Through an effective evaluation of corn silage produced from three different corn hybrids it was concluded waxy corn hybrids can effectively be utilized in corn silage production, resulting in DMI levels and milk yields similar to normal corn hybrids. However, corn silage produced from waxy corn hybrids can not support as high of levels in comparison to brown midrib hybrids. The digestibility of diets based on brown midrib corn silage is higher compared with waxy and normal corn hybrid based diets.

The starch levels of the waxy corn silage were higher then the control and brown midrib corn silage. However, the lack of kernel processing when harvesting the corn silage could have reduced the digestibility of all the silages. Thusly further research should be conducted utilizing waxy corn silage harvested with kernel processing to further evaluate the potential of waxy corn hybrids.