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Inclusion of Barley Fodder in Alfalfa/Grass-Based Diets on Milk Production in Goats and Milking Sheep

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Abstract: The purpose of this study was to determine the effect of Barley Sprout Fodder (BSF) on milk production and milk composition of Saanen goats and Friesian ewes. Twenty Saanen does (1-year-old) and twenty East Friesian ewes (1 to 5 years old), were selected for this experiment, where each species was divided into four treatment groups. Goat treatments consisted of 0 (CRTL), 758 (BSF1), 1498 (BSF2) and 2270 (BSF3) g wet BSF/d added to an alfalfa/grass hay mix provided in random order. Sheep treatments were similar, but 0, 454, 908, and 1362 g wet BSF/d. The dry matter content of the fodder was 10.7%. A grain mix was fed to the goats (798 DM g/d) and sheep (400 DM g/d) during morning and evening milking. Treatment periods were fifteen days. Feed consumed was measured and milk yield and samples were collected on days 13 and 14. Milk samples were analyzed for milk fat, protein, and lactose. The cheese was made from day 14 milk and milk and cheese were analyzed for fatty acid composition. Total DM intake was between 2.7 and 2.9 kg/d for does and was different ($P<0.05$) between BSF treatments, 2.6 to 3.0 kg/d for ewes. Milk yield was not affected by BSF treatment. Goat milk yield averaged 2681 g/d across the treatments, while sheep was 1021 g/d. Milk fat content increased numerically from 77 to 82 g/d for goats and 50 to 58 g/d for sheep. BSF did not affect goat milk protein g/d, but sheep milk protein increased from 46 to 53 g/d. Goat milk lactose was not changed with BSF inclusion, while sheep milk lactose increased from 47 to 54 g/d. Total solids were not different from BSF in the diet for goats but was for sheep increasing from 143 to 164 g/d. There were no differences in cheese fatty acid composition for either species. The CRTL diet cost \$0.82/day for goats and \$0.72/d for sheep, while the high level of BSF inclusion cost \$1.06/d for goats and \$0.91/d for sheep. Based on the parameters of this study, the inclusion of BSF had relatively no effect on goat milk parameters but did improve milk solids in sheep milk, with no increase in milk yield.

Keywords: Sheep, Goats, Milk Components, Sprouted Fodder, Barley

Introduction

The recent estimate of sheep dairies in the U.S. is 100, producing nearly 9.4 million pounds of milk. Cheese processing from sheep milk is approximately 2 million pounds. Imported sheep cheese is between 53 million to 73 million pounds, leaving a large niche that U.S. producers can fill as domestic cheese products become more popular. There are an estimated 380,000 milk goats in the U.S. producing approximately 310 million pounds of milk. About 24% is consumed as liquid milk and 75% is processed into cheese (Milani and Wendorff, 2011). These two species represent about 0.08% of the total milk produced in the U.S. and most come from small producers.

Hydroponic barley sprouts are not a new technology but a reemerging technique that is being looked at for small farms with limited land and feed resources. One major draw is the ability to produce a forage year-round within a small footprint for production and storage. Another aspect of value is the ability to produce organic forage, maintaining the organic status of value-added products. Barley Sprout Fodder (BSF) digestibility has been determined to be approximately 90%, while grass and alfalfa hays average 60 to 65%. Understanding the nutritive value of fodder and its effects on milk production and milk composition in goats and milking sheep are important aspects of feeding BSF that need to be examined. This knowledge will aid goat and sheep dairy producers in the use and efficacy of fodder as a nutritional tool where limited farmland is a factor for productivity. Our focus for this study was to look at how barley sprout fodder affects the DM intake of goats and sheep and their milk characteristics. Our objectives were to determine if replacing grass hay with BSF affects milk production and milk composition and if the fatty acid profile of milk and cheese is altered. We also calculated the economics of incorporating BSF into the diet. We hypothesized the incorporation of BSF in place of grass hay will increase milk production, increase milk solids (protein and fat) and alter the fatty acid composition.

Materials and Methods

Animals

Twenty Saanen does (1-year-old) and twenty East Friesian ewes, (1 to 5 years old), were selected for this experiment under the approval of the BYU IACUC (#19-0201). Each of the doe and ewe groups were housed as species groups of five animals per treatment in pens where water and trace mineral salt blocks were provided free choice. At birth, lambs and kids were removed from the mother and reared artificially. The groups were fed the CRTL diet for 45-days before the beginning of the experiment to acclimate them to the base diet. The animals were milked daily at 0500 and 1700, where they received the grain mix (1596 g/d for does and 798 g/d divided between the two milking). Each group received each of four treatments in a 4 x 4 Latin square design to account for Days in Milk (DiM) and the same treatment from following the same across all treatment repetitions. Each treatment period was for 15 days, with 14 days between sample collection (Otaru *et al*., 2020). The DIM for each animal was calculated from d-14 of each treatment. The chemical composition of diet components is presented in Table 1. Treatments consisted of four diets where grass hay was replaced with Barley Sprout Fodder (BSF) as outlined in Table 2. The diets were formulated to provide similar protein and energy levels; 900 g protein and 14.0 Mcal energy for does and 413 g protein and 6.8 Mcal for ewes each day. Energy and protein nutrient levels were formulated for doe and ewe weights and production levels (NRC, 2007). Grass and alfalfa hay were chopped and mixed for each treatment and fed daily at 0700 each morning. Barley fodder was grown over a 6-d period in a self-contained unit (Model F-110, Fodder Works, Grass Valley, CA, USA). Each morning BSF was removed from the growth unit, weighed for each group and fed at the 0700 feedings. Seed trays were cleaned and Barley Seed (BSG; Wheatland Seed, Brigham City, UT, USA) was added to the unit. Feed consumed and feed refused were measured daily for each group.

Samples

Samples were taken on days 14 and 15 to allow for a 14-day acclimation to the treatment diet. Milk production was measured on d-14 and d-15 of each treatment period using a Waikato milk meter (Waikato Milking Systems LP, Verona, WI, USA), and daily milk production averages for the two days were determined. Samples were collected from each animal at the d-15 milking and the samples were analyzed for milk composition by the Rocky Mountain DHIA Lab (Logan, UT, USA). A sample of milk from each animal was taken and combined for each treatment on the d-14 and d-15 for fatty acid profile determination by the Brigham Young University Chromatography Lab. Milk from d-15 was collected from each treatment and placed in separate containers for cheese processing immediately following collection.

Simple mozzarella-style cheese was made. The recipe for the cheese was 1 kg of milk heated to 34°C. Twenty-three g citric acid was stirred in, 1 mL rennet and 1 mL calcium chloride added and the mix gently stirred for 5 min. The mix was allowed to stand for 60 min. The curds were separated from the whey by straining through four layers of cheesecloth.

Table 1: Chemical composition a of the diet components expressed on a percent dry matter basis

	Alfalfa	Grass	Barley fodder grain	Fodder	Corn	Barley	Beet pulp	Soybean meal
Dry matter, %	90.60	92.30	91.00	10.70	82.90	88.60	90.80	89.70
Crude protein	21.30	16.90	9.20	12.70	8.60	12.60	10.10	50.60
NDF	38.10	52.30	12.80	36.40	9.40	15.80	40.20	12.10
ADF	31.40	35.40	4.20	17.40	3.40	5.40	40.20	7.50
Lignin	6.90	5.50	1.10	-0.00	1.30	1.30	-0.00	-0.00
NFC	28.80	16.60	72.40	40.60	76.70	65.20	37.60	27.70
Starch	0.80	0.30	50.60	-0.00	76.70	51.70	-0.00	-0.00
Fat	2.40	3.20	2.30	-0.00	4.00	2.80	1.20	1.80
Ash	9.45	11.10	3.30	-0.00	1.35	3.60	10.90	7.70
ME, Mcal/kg	2.44	2.29	3.29	2.42	3.54	3.35	2.27	3.61
NEL, Mcal/kg	1.43	1.28	1.89	1.45	2.07	1.94	1.32	1.83
NEm, Mcal/kg	1.32	1.23	2.00	1.39	2.20	2.02	1.21	1.89

[a]Wet chemistry analysis by dairy one, ithaca, NY

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Table 2: Treatment diets fed (g/kg DM) for goats and sheep

	CRTL	BSF1	BSF2	BSF3
Hay mix				
Alfalfa hay	611.0000	663.000	724.000	797.000
Grass hay	389.0000	337.000	276.000	203.000
Cost ($/kg)	0.2250	0.229	0.233	0.238
BSF*				
Goat (g DM)	0.0000	84.000	167.000	243.000
Cost ($)	0.0000	0.140	0.270	0.390
Sheep (g DM)	0.0000	49.000	97.000	146.000
Cost ($)	0.0000	0.080	0.160	0.240
Grain mix				
Barley	588.0000	588.000	588.000	588.000
Flacked corn	183.0000	177.000	170.000	164.000
Beet pulp	115.0000	115.000	115.000	115.000
Soybean meal	113.0000	120.000	128.000	135.000
Cost ($/kg)	0.3430	0.346	0.350	0.0353
Diet Nutrient Composition				
Dry matter, %	90.2000	84.100	79.000	74.7000
Crude protein, %	17.1000	16.900	16.800	16.7000
NDF, %	33.0000	32.800	32.600	32.3000
ADF, %	22.6000	22.000	21.600	21.2000
Fat, %	2.7000	2.500	2.300	2.1000
Ash, %	7.8000	7.200	6.600	6.1000
ME, Mcal/kg	2.7500	2.730	2.710	2.7000
NE_m, Mcal/kg	1.5900	1.550	1.550	1.4500
NE_l, Mcal/kg	1.5600	1.580	1.580	1.5700

*BSF = Barley Sprout Fodder; cost ($/DM BSF fed/d)

The cheese curds were kneaded in a glass bowl to remove additional whey. The cheese curds were then heated in a microwave oven for 30 sec, removed and kneaded more. The same individual made the cheese to keep the process the same and to keep the final consistency the same. The ratio of cheese produced to the milk used was recorded. The cheese from each treatment was analyzed for fatty acid content.

Statistics

Statistical analysis was conducted with the proc Mixed module in SAS (2019). Fixed main effects included species, treatment, group and repetition, with animal set as a random effect to account for repeated measures. The least square means for species, treatment and repetition were determined to be significant at $P<0.05$. Model comparisons included treatment comparisons for the response variables weight, DMI, milk yield, milk composition, fatty acid profile and economic cost.

Results

Dry Matter Intake

Doe and ewe body weight is presented in Table 3. No bodyweight differences were found between treatments for each species. Doe mixed hay DMI was different ($P<0.05$) between CTRL at 1216 g/d, decreasing to 950 g/d for BSF3. The mixed hay DMI for ewes was different ($P<0.05$), decreasing from 2022 and 2154 g/d for CTRL and BSF1 to 1674 g/d for BSF3. The mixed grain fed to the does and ewes was set at 1 kg as-fed given at the two milking's for the ewes and 2 kg as-fed for the does at each milking. Daily DM grain-fed is presented in Table 3. Total DMI was not changed across the treatments for both does and ewes from 2812 g/d for doe CTRL to 3186 g/d to 3408 g/d for the BSF treatments. Ewe total DMI increased ($P<0.05$) for CRTL from 3210 g/d to 3123 g/d for BSF inclusion.

Barley Sprout Fodder and Economics

Fodder was fed at 0, 782, 1564 and 2273 g/d as-fed (0, 84, 167 and 243 g DM/d) for does and 0, 454, 908 and 1362 g/d as-fed (0, 49, 97 and 146 g DM/d) for ewes. Fodder intake for the does was different ($P<0.05$) across all treatments, except between BSF2 and BSF3 at 0, 72, 130 and 172 g DM BSF/d. Ewe fodder intake differed ($P<0.05$) across all treatments at 0, 52, 101 and 146 g DM BSF/d.

Feed costs (Table 3) are based on the following prices:

Alfalfa	$0.25/DM kg
Grass	$0.18/DM kg
Barley sprout grain, BSG	$0.61/DM kg
Feed barley grain, FBG	$0.29/DM kg
Corn	$0.31/DM kg
Beet pulp	$0.37/DM kg
Soybean meal	$0.69/DM kg

These prices are typical for the Utah, USA area. Using these prices, feed costs ranged from \$0.82 to \$0.96 for does with CRTL differing (P<0.05) from BSF2 and BSF3. Ewes, on the other hand, were different (P<0.05) between CRTL and BSF1, \$0.72 to \$0.82 respectively, BSF2 (\$0.80) and BSF3 (\$0.83). These feed costs included the mixed hay, grain mix, and fodder, excluding the BSF production costs.

The BSF production costs are based on the following prices for Utah, USA at the time of the study:

Electricity 0.3811 kwh @ \$0.144508/kwh = \$0.055/h or \$1.32/d
Water 7.95 liters/h = \$0.011/h or \$0.26/d
Labor 15 min/day to clean and reload barley trays @ \$15/h = > \$3.75/day

Other costs:
Milking Labor Two milkers for 2 h twice daily at \$15/h per milker = \$120.00/d for the 40 animals, milking 5 animals at a time.
Miscellaneous Soap, filters, etc. = \$5.00/d

The BSF unit we used for this study produces 50 kg of wet BSF per day (5.35 kg DM BSF/d). The BSF production cost for the 5.35 kg DM BSF including the BSG (5.5 kg DM BSG/5.35 kg DM BSF) was \$8.66/d, or \$1.62/kg DM. Labor and miscellaneous cost were \$3.13/animal/d. When added to the feed costs and BSF production cost, the total cost per doe was \$3.95 to \$4.92 per day, while the ewe cost was \$3.86 to \$4.12 per day.

Milk Parameters

Milk yield and composition are presented in Table 4. Days In Milk (DIM) was not different between treatments for either the does or the ewes indicating that the stage of lactation was not different across the treatments. Milk yield was not different between treatments for either species. Yield for does range from 2637 to 2740 g/d, while ewe yield ranged from 948 to 1081 g/d. Percentage milk fat did not differ between treatments ranging from 2.57 to 2.88%, with g/d ranging from 76.7 to 82.3. Milk fat percentage for the ewes ranged from 5.57 to 6.00% and on a g/d basis, CRTL was less (P<0.05) from BSF3 at 49.9 and 57.7 g/d. Milk protein percent was different (P<0.05) between BSF2 and BSF3 for does 2.88 and 2.72% respectively. Doe milk protein g/d was not different and ranged from 69.6 to 74.0 g/d. Milk protein percent for ewes was not different with a range of 4.80 to 4.90%. On a g/d basis, milk protein for the ewes did differ (P<0.05) between CTRL and BSF3 at 44.9 and 56.2 g/d respectively. Lactose percentage was not different between treatments for both does and ewes; does range from 4.47 to 4.54% and ewes from 5.02 to 5.06%. The g/d of lactose was not different for the does (112.0 to 115.6 g/d) or for ewes (47.3 to 54.1 g/d).

Table 3: Bodyweight, Dry Matter Intake (DMI) and daily cost for goats and sheep fed varying levels of barley fodder

	Treatment				
	CRTL	BSF1	BSF2	BSF3	SEM
Goats					
Body weight, kg	49.6	49.9	49.2	49.5	0.60
Mixed hay, g	1216^{c}	1227^{c}	1052^{b}	950^{a}	18.00
Mixed grain, g	1596	1596	1596	1596	0.00
BSF*, g	0^{a}	72^{b}	130^{c}	172^{c}	18.00
Total DMI, g	2812	2895	2778	2718	70.00
Feed Cost**, \$/d	0.82	0.83	0.80	0.78	0.02
BSF Cost, \$/d	0.0^{a}	0.13^{b}	0.21^{c}	0.28^{d}	0.01
Total Feed Cost, \$/d	0.82^{a}	0.96^{b}	1.01^{bc}	1.06^{c}	0.03
Sheep					
Body weight, kg	65.7	65.3	66.0	66.3	1.60
Mixed hay, g	2022^{c}	2154^{d}	1818^{b}	1674^{a}	14.00
Mixed grain, g	798	798	798	798	0.00
Fodder, g	0^{a}	52^{b}	101^{c}	146^{d}	14.00
Total DMI, g	2820^{bc}	3004^{c}	2718^{b}	2618^{a}	68.00
Feed Cost, \$/d	0.72	0.76	0.69	0.67	0.02
BSF Cost, \$/d	0.0^{a}	0.13^{b}	0.16^{c}	0.24^{d}	0.01
Total Feed Cost, \$/d	0.72^{a}	0.89^{b}	0.85^{b}	0.91^{b}	0.03

*BSF = Barley Sprout Fodder; BSF Cost = Barley Sprout grain, electricity, water and labor \$1.62/kg DM BSF
**Cost = hay and grain per day
[abcd]Rows with differing superscripts are different at P<0.05

Table 4: Effects of Barley Sprout Fodder (BSF) dietary inclusion on milk yield and milk components

		Treatment				
		CRTL	BSF1	BSF2	BSF3	SEM
Milk yield	Goats	2740	2637	2641	2707	53.020
g/d	Sheep	948	1001	1081	1052	
Milk Fat,	Goats	2.61	2.75	2.88	2.57	0.093
%	Sheep	5.57	5.98	5.62	6.00	
Milk Fat,	Goats	80.6	76.7	79.7	82.3	2.020
g/d	Sheep	49.9^{a}	54.8^{ab}	54.9^{ab}	57.7^{b}	
Milk Protein,	Goats	2.75^{ab}	2.77^{ab}	2.88^{b}	2.72^{a}	0.035
%	Sheep	4.85	4.86	4.80	4.90	
Milk Protein,	Goats	74.0	69.6	70.4	71.0	1.054
g/d	Sheep	45.6^{a}	49.1^{ab}	51.7^{b}	52.7^{b}	
Milk Lactose,	Goats	4.48	4.51	4.54	4.47	0.0021
%	Sheep	5.06	5.02	5.05	5.02	
Milk Lactose,	Goats	115.6	112.0	113.1	113.3	2.037
g/d	Sheep	47.3^{a}	49.6^{ab}	54.1^{b}	53.2^{ab}	
Total Solids	Goats	270.3	258.5	263.4	266.8	5.081
g/d	Sheep	142.7^{a}	153.5^{ab}	160.7^{b}	163.5^{b}	
Milk Urea,	Goats	57.0	28.4	25.5	39.8	10.020
mmol/l	Sheep	24.7	27.6	30.4	33.3	
DIM*, d	Goats	97.3	97.5	98.9	98.7	5.030
	Sheep	94.7	93.8	96.0	92.0	
Cheese**, %	Goats	7.9	8.0	7.8	7.9	0.007
	Sheep	15.4^{b}	15.1^{a}	15.5^{b}	15.6^{b}	

[abc]Rows with differing superscripts are different at $P<0.05$
*DIM = Days In Milk
**Cheese = ratio of milk to cheese produced

Table 5: Effects of dietary barley fodder on milk and cheese fatty acids composition.

Fatty acids	Milk (mg/ml) Sheep		Goat			Cheese (mg/g) Sheep		Goat		
	No Fodder	Fodder	No Fodder	Fodder	SEM	No Fodder	Fodder	No Fodder	Fodder	SEM
4:0	0.366	0.446	0.304	0.187	0.055	0.252	0.256	0.054	0.101	0.052
6:0	0.135	0.166	0.135	0.059	0.023	0.170	0.149	0.034	0.046	0.035
8:0	0.125	0.154	0.135	0.058	0.021	0.146	0.132	0.039	0.050	0.028
10:0	0.399	0.471	0.451	0.198	0.062	0.426	0.383	0.123	0.306	0.067
12:0	0.227	0.251	0.180	0.117	0.030	0.230	0.210	0.056	0.070	0.046
14:0	0.475	0.537	0.428	0.248	0.062	0.515	0.415	0.116	0.154	0.098
14:1 cis-9	0.035	0.041	0.017	0.000	0.009	0.067	0.055	0.000	0.032	0.015
16:0	1.023	1.228	1.053	0.599	0.133	1.207	0.977	0.289	0.356	0.227
16:1 cis-10	0.045	0.057	0.026	0.081	0.012	0.083	0.071	0.000	0.029	0.019
18:0	0.202	0.217	0.347	0.000	0.072	0.330	0.343	0.298	0.304	0.082
18:1 cis-10	0.526	0.575	0.634	0.240	0.087	1.204	0.910	0.112	0.348	0.251
18:2 CLA cis-9 trans-11	0.081	0.091	0.116	0.000	0.025	0.119	0.100	0.069	0.084	0.011
18:3 cis-9,12,15	0.041	0.043	0.027	0.187	0.038	0.041	0.035	0.012	0.024	0.006
20:0	0.043	0.053	0.023	0.059	0.009	0.078	0.062	0.000	0.035	0.017
20:1 cis 11	0.000	0.011	0.304	0.058	0.071	0.017	0.019	0.000	0.013	0.004
20:3 cis 5,8,11	0.000	0.446	0.135	0.198	0.093	0.013	0.013	0.000	0.000	0.003
SFA	2.995	3.423	2.894	1.525	0.201	3.354	2.927	1.009	1.422	0.231
MUFA	0.606	0.109	0.981	0.379	0.185	0.167	1.349	0.112	0.422	0.287
PUFA	0.122	0.580	0.278	0.385	0.096	0.173	0.148	0.069	0.108	0.023

SFA = Saturated Fatty Acids
MUFA = Mono-Unsaturated Fatty Acids
PUFA = Poly-Unsaturated Fatty Acids

There were no differences between treatments for milk: Cheese ratio. Values in Table 5 represent comparisons between no fodder and fodder fatty acids for milk and cheese where no differences were determined.

Discussion

Saanen goats are a popular milking breed in the U.S. and were readily available for this study. The same is true for the Friesian ewes. Grain sprout fodder is a green roughage feed that can be produced year-round from wheat, sorghum, corn, and BSG, to name a few, BSF being the most popular. We found the BSF protein content was slightly higher in the barley seed, 9% compared to 13%. The fodder is 90% digestible, so animals should glean more nutrients from feeding it. Fodder production requires less space and water than the fields needed to produce grass or alfalfa hay. Most fodder production is 6 to 8 days, whereas 1 kg of barley grain will produce 7-10 kg (Abd Rahim and Omar, 2015). We used 6 kg of barley seed to produce 50 kg of wet BSF. The typical dry matter content of fodder is 18% compared to alfalfa or grass hays at 90%. Gebremedhin (2015) showed a 14.2% DM for BSF, while Fazaeli *et al*. (2012) showed 19.3% DM for 6-d BSF. In this study, we found the DM of BSF to be 10.7%. Hafla *et al*. (2014) found crude protein of barley grain and BSF at 12.7 and 14.7%, higher than the variety we used (9.2 and 12.7%). Dung *et al*. (2010) showed a 21.9% loss of DM between barley grain and 7-d BSF. The alfalfa and grass hay used in this study contained 90.6 and 92.3% DM.

Expressed on a DM basis 5.46 kg barley seed produced 5.35 DM kg BSF. Fazaeli *et al*. (2012) concluded the loss in DM between seed and sprouted fodder was due to carbohydrate losses from the germination processes. Dung *et al*. (2010) showed a 2% loss of ME between barley grain and BSF. This was evident in our study where ME and NEm were less for BSF than barley grain, 2.42 to 3.29 Mcal ME and 1.39 to 2.00 Mcal NEm. On an as-fed per kg basis, ME is 2.99 Mcal for the grain and 0.26 Mcal for the BSF. The CP content comparison between the barley sprout grain and BSF per kg as-fed is 83.7 g for the grain and 13.5 g for the fodder. Dry matter content plays a major role in the feeding of BSF, so care needs to be taken into account when looking at the nutritional value of BSF.

Although they are related, the grain is a starch concentrated feed, while BSF is a forage. Digestibility of barley grain is 62% (Morgan and Campling, 1978) in cattle, while BSF has been reported at 75 to 90% (Prasad *et al*., 1998) The digestion of these two feeds is carried out by two different types of microbes in the rumen, one group that consumes starch and sugars and another group that consumes the cellulolytic or structural component of the plant. The largest population of microbes found in the rumen are those that consume cellulolytic plant material.

It has been pointed out that BSF is not intended to completely replace dry hay (Prasad *et al*., 1998; Badran, 2017), where they concluded feeding sprouted grain fodder increased production parameters when fed in conjunction with hay forages. Based on estimated nutrient requirements (NRC, 2007), the ewes and does in our study should be consuming approximately 2.29 kg of DM feed. Fed BSF alone, the ewe would need to eat 21 kg of fresh BSF. This amount of forage material would be difficult for a ewe to consume in one day. Dry matter intake was affected ($P<0.05$) by the BSF treatments, decreasing the mixed hay intake between 78 and 83% of the treatment without BSF. This was expected since we were feeding 2.3 and 1.36 kg/d BSF on a wet weight basis.

We anticipated BSF inclusion would increase milk yield due to a higher diet digestibility with the inclusion of BSF, also described by (Salo, 2019). Milk yield from our study remained the same across the treatments for both sheep and goats. This is similar to findings by Badran (2017) in Awassi ewes and Saanen goats (Hayati *et al*., 2018). While Salo (2019) reported improvement in milk yield and composition in dairy cows. Milk fat percent and g/d were not affected by the inclusion of BSF for goats or sheep. Pulina *et al*. (2006) explained that milk fat is affected by energy balance in sheep. The lack of response of milk fat due to BSF may be attributed to our efforts to make the diet isocaloric across the treatments. Milk protein g/d did increase with the inclusion of BSF for the ewes between the CRTL and BSF3 groups and was similar for lactose. According to Pulina *et al*. (2006), milk fat is easier to manipulate than protein.

Milk fatty acid composition is similar between cows, sheep and goats (Djordjevic *et al*., 2019). The fatty acid composition can be altered by dry hay, grass and silage composition in the diet (Chilliard *et al*. 2001; Dewhurst *et al*., 2006). Heins (2016) examined BSF in dairy cows and reported no shift in milk fatty acids between treatments. In our study, there was a numerical shift in Saturated Fatty Acids (SFA), MUFA and PUFA with the inclusion of BSF in the diet for our sheep where SFA and PUFA increased and, MUFA decreased. In the goats, SFA and MUFA decreased and PUFA increased. Though not significant, the goat trend follows what Elgersma (2015) described of dairy cows eating higher portions of grass where grass decreased SFA and increased PUFA. This was also substantiated by Couvreur *et al*. (2006) and Rego *et al*. (2016).

The cost of BSF production based on the conditions of this study was \$1.62/kg DM BSF compared to \$0.61/kg DM BSG or \$0.29/kg DM FBG. Mixed hay DM intake did decrease between the CRTL and BSF3 treatments for both the goats and the sheep. The BSF decreased mixed hay intake by 22% for goats and 17% for sheep, where the cost savings was \$0.04 for goats and \$0.05 for sheep. The cost difference for the addition of BSF, between the CRTL and BSF3, is \$0.24/goat and \$0.19/ewe. The DM hay saved for does and ewes are 40 kg and 53 kg for a 150-d lactation per animal, which equates to \$10 to \$13 per animal. The current market value for hay farm ground in Utah, U.S. is approximately \$24,961/ha. Alfalfa hay production will average 13-ton DM hay/ha for a 4-

cutting season. The cost of water used is estimated to be $543/year/ha. Added to this is the cost of the equipment for harvest, the fuel and the labor.

Conclusion

Arguments against the use of fodder in animal agriculture include the loss of available dietary energy and the decrease in the dry matter by the sprouting process. Labor and energy costs are also negative factors for fodder use but can be offset by the cost of farmland, natural resources and harvesting equipment. These are valid points, but the use of fodder in feeding animals comes down to the farmer weighing their resources and production objectives. Feeding BSF at the levels we fed did not affect milk yield. Solids (fat, protein, lactose and total) for sheep increased with BSF. BSF inclusion at the highest level we fed will increase solids in sheep milk. Barley fodder may cost more to feed on a dry matter basis, but land, storage and year-round availability are important factors in the decision-making process. Continued research is needed to examine at what level BSF inclusion begins to hinder milk production.

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Authors Contributions

All authors equally contributed in this study.

Ethics

This article is original and contains unpublished material. The corresponding author confirms that all of the other authors have read and approved the manuscript and no ethical issues involved.

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