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Forage Sorghum Ensiled With Alfalfa as a Potential Alternative Feeding Strategy in Nevada

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Introduction

Across the United States and in Nevada, the two main feed crops cultivated for confined feeding systems (e.g., dairy and beef feedlot) are alfalfa (*Medicago sativa* L.) and corn (*Zea mays* L.) (Conrad and Klopfenstein, 1988; Osterholz et al., 2020). Nutritionally, both alfalfa and corn have been ranked as outstanding feed crops used as green chop, silage or hay for all classes of ruminant livestock, and in particular, for dairy systems.

However, feeding management strategies to meet the nutritional demand of ruminant livestock need constant modification and innovative approaches in the advent of water scarcity for crop irrigation in both arid and semiarid environments. Both high biomass production and forage nutritive value are critical for sustaining a profitable ruminant livestock industry (e.g., dairy cattle, dairy goats, feedlot beef cattle). However, irrigated alfalfa and silage corn irrigation are among the largest water users (Richter et al., 2020). Further, corn requires a substantial amount of annual nitrogen input to maximize yield (e.g., Marsalis et al., 2010). With the frequent occurrence of drought and limited water supplies, forages that minimize the water footprint for feed crops in Nevada provide multiple benefits (e.g., Martin et al., 2017).

Producers should consider alternative feed crops that reduce water and nitrogen inputs. Considering the aforementioned attributes, an alternative feed is forage sorghum [*Sorghum bicolor* (L.) Moench] silage. Among forage sorghum's positive traits are rapid growth, high biomass production and high production during the summer's hottest months (Pedersen and Rooney, 2004). Also, forage sorghum requires less water than alfalfa or corn, less nitrogen than corn, and is very tolerant to drought stress (Contreras-Govea et al., 2009; Bhattarai et al., 2020).

Forage quality of forage sorghums has improved with cultivars possessing the Brown Midrib (BMR) trait (Jung and Allen, 1995), but feed value for high-producing animals (e.g., dairy systems) remains limited due to the low protein content and digestibility (e.g., Contreras-Govea et al., 2010). Incorporating alfalfa with sorghum for silage can enhance the overall nutritional value of the feed. The objective of this study was to evaluate the effects of incorporating varying proportions of third-cut alfalfa with ensiled forage sorghum on overall feed quality.

Methods

This study was carried out at the University of Nevada, Reno Main Station Field Laboratory, Reno, Nevada, in 2017. The forage material used for ensilage came from a forage sorghum varietal trial using the cultivars CW7700, Canex BMR, DwarfKing, HayKing, and SilageKing. The alfalfa material used in this study came from a third-cutting of the Cinch variety grown in a production field at the University's Main Station Field Laboratory. The agronomic input for the forage sorghum evaluation was 40 lb P_2O_5/acre, and 80 lb N/acre. Forage sorghum was seeded on June 14, 2017, and harvested 107 days after sowing (Sept. 29, 2017) at the time of the scheduled third cut of alfalfa. The sorghum varietal trial was irrigated once weekly using a solid-set sprinkler system based on grass reference evapotranspiration. For the alfalfa production field, irrigation was carried out using wheel lines weekly. The source of irrigation was reclaimed wastewater from the Truckee Meadows Water Reclamation Chalk Bluff Facility, in Reno, Nevada.

Silage preparation (Ensilage process)

Silage was made one day after harvest by first wilting the chopped materials of the sorghum varieties and alfalfa in the field for 24 hours. The sorghum varieties and alfalfa were chopped separately to an average theoretical particle chop length of 14 mm using a Flail forage harvester.

Based on pre-ensilage moisture determination, 600 g of forage dry matter was used for each treatment. The silage materials used were sorghum only (100%), sorghum-alfalfa mixture (50:50), and sorghum-alfalfa mixture (75:25). There were 15 silage treatments replicated four times (Table 1). For example, for the 50:50 mixture, the equivalent fresh weight of 300 g of sorghum and 300 g of alfalfa dry matter were weighed and mixed thoroughly in a plastic bucket. Silage material was then placed in individual vacuum-sealed plastic bags for a 28-day ensilage duration. The silage treatments were stored in an enclosed box at ambient temperature for the duration of the study.

Table 1. Forage sorghum-sudangrass varieties and alfalfa silage mixture composition.

Treatment	**Silage Composition†**
1	CW7700
2	Canex BMR
3	DwarfKing BMR
4	HayKing
5	SilageKing
6	CW7700-Alfalfa (50:50)
7	CW7700-Alfalfa (75:25)
8	Canex BMR-Alfalfa (50:50)
9	Canex BMR-Alfalfa (75:25)
10	DwarfKing-Alfalfa (50:50)
11	DwarfKing-Alfalfa (75:25)
12	HayKing-Alfalfa (50:50
13	HayKing-Alfalfa (75:25)
14	SilageKing-Alfalfa (50:50)
15	SilageKing-Alfalfa (75:25)

†Sorghum-alfalfa mixtures were formulated on a dry matter basis as 50% sorghum and 50% alfalfa, or 75% sorghum and 25% alfalfa.

Silage quality parameters

Silage quality parameters measured were silage pH, silage dry matter, acid detergent fiber [ADF] and neutral detergent fiber [NDF]. Silage pH for each treatment replicate was measured by adding 10 g of sample into a 250-mL beaker with 200 mL deionized water and stirred thoroughly before measuring using a pH meter. To determine the silage dry matter, ADF and NDF, subsamples of 100 g were collected from each silage treatment replicate. The subsamples were oven-dried at 60 C for 72 hours. Dried subsamples were ground separately using a Wiley mill (Model 4, Thomas Scientific, Swedesboro, NJ) to pass a 1mm screen and stored in Whirl-Pak sample bags. Neutral detergent fiber (NDF) and acid detergent fiber (ADF) analyses were done according to the ANKOM procedure using the ANKOM 2000 Fiber Analyzer (ANKOM Technology, Macedon, NY, USA).

In this silage study, digestible dry matter (DDM), dry matter intake (DMI), total digestible nutrients (TDN), relative forage quality (RFQ) and net energy for lactation (NE_L) were estimated for each silage treatment using the following formulae (Horrocks and Vallentine, 1999; Moore and Undersander, 2002):

1) DDM (Digestible dry matter) = 88.9 - (.779 × %ADF)
2) DMI (Dry matter intake) = 120 / %NDF
3) TDN (Total digestible nutrients) = (-1.291 × ADF) + 101.35
4) RFQ = (DMI, % of body weight [BW] of dairy cattle) × (TDN, % of DM)/1.23.
5) NE_L (Net energy for lactation) = 1.044 – (0.0119 × %ADF)

Data analysis

Data were analyzed using the mixed model procedure (PROC MIXED) in SAS. Silage treatment (sole sorghum and sorghum-alfalfa mixtures) was considered a fixed effect, and replication was a random effect. Orthogonal contrasts compared the sorghum-only silage versus the compositional mixtures of sorghum-alfalfa. All responses were considered different when the *P*-value was < 0.05.

Results and discussion

Silage pH and dry matter

This study focused on silage formulations using sorghum and alfalfa as a potential means of reducing the water footprint in Nevada feed crops and livestock systems. Silage pH is a measure of its acidity and a key fermentation characteristic of silage. Silage pH was not different among treatments after a 28-day ensiling period (Table 2). The pH range in this study was 4.5 to 4.8, which is within the suggested range (4.3 to 5.0) for legume and grass silage (Kung et al., 2018). Unlike this study, Zhang et al. (2015) reported a significant decrease in the sweet sorghum-alfalfa silage pH as the proportion of sweet sorghum increased in the mixture. Silage pH ranged from 4.92 to 4.51, as the proportion of sweet sorghum increased from 20% to 80% in the mixture with alfalfa (Zhang et al., 2015). The fermentation pH of pure sweet sorghum was 4.16, which was lower than the pH of the different sorghum varieties in this study.

High recovery of dry matter (DM) is critical in silage production (Kung et al., 2018), and in this study, silage treatment affected DM (Table 2). Silage treatments 4 and 13 had greater DM content than treatments 6, 7, 8 and 14, but not any of the others (Table 2). Treatment 7 had the lowest DM content among all other treatments, except treatments 6 and 8 (Table 2). Typically, the silage DM content is influenced by what occurred at the pre-ensiled, fermentation, stable and feed-out phases (Borreani et al., 2018). The silage dry matter content in this study ranged from 31.6% to 48.7% among treatments, and overall was marginally greater than those (28.7% – 39.3%) reported for sweet sorghum-alfalfa silage at varying proportions (Zhang et al., 2015).

Fiber fractions: neutral and acid detergent fiber content

The neutral detergent fiber (NDF) content is an estimate of cellulose, hemicellulose, lignin and silica (cell wall material) after digesting the samples in a neutral detergent solution. This metric NDF is a useful predictor of voluntary feed intake and differed among silage treatments (Table 2). The NDF content was greatest for the sorghum-only (HayKing) silage treatment 4 (Table 2). Silage treatment 10 had lower NDF than all other treatments, except 8 and 14 (Table 2).

The acid detergent fiber (ADF) content is the residue (cellulose, lignin and insoluble minerals) remaining after digesting the forage sample with an acid detergent solution and is used as a predictor of forage digestibility. In this study, the ADF content of the silage differed among treatments (Table 2). Silage treatment 1 (CW7700) had the greatest ADF content among silage treatments (Table 2). Silage treatment 10, a 50:50 mixture of DwarfKing sorghum-alfalfa, had lower ADF content than all sorghum-only silage treatments (1, 2, 3, 4 and 5) and the mixed silage treatments 6, 7, 13, 14 and 15 (Table 2). The NDF and ADF contents in this study were dictated by the proportion of alfalfa mixed with sorghum. In this study, as the proportion of alfalfa increased in the mixture with sorghum, the ADF and NDF contents decreased, similar to the observation made by Zhang et al. (2015).

Table 2. Silage pH, dry matter (DM), neutral detergent fiber (NDF) and acid detergent fiber (ADF) for the different silage treatments after 28 days of ensilage.

Treatment	Silage Composition	pH	DM	NDF	ADF
				%	
1	CW7700	4.7	41.4 ^{ab†}	52.9 ^{b}	41.4 ^{a}
2	Canex BMR	4.5	44.9 ^{ab}	52.2 ^{bc}	35.4 ^{bcd}
3	DwarfKing BMR	4.6	45.6 ^{ab}	51.7 ^{bc}	32.7 ^{def}
4	HayKing	4.7	48.7 ^{a}	56.3 ^{a}	36.1 ^{bc}
5	SilageKing	4.6	45.0 ^{ab}	49.9 ^{cd}	35.5 ^{bc}
6	CW7700-Alfalfa (50:50)	4.6	37.9 ^{bc}	42.3 ^{fg}	33.7 ^{cdef}
7	CW7700-Alfalfa (75:25)	4.7	31.6 ^{c}	47.3 ^{de}	37.1 ^{b}
8	Canex BMR-Alfalfa (50:50)	4.6	39.2 ^{bc}	41.5 ^{gh}	31.2 ^{fg}
9	Canex BMR-Alfalfa (75:25)	4.6	43.5 ^{ab}	46.7 ^{e}	32.5 ^{efg}
10	DwarfKing-Alfalfa (50:50)	4.6	41.0 ^{ab}	39.1 ^{h}	29.8 ^{g}
11	DwarfKing-Alfalfa (75:25)	4.5	43.7 ^{ab}	46.7 ^{e}	32.6 ^{efg}
12	HayKing-Alfalfa (50:50	4.8	43.3 ^{ab}	46.0 ^{e}	32.5 ^{efg}
13	HayKing-Alfalfa (75:25)	4.8	48.7 ^{a}	53.3 ^{b}	35.0 ^{bcde}
14	SilageKing-Alfalfa (50:50)	4.7	40.3 ^{b}	40.9 ^{gh}	33.9 ^{cdef}
15	SilageKing-Alfalfa (75:25)	4.6	43.4 ^{ab}	45.0 ^{ef}	34.6 ^{bcde}
Standard Error		0.1	2.9	0.95	1.0
P-value		0.416	0.021	< 0.001	< 0.001

†Means followed by the same letter superscript within the same column are not different $P >$ 0.05. The means reported are all least square means.

Silage estimated feed values

Forage species and their associated intrinsic characteristics (e.g., nutritional profile) are critical factors governing the digestible dry matter (DDM), dry matter intake (DMI), total digestible nutrients (TDN), relative forage quality (RFQ), net energy for lactation (NE_L) and ultimately production responses from animals. The estimated percent DDM depended upon silage treatment (Table 3). Silage treatment 10 had greater DDM than all other treatments, except for treatments 8 and 12 (Table 3). The DDM was least for silage treatment 1 sorghum-only (CW7700) treatment (Table 3). In a silage study by Zhang et al. (2015) using sorghum and alfalfa mixed at different proportions, digestible dry matter increased with a greater proportion of alfalfa in the mixture, similar to the results of this study.

Silage treatment 10 had the greatest DMI (Table 3). In addition, silage treatments 8 and 14 had greater DMI than all sorghum-only silage treatments (1, 2, 3, 4 and 5) and the mixed sorghum-alfalfa silage treatments of 7, 9, 11, 12, 13 and 15 (Table 3).

The estimated TDN differed among silage treatments (Table 3). The TDN for silage treatment 10 was greater than all other treatments, except, 9, 11 and 12 (Table 3). The sorghum-only silage treatment 1 (CW7700) had the lowest TDN in this study (Table 3).

The RFQ value differed among silage treatments (Table 3). Silage treatment 1 (CW7700) had the lowest RFQ among all other silage treatments, except 4 (Table 3). The 50:50 mixed silage treatment 10 (DwarfKing-Alfalfa) had the greatest RFQ among all other treatments, except 8 (Table 3).

The estimated NE$_L$ was greater for silage treatment 10 than for silage treatments 1, 2, 4, 5, 7, 13 and 15 (Table 3). The lowest net energy for lactation was produced by the sorghum-only (CW7700) silage treatment 1 (Table 3).

Table 3. Silage feed predictive values of digestible dry matter (DDM), dry matter intake (DMI), total digestible nutrients (TDN), relative forage quality (RFQ) and net energy for lactation (NE$_L$) after 28 days of ensilage.

Treatment	Silage Composition	DDM	DMI	TDN	RFQ	NE$_L$
		------------------------	--%--	------------------------		(Mcal/lb DM)
1	CW7700	56.7 ^{g†}	2.2 ^{gf}	48.0 ^{g}	89 ^{h}	0.54 ^{f}
2	Canex BMR	61.3 ^{def}	2.3 ^{f}	55.6 ^{ef}	104 ^{fg}	0.62 ^{cde}
3	Dwarf King BMR	63.5 ^{bcd}	2.3 ^{f}	59.2 ^{bcd}	112 ^{ef}	0.66 ^{abc}
4	HayKing	60.8 ^{ef}	2.1 ^{g}	54.7 ^{fe}	95 ^{gh}	0.61 ^{de}
5	Silage King	61.2 ^{ef}	2.4 ^{ef}	55.5 ^{fe}	109 ^{f}	0.62 ^{cde}
6	CW7700-Alfalfa (50:50)	62.7 ^{bcde}	2.9 $_{bc}$	57.8 ^{bcde}	134 ^{bcd}	0.65 ^{abcd}
7	CW7700-Alfalfa (75:25)	60.0 ^{f}	2.6 ^{de}	53.4 ^{f}	110 ^{f}	0.60 ^{e}
8	Canex BMR-Alfalfa (50:50)	64.6 ^{ab}	2.9 ^{b}	61.1 ^{ab}	145 ^{ab}	0.67 ^{ab}
9	Canex BMR-Alfalfa (75:25)	63.6 ^{bc}	2.6 ^{de}	59.4 ^{abc}	124 ^{de}	0.65 ^{abcd}
10	Dwarf King-Alfalfa (50:50)	65.8 ^{a}	3.1 ^{a}	63.0 ^{a}	157 ^{a}	0.68 ^{a}
11	Dwarf King-Alfalfa (75:25)	63.5 ^{bc}	2.6 ^{de}	59.4 ^{abc}	124 ^{de}	0.66 ^{abc}
12	HayKing-Alfalfa (50:50	63.6 ^{abc}	2.6 ^{d}	59.5 ^{abc}	126 ^{cd}	0.66 ^{abc}
13	HayKing-Alfalfa (75:25)	61.6 ^{cdef}	2.2 ^{gf}	56.2 ^{cdef}	103 ^{fg}	0.63 ^{bcde}
14	Silage King-Alfalfa (50:50)	62.5 ^{bcde}	2.9 ^{b}	57.6 ^{bcde}	138 ^{bc}	0.65 ^{abcd}
15	Silage King-Alfalfa (75:25)	62.0 ^{cdef}	2.7 ^{cd}	56.7 ^{cdef}	124 ^{de}	0.62 ^{cde}
Standard Error		0.8	0.06	1.3	4.7	0.01
P-value		< 0.001	< 0.001	< 0.001	< 0.001	< 0.001

[†] Means followed by the same letter superscript within the same column are not different $P > 0.05$. The means reported are all least square means.

Silage compositional effect

To have a clear understanding of the impact of the silage composition, silage treatments were grouped as sole sorghum, a 50:50 mixture of sorghum-alfalfa, and a 75:25 mixture of sorghum-alfalfa (Table 4). Silage pH was not different among the groups, and there was only a tendency for the 50:50 mixture of sorghum-alfalfa to have a greater percent DM than the sorghum-only silage (Table 4). Silage NDF and ADF were lowest, while the estimated DDM, DMI, TDN and RFQ were greatest for the 50:50 mixture of sorghum-alfalfa compared with either the sorghum-only silage or the 75:25 sorghum-alfalfa silage mixture (Table 4). The estimated NE_L was also greater for the 50:50 sorghum-alfalfa mixture relative to the sorghum-only silage and the 75:25 mixture of sorghum-alfalfa silage, but these two were not different (Table 4). Like Contreras-Govea et al. (2011), the addition of legumes in warm-season forages (e.g., sorghum) will improve most silage quality constituents.

Table 4. Silage composition group effect on silage pH, dry matter (DM), neutral detergent fiber (NDF) and acid detergent fiber (ADF); and predictive feed values of digestible dry matter (DDM), dry matter intake (DMI), total digestible nutrients (TDN), relative forage quality (RFQ) and net energy for lactation (NE_L) after 28 days of ensilage.

Silage Composition Group	pH	DM	NDF	ADF	DDM	DMI	TDN	RFQ	NE_L
		----------------------------------%----------------------------------							(Mcal/lb DM)
Sorghum-only	4.6	45.1 ^{a}[†]	52.6 ^{a}	36.2 ^{a}	60.7 ^{c}	2.3 ^{c}	54.6 ^{c}	102 ^{c}	0.61 ^{b}
Sorghum-Alfalfa (50:50)	4.6	40.3 ^{b}	42.0 ^{c}	32.2 ^{c}	63.8 ^{a}	2.9 ^{a}	59.8 ^{a}	140 ^{a}	0.66 ^{a}
Sorghum-Alfalfa (75:25)	4.6	42.2 ^{ab}	47.8 ^{b}	34.4 ^{b}	62.1 ^{b}	2.5 ^{b}	57.0 ^{b}	117 ^{b}	0.63 ^{b}
Standard Error	0.04	1.4	0.7	0.6	0.5	0.03	0.8	3.0	0.01
P-value	0.8	0.066	< 0.001	0.002	0.002	< 0.001	0.002	< 0.001	0.006

[†] Means followed by the same letter superscript within the same column are not different $P > 0.05$. The means reported are all least square means.

Summary and implications

This silage production study revealed a sorghum varietal effect on silage nutritive value and estimated feed quality parameters. However, the silage feed quality impact was heavily dependent on the proportion of sorghum and alfalfa in the silage feed. Based on the RFQ value and nutritional requirements for various classes of ruminant livestock, the sorghum-alfalfa 50:50 mixture meets forage quality requirements for dairy cattle feeding. The sorghum-only silage is generally suited for heifers 18 – 24 months old and dry cows (beef cattle), while the 75:25 sorghum-alfalfa silage mixture is suited for heifers 12 – 18 months old and for beef cow-calf. Therefore, ensiling alfalfa and sorghum in mixtures is a suitable practical approach since both constituents have limitations in either nutritive value (sorghum) or fermentation characteristics (alfalfa), but combining them overcomes their respective limitations and improves silage quality. A 50:50 sorghum-alfalfa mixture seems most suited when producing mixed sorghum-alfalfa silage in Nevada. The implication for Nevada feed crops and livestock producers is that some of the existing land growing alfalfa could produce sorghum and significantly reduce the overall water needs for crop production (e.g., alfalfa-only production). Additionally, first- and second-year forage sorghum that replaces alfalfa fields will require little or no nitrogen to maximize yield because of nitrogen residual buildup (nitrogen credit) from alfalfa nitrogen-fixing ability (e.g., Yost et al., 2013, 2014). This strategic approach increases flexibility for livestock feed production in water-scarce environments such as Nevada, while enhancing ruminant livestock production, as well as economic and environmental sustainability.

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