SORGHUM USE IN DAIRY CATTLE DIETS

SORGHUM THE SMART CHOICE

INTRODUCTION

Grain sorghum is a feedstuff with excellent nutritional value that fits well in dairy cattle diets. Sorghum is often grown in areas where the precipitation and/or irrigation does not support the economical production of corn or other crops that require an abundance of water. Numerous research trials have demonstrated sorghum can replace corn in dairy rations and maintain performance of lactating dairy cows when processed correctly. As a result, dairy operations located in areas where sorghum is grown can utilize this cereal grain as a cost-efficient replacement to corn.

Grain sorghum on average typically has more protein than corn and is comparable in terms of energy. Starch is a major source of energy for high-producing dairy cows. Sorghum has a complex starch-protein matrix, which can reduce access of digestive enzymes and impede digestibility. For this reason, steam-flaking sorghum is the preferred processing method because it disrupts the protein matrix surrounding the starch, improving starch utilization and the efficiency of milk production. This feeding guide was developed to provide information on grain sorghum's nutritive value and present information on its use in the dairy industry. A companion guide on forage sorghum use in beef and dairy cattle diets can be found on the Sorghum Checkoff website or provided upon request.

GRAIN SORGHUM FEEDING VALUE

Sorghum, corn, wheat and barley are all potential sources of energy for dairy animals. Depending upon local climatic conditions, one grain may be preferred over another. Corn is usually the energy source of choice, but some climatic conditions may limit or negate its productivity. Average nutrient values for sorghum, corn, wheat and barley are reported in Table 1. Values were obtained from the Dairy One Forage Laboratory and represent the average value for all samples analyzed from May, 2000 through April 2016. Crude protein levels are highest for wheat, followed by sorghum, barley and corn. The fiber, as measured by acid detergent fiber (ADF), is lowest for corn and wheat and higher for sorghum and barley. The values for sorghum and barley are variable and may be a reflection of an increased proportion of seed coat to endosperm and germ as compared to corn or wheat. This also likely contributes to the overall greater level of ADF found in the sorghum and barley. While differences exist, they are small and would not have a large negative effect on ruminant digestion.

Energy values are expressed in terms net energy for maintenance (NEm), gain (NEg) and lactation (NEl). These are a reflection of how an

animal would utilize energy from a feedstuff. Sorghum and corn are very comparable in terms of energy. Tabular values indicate a slight advantage for corn over sorghum, but the difference is relatively small. Small differences in tabular values may not be detected in animal trials. The 24-hour in vitro true digestibility (based on a smaller sample size from Dairy One) also suggests sorghum and corn are similar in terms of overall digestibility within the rumen. Due to the influence of climate, agricultural practices and genetics, grain sources should be analyzed and the resulting nutrient profiles used to formulate animal diets rather than utilizing the tabular values.

GRAIN SORGHUM FEEDING VALUE

TABLE 1. SORGHUM NUTRITIVE VALUES COMPARED TO OTHER FEED GRAINS, WITH THE NORMAL NUTRIENT RANGE LISTED BELOW IN PARENTHESES[1].

ITEM	SORGHUM	CORN	WHEAT	BARLEY
DRY MATTER, %	90.2 (87.8-92.6)	88.9 (85.3-92.6)	89.0 (87.2-90.8)	89.5 (87.0-92.0)
CRUDE PROTEIN %	12.5 (10.6-14.3)	9.0 (7.4-10.5)	13.6 (11.0-16.3)	11.9 (9.7-14.2)
NDF, %	8.4 (0.0-17.3)	10.0 (7.1-13.0)	13.2 (7.6-18.9)	19.0 (12.9-25.2)
ADF, %	5.1 (0.5-9.7)	3.7 (2.3-5.2)	4.7 (1.5-7.9)	7.6 (4.1-11.0)
ASH, %	2.6 (1.7-3.5)	1.6 (0.4-2.8)	2.2 (0.9-3.5)	3.0 (2.0-3.9)
NE_M, Mcal/lb	1.00 (0.92-1.06)	1.00 (0.97-1.03)	0.93 (0.89-0.97)	0.89 (0.85-0.94)
NE_G, Mcal/lb	0.68 (0.62-0.74)	0.69 (0.67-0.72)	0.63 (0.60-0.66)	0.60 (0.56-0.64)
NE_L, Mcal/lb	0.93 (0.88-0.99)	0.94 (0.92-0.97)	0.88 (0.86-0.91)	0.85 (0.82-0.89)
24 HR IVTD, %	94.5 (91.7-97.3)	94.3 (86.5-102.1)	92.1 (89.0-95.2)	88.9 (83.3-94.5)

[1]Source: Dairy One Laboratory, Ithica, NY. Samples analyzed between May 2000 to April 2016. NDF = Neutral Detergent Fiber; ADF = Acid Detergent Fiber; NEm = Net Energy of Maintenance; Net Energy of Gain; Net Energy of Lactation; IVTD = In Vitro True Digestibility.

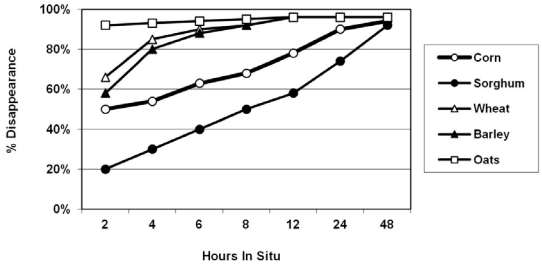
FERMENTATION RATE

Sorghum grain can be an effective source of starch for dairy cattle. Starch is the primary energy source in dairy cow diets when feeding for high levels of milk production. Utilization of starch in the rumen is a primary concern for improving milk yield and efficiency of production. As a result, determining and understanding the ruminal fermentation patterns of various grain sources is important when attempting to achieve high levels of milk production and increasing production efficiency.

Ruminal fermentation patterns can vary based on the type of grain. As indicated by Figures 1 and 2, sorghum ferments at a slower rate when compared to oats, wheat, barley and corn. After 48 hours of ruminal exposure, all five grains reach a similar point for dry matter and starch disappearance. Sorghum simply requires a longer residence time in the rumen to reach a similar point. Differences in ruminal fermentation of sorghum are likely due to a combination of characteristics, such as a complex starch-protein matrix, which is more resistant to moisture and enzyme

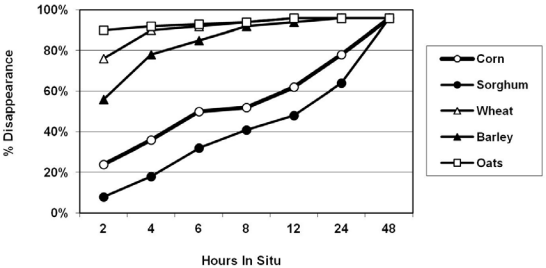
GRAIN SORGHUM IN DIETS

FIGURE 1. IN SITU DRY MATTER DISAPPEARANCE OF FIVE GRAINS



Adapted from Herrera-Saldana et al., 1990.

FIGURE 2. IN SITU STARCH DISAPPEARANCE OF FIVE GRAINS



Adapted from Herrera-Saldana et al., 1990.

penetration than corn or other grains (Herrera-Saldana et al., 1990 and Theurer, 1986). Sorghum also has a higher ratio of amylose compared to amylopectin and a small starch granule size when compared to other grains, which may also contribute to a slower rate of fermentation. In some cases, a mixture of grains may provide a more optimal ruminal fermentation pattern than a single grain. For example, a small amount (1-2 pounds) of wheat, barley or oats added to a ration will increase the amount of starch available immediately after feeding. When combined with either corn or sorghum, this provides a higher and more stable level of rumen-available starch over the span of time between feedings. This often has a positive effect upon milk production and efficiency of production.

LACTATING DAIRY COWS

For many years, sorghum was considered to be of lesser value than corn due to its decreased digestibility when either dry-rolled or ground. However, this decreased digestibility did not always result in a significant decrease in milk production when feeding rolled or ground grains (Mitzner et al.,

1994). There is a wealth of data that supports the replacement of corn with sorghum in lactating cow diets without decreasing milk production or performance (Mitzner et al., 1994 and Theurer et al., 1999). Mitzner and coworkers (1999) fed rolled and finely ground corn and sorghum and observed no differences in dry matter intake, milk yield, milk fat percentage or body weight due to the source of grain. Based on this evidence and others, it can be concluded that sorghum and corn can be interchanged in the diet of lactating dairy cows. **Processing method is an important consideration to maintain animal performance when replacing corn with sorghum.**

DRY DAIRY COWS

Specific references to the feeding of sorghum grain to dry dairy cows were not found. However, it could be assumed that the relationships found in lactating dairy cattle concerning the feeding of sorghum grain would apply to dry dairy cows. Feeding sorghum grain as a replacement for corn in dry cow diets would be acceptable and should not

result in any adverse effects. It is important to apply accepted ration balancing guidelines to control energy intake during this period to avoid weight loss or excessive weight gain.

CALVES & HEIFERS

The feeding of sorghum grain to calves has been evaluated in several studies. These studies have focused on the impact of processing upon calf growth. Abdelgadir and Morrill (1995) fed sorghum grain that was raw, roasted or conglomerated. They reported no difference in calf performance due to grain processing. Sorghum meal is also a preferred feed ingredient by newly weaned dairy calves and considered highly palatable (Miller-Cushon et al., 2014). Palatability and acceptability of starter ration ingredients are important to encourage solid feed intake during the milk-feeding stage. Further investigation into the impact of sorghum on calf performance is required to fully evaluate the use of sorghum in this area of production.

Feeding sorghum to growing dairy heifers has not been evaluated in recently published

GRAIN SORGHUM IN DIETS

research. However, several studies have evaluated the use of sorghum in growing beef rations. Diets containing more than 65 percent high-tannin sorghum grain have been shown to reduce animal growth (Larrain et al., 2009; Maxson et al., 1973). High tannin or 'bird resistant' sorghum varieties are grown in certain regions of the world. **Commodity sorghum grown in the U.S. has no detectable levels of tannin (U.S. Grains Council, 2017) because of the improved feeding value to the livestock and poultry industries.** Therefore, animal performance issues related to tannin in sorghum should not be an issue if sorghum is sourced from the U.S.

It appears processing has an important impact on starch digestibility and ruminal bacterial protein production. It is well documented that the rate and extent of starch digestibility is improved when sorghum is more extensively processed. Likewise, an increase in ruminal bacterial protein production when feeding more extensively processed sorghum has been reported (Rahnema et al., 1987; Zinn et al., 2008). Processing is important for utilization of sorghum starch in the rumen. It appears that sorghum can be a replacement for corn in growing diets.

SORGHUM PROCESSING

Sorghum grain is one of the most difficult whole grains for cattle to crush when chewing. As a result, processing sorghum grain is the most common method to increase the rate and extent of starch digestion. Most nutritionists will choose to feed one grain over another based on the cost of the grain and the cost to process it. Common processing options for sorghum include dry-rolling, grinding, steam-rolling, steam-flaking and pelleting. The goal of grain processing is to increase energy/starch availability in the rumen. When processed correctly, sorghum can replace corn in dairy cow diets and maintain production levels.

PARTICLE SIZE

The most researched factor surrounding the use of sorghum in ruminant diets is processing. Mitzner and others (1994) found no differences due to grain source when they compared dry-rolling with fine grinding of both corn and sorghum. In another report, Titgemeyer and Shirley (1997) reported pelleting sorghum grain improved its nutritional value as compared to dry-rolled. It appears particle size or further processing may be necessary for sorghum grain to be

utilized efficiently. This becomes even more evident when considering the effects of thermal processing upon sorghum utilization.

THERMAL PROCESSING

The proper combination of heat, pressure and moisture are key to disrupting the starch-protein matrix found in sorghum. Theurer and co-workers (1999) completed a review of the literature examining the effects of thermal processing of corn and sorghum and its relationship to milk production. In summary of 19 lactation trials, they found steam-flaking of either corn or sorghum resulted in a 20 percent increase in net energy for lactation as compared to dry-rolled grains. They also concluded the feeding value of steam-flaked corn and sorghum were similar. A summary of six studies comparing steam-flaked corn to steam-rolled corn showed an increase in milk production, milk protein yield and milk fat percent when feeding steam-flaked corn (Table 2). Intakes and production efficiency were not affected by treatment and total digestive tract starch digestion was increased. The same comparison was made for sorghum with 24 studies (Table 3) and steam-flaking

improved intake, milk production, milk protein percent and yield and milk fat percent. Total digestive tract starch digestibility was also increased by 17 percent. The group then made direct comparisons of corn and sorghum (Table 4) and found steam-flaked corn and sorghum were similar in intakes and lactation performance. From these compiled data sets, corn and sorghum are both equally effective as a starch source for lactating dairy cow diets.

Researchers (Theurer et al., 1999) then examined the site and extent of starch digestion. When comparing steam-flaking to dry-rolling, they found an increase in ruminal starch digestion for both corn and sorghum. This is significant as ruminal starch digestion increases ruminal microbial protein production, which can increase available protein for milk production.

The main advantages of thermal processing are an increase in ruminal starch digestion and the resulting improvement in net energy for lactation. It is estimated that when compared to dry-rolled sorghum, net energy values should be increased by 13 to 20 percent (Theurer et al., 1999). This additional

SORGHUM PROCESSING

energy could be used for milk production in lactating cows or, in the case of late lactation cows, reduce the amount of grain needed in the diet.

TABLE 2. STEAM-FLAKED COMPARED TO STEAM-ROLLED CORN IN LACTATING DAIRY COW DIETS

ITEM	SR[1]	SF[2]	P <
DRY MATTER INTAKE, LB/D	58.4	58.4	0.93
MILK, LB/D	78.9	83.8	0.02
PROTEIN, %	2.99	3.06	0.11
PROTEIN, KG	2.36	2.56	0.01
FAT, %	3.11	2.98	0.02
FAT, KG	2.47	2.49	0.44
TOTAL TRACT STARCH DIGESTION, %	87.4	95.7	0.05

[1]Steam-rolled to a density of 38 lb/ bu.
[2]Steam-flaked to a density of 28 lb/bu.
Adapted from Theurer et al., 1999.

TABLE 3. STEAM-FLAKED COMPARED TO STEAM-ROLLED SORGHUM IN LACTATING DAIRY COW DIETS

	SR[1]	SF[2]	P≤
DRY MATTER INTAKE, LB/D	56.4	55.3	0.23
MILK, LB/D	78.5	82.5	0.01
PROTEIN, %	2.95	3.02	0.01
PROTEIN, KG	2.34	2.51	0.01
FAT, %	3.20	3.03	0.01
FAT, KG	2.51	2.51	0.90
TOTAL TRACT STARCH DIGESTION, %	83.7	97.1	0.01

[1]Steam-rolled to a density of 38 lb/bu.
[2]Steam-flaked to a density of 28 lb/bu.
Adapted from Theurer et al., 1999.

TABLE 4. STEAM-FLAKED CORN AND SORGHUM GRAIN IN LACTATING DAIRY COW DIETS

	SFS[1]	SFC[2]	P≤
DRY MATTER INTAKE, LB/D	57.1	57.6	0.82
MILK, LB/D	80.5	81.4	0.84
PROTEIN, %	2.96	3.00	0.58
PROTEIN, KG	2.38	2.43	0.71
FAT, %	3.19	3.11	0.45
FAT, KG	2.56	2.51	0.81
TOTAL TRACT STARCH DIGESTION, %	98.6	97.9	0.86

[1]Steam-flaked sorghum to a density of 28 lb/bu.
[2]Steam-flaked corn to a density of 28 lb/bu.
Adapted from Theurer et al., 1999.

ADDING VALUE

Processing sorghum grain by grinding, rolling, steam-rolling or steam-flaking is necessary to disrupt the protein matrix surrounding the starch granules and the disorganization of the starch granules. The greater disruption of the protein matrix and starch granules results from steam-flaking as compared to the other methods. This is because it combines moisture, pressure and heat in a consistent process, which renders a greater proportion of the starch available to the rumen microbes. Additional ruminal starch availability also improves protein availability by increasing microbial crude protein production.

Many economic factors including local grain availability, transportation, processing cost, facilities, etc. must be considered when determining the value of additional processing on a dairy. For those dairies located near beef feedyards, it may be possible for the feedyard to steam-flake grain for the dairy. In many cases, the feedyard may have excess flaking capacity and be willing to flake grain for the dairy producer. Similar to recommendations for beef cattle, the Dairy NRC (NRC, 2001) recommends a flake density of 28 lb/bu for grain sorghum. Reduced DMI and lower milk production were reported when lactating cows were fed thin sorghum flakes (< 23 lb/bu; Moore et al., 1992, Santos et al., 1997).

SORGHUM DISTILLERS GRAINS

With the growth of the U.S. ethanol industry, some ethanol plants located in the Midwest and Southwest utilize sorghum as a feedstock because it is readily available and more cost effective than corn. The resulting sorghum byproduct can be used in the livestock industry as a source of energy and protein. The difference in nutrient composition between sorghum distillers grains (DGS) and corn DGS is similar to the nutritional differences between the two parent grains. Starch comprises about two-thirds of these grains. When the starch within the grain is removed and converted to ethanol, the remaining nutrients within the byproduct, such as protein, fat, fiber and minerals, are concentrated approximately threefold. Because sorghum has more protein and fiber than corn, these differences in nutrient content are reflected in the DGS (Table 5). Likewise, because sorghum grain color can vary from red to bronze to white, the resulting DGS product can also vary in color due to the parent grain. Historically, corn DGS color has been related to nutritional quality due to ethanol plant processes. However, color is not a reliable

indicator of sorghum DGS quality simply due to a wide variation in sorghum seed coat color.

Distillers grains are a good source of protein and energy for lactating dairy cattle (Schingoethe et al. 2009). Many lactating dairy cattle are fed 3-5 pounds of DGS each day. It is also used in calf and heifer diets. Greater amounts of DGS can be included without negative impacts on milk production, but there is no nutritional advantage to feeding greater amounts of DGS since diets may contain excess protein and phosphorus. Few studies have compared DGS produced from different grain sources in dairy cattle rations. In a single study comparing grain source (corn and sorghum) and physical form (wet and dry), when fed at 15 percent of DM to lactating dairy cows, there were no differences in lactational performance or ruminal digestibility (Al-Suwaiegh et al., 2002). Milk production was slightly less for cows consuming sorghum DGS compared to corn DGS. However, milk production efficiency and milk components were not affected by the DGS grain source.

While a number of cattle feeding (beef and dairy) studies have been conducted

using DGS, results comparing sorghum to corn DGS indicate some inconsistencies. Challenges with feeding DGS are likely due to small differences in any of the processes within plants over time and between plants, such as the quality and quantity of solubles added back, oil recovery, extent of fermentation, drying temperatures and others. Additional research in this area will increase the confidence of animal nutritionists when incorporating sorghum DGS in rations.

TABLE 5. TYPICAL NUTRIENT COMPOSITION OF SORGHUM AND CORN DRIED DISTILLERS GRAINS WITH SOLUBLES (AS-FED)[1]

ITEM	SORGHUM DDGS	CORN DDGS	
	9.8% OIL	>6% AND <10% OIL	>10%OIL
DM%	89.8	89.3	89.3
CP, %	30.8	27.4	27.3
NDF, %	33.6	30.5	32.5
ADF, %	22.7	12.0	11.8
FAT, %	9.8	8.9	10.4
CA, %	0.12	0.08	0.12
P, %	0.76	0.60	0.73

[1]Values are derived from NRC, 2012. Nutrient Requirements of swine.

The main economic advantages resulting from the utilization of sorghum grain in dairy diets will likely result from savings in the cost of production as compared to corn. Most of these savings will likely be the result of lower seed costs and the ability to grow sorghum on much less water than corn. For dairy producers producing their own forage and/or grain, this can be a significant savings over purchasing feedstuffs from others. For producers purchasing feedstuffs, the question is a bit more complicated. In areas with limited rainfall or irrigation water, sorghum offers the advantage of reduced transportation costs associated with locally grown feedstuffs.

Examples of dairy rations replacing corn with sorghum are found in Table 6. Because sorghum grain contains more crude protein than corn, a portion of the soybean meal can be replaced. Amino acid quality is not as important for ruminant animals as most of the sorghum protein should be converted into microbial protein in the rumen. Sorghum does have a slightly greater ash content than corn, but it will have minimal effects upon the mineral supplementation of dairy diets.

Thus, the main advantage would be the opportunity to reduce the supplemental crude protein level of the diet if sorghum is replacing corn.

EXAMPLE LACTATING COW DIETS

TABLE 6. EXAMPLE DIETS THAT REPLACE CORN PRODUCTS (GRAIN AND SILAGE) WITH SORGHUM (GRAIN AND SILAGE).

ITEM	SORGHUM BASED	CORN BASED
	LB/DM PER COW	LB/DM PER COW
ALFALFA HAY	10.0	10.0
ALFALFA HAYLAGE	5.0	5.0
CORN SILAGE	0	16.0
SORGHUM SILAGE	15.0	0
CORN GRAIN	0	10.0
SORGHUM GRAIN	10.0	0
DISTILLERS GRAINS	3.0	3.0
SOYBEAN MEAL	5.5	6.5
WHOLE COTTONSEED	4.0	4.0
MINERAL AND VITAMIN	1.5	1.5
EXPECTED MILK, LB	85	85

EXAMPLE DRY COW DIETS

TABLE 6. (CONTINUED)

ITEM	SORGHUM BASED	CORN BASED
	LB/DM PER COW	LB/DM PER COW
WHEAT STRAW	15.0	15.0
CORN SILAGE	0	5.0
SORGHUM SILAGE	5.0	0
CORN GRAIN	0	1.0
SORGHUM GRAIN	1.0	0
DISTILLERS GRAINS	4.0	4.0
MINERAL AND VITAMIN	1.0	1.0

CONCLUSIONS

Utilization of properly processed sorghum grain in lactating dairy cow diets results in similar milk production as corn. This has been proven in numerous research trials. Processing is very important to get maximum utilization of the sorghum. Steam-flaking can increase the energy value of sorghum 13 to 20 percent and increases the utilization of sorghum in the rumen to produce microbial protein. These increases are a result of the disruption of the starch matrix and the protein matrix covering the starch due to the moisture, heat and pressure associated with steam-flaking. This results in increased milk production as compared to dry-rolling. Steam-flaked sorghum results in similar milk production as steam-flaked corn.

Any grain or starch can be utilized to produce ethanol. Sorghum is the second most common grain used to produce ethanol in the U.S., with corn being the primary feedstock. The resulting sorghum byproduct can be used in dairy cattle diets. Inconsistent results in animal feeding trials may be due to different processes used at the ethanol plant. New ethanol technologies, such as oil recovery, may further add to a nutritionally inconsistent

byproduct and contribute to varying results observed in animal feeding trials.

Grain sorghum and sorghum DGS can be used in dairy cattle diets while maintaining performance. Forage sorghum use in dairy rations has increased in recent years, especially in water-restricted regions. An additional feeding guide on forage sorghum can be found on the Sorghum Checkoff website or by request.

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