

Effects of Increased Inclusion of Algae Meal on Lamb Total Tract Digestibility

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Summary and Implications

Algae meal is a novel coproduct created by the unique combination of soybean hulls and oil-extracted heterotrophic micro algae. Algae meal is highly digestible by ruminants and was readily consumed by lambs when included at up to 60% of the diet dry matter. This suggests that algae meal could potentially replace corn or soybean hulls and serve as a valuable component of feedlot diets.

Introduction

Recently a new coproduct has become available from the large scale commercial production of heterotrophic microalgae utilized for bioenergy and oil. This coproduct, when combined with soyhulls, offers a unique combination of fiber, protein, and fat and may play a role as an alternative feedstuff in animal diets. The ruminant animal, with their unique capability to convert what would otherwise be waste products into nutritious animal protein via fermentation, serves as the ideal model for analyzing this coproduct. Naturally produced microalgae has been previously studied however, concentrations of Na, Fe, Cu, and Al, ultimately limited inclusion in diets because of potential for toxicity of micro- and macro minerals. The algae used in the current study is produced by a heterotrophic fermentation process and grown in dark fermenters, and the resulting algae meal is not limited by excess micronutrients. Previous research showed that beef cattle will readily consume algae meal at concentrations less than 45% diet DM. The nutrient composition of algae meal suggests that this feedstuff may serve as a valuable replacement for soyhulls or perhaps corn. Therefore the objective of this study was to determine the impact of replacing corn with increasing inclusions of algae meal on total tract nutrient digestibility in sheep.

Materials and Methods

Experimental design. Ten whiteface cross wethers (74.3 ± 1.22 lbs) were used in a replicated 5 x 5 Latin square to determine the digestibility of diet dry matter (DM) and nutrients in sheep fed one of 5 diets (n = 2 lambs per

treatment per period) containing varying concentrations of algae meal (ALG). Treatments included one of 5 diets (Table 1): a corn-based control (CON), 15% algae meal (15% ALG), 30% algae meal (30% ALG), 45% algae meal (45% ALG), and 60% algae meal (60% ALG). Algae meal replaced corn on a DM basis. Experimental periods lasted 15 d with 10 d for adaptation to treatment diets and 5 d for total fecal and urine collection. For the first 3 d of adaptation lambs were paired by treatment and housed in pens. On d 4 lambs were moved to individual metabolism crates to allow for total collection of urine and feces.

Sample collection and analysis. From d 10-15 urine and feces were collected and subsampled. Composites of each treatment TMR (50 g/d) were collected during d 10 through d 15 to determine partial DM. If feed refusals (orts) were present they were removed daily, weighed, and a subsample was taken.

Once samples were dried, TMR, orts and fecal samples were ground and composited by sheep within period on an equal dried weight basis. The true DM, organic matter (OM), NDF, and ADF of TMR, orts, and fecal samples were determined. Urine was pooled by sheep within period. A subsample of urine, fecal, orts, and feed was sent to the University of Arkansas Central Analytical Laboratory (Poultry Science Center, Fayetteville, AR) for nitrogen and ether extract analysis.

Digestibility of all nutrients was calculated based on true DM for each period. Digestibility was calculated as a percent by subtracting the total output from the total intake, dividing by total intake, and multiplying the value by 100. Total intake is defined by the total feed offered minus the orts. Total output is defined as the total fecal output.

Statistical Analysis. Data were analyzed by ANOVA using the Mixed procedure of SAS (SAS Institute, Inc., Cary, NC). Individual lamb served as the experimental unit for all analysis (n = 10). Period, dietary treatment, and lamb within square were considered fixed effects for digestibility, input, and output analysis and period and dietary treatment were considered fixed effects for dietary analysis. Four single degree of freedom contrast statements were constructed prior to analysis: 1) CON vs. ALG, 2) linear, 3) quadratic, and 4) cubic effects of increasing inclusion of ALG (0, 15, 30, and 45% DM of ALG).

Results

Diet Composition. The analyzed composition of the experimental diets is reported in Table 2. Dry matter was

lower ($P < 0.001$) for CON than ALG. There were linear ($P < 0.001$) and quadratic ($P = 0.02$) effects of ALG inclusion on diet DM. Neutral detergent fiber, ADF, and ether extract concentrations were lesser ($P < 0.001$) for CON than ALG, and there was a linear ($P < 0.001$) increase in these nutrients as inclusion of ALG increased in the diet. Nitrogen, and thus CP, did not differ across diets ($P = 0.33$).

Intake and Digestibility. Dry matter intake and diet digestibility data are reported in Table 3. During the 5 d collection period lamb DMI and OMI were lesser ($P = 0.01$) for CON than ALG, and there was both a linear ($P \leq 0.04$) increase and a tendency for a quadratic ($P = 0.09$) effect of ALG inclusion. This is likely explained by the lesser DMI and OMI of lambs on the CON diet while lambs consuming ALG at any concentration had similar DMI and OMI. Dry matter digestibility was greater ($P < 0.001$) for CON than ALG and linearly ($P < 0.001$) decreased as the inclusion of ALG increased. Neutral detergent fiber and ADF digestibility were lesser ($P \leq 0.01$) for CON than ALG. There was a linear ($P \leq 0.04$) and cubic ($P \leq 0.03$) effect of ALG inclusion for NDF and ADF digestibility data. This is due to lesser digestibility by CON and greater digestibility by 60% ALG, while the intermediate ALG inclusions (15, 30, and 45%) were very similar. Ether extract digestibility was lesser ($P = 0.002$) for CON than ALG, and there was a linear ($P = 0.002$) increase in ether extract digestibility due to the lesser digestibility by the CON lambs and the increased digestibility by the 60% ALG lambs. Lambs consuming the CON diet had greater ($P < 0.001$) N digestibility than ALG lambs. There was both a linear ($P < 0.001$) and cubic ($P = 0.03$) effect for N digestibility, likely explained by the lesser, yet similar, N digestibility's of the 30% ALG, 45% ALG, and 60% ALG lambs compared to CON and 15% ALG lambs.

Discussion

Algae meal offers an attractive nutrient profile for cattle; however, the utility of this material as a ruminant feedstuff must be determined. With volatile corn prices and a constantly rising demand for corn, algae meal could serve as an alternative feedstuff in cattle diets. The ruminant animal serves as the perfect model to consume waste products from biofuels and other bioproducts with their ability to utilize fermentation to access energy from fibrous feedstuffs. This is the first attempt at feeding algae meal to lambs and it is important to note that the algae meal was readily consumed as noted by the linear increase in DMI. Also, there was minimal sorting and feed refusals throughout the trial suggesting palatability and preference are of minimal concern for this feedstuff. However, the limitations of this experimental design did not allow for growth and carcass parameters to be measured. Therefore, a longer trial under more practical conditions will be required.

In previous work it was noted that beef cattle will readily consume algae meal at up to 45% of the diet DM; however, cattle did not show a preference for, or against, TMR containing algae meal compared with TMR containing dried rolled corn. Thus, palatability, or a preference for algae meal, is likely not driving the increased DMI exhibited by lambs in the present study. Ground soyhulls have a smaller particle size causing increased passage rate from the rumen. Furthermore, it is known that increased consumption of feed will lead to increased passage rate caused by added feed increasing and pressuring the flow of undigested residues. Increased DM and OM intake could also be driven by the lesser available energy of the algae meal, indicating that lambs are simply consuming more DM to meet their energy needs.

Increasing feed intake can also lead to a depression in diet digestibility. Therefore, increased intake may also help explain the decrease in DM and OM digestibility. Alternately, the inclusion of soyhulls in algae meal may help explain the differences among treatments. Soyhulls, fed at increasing inclusions at the expense of corn, have been shown to decrease DM digestibility as well as OM digestibility.

Feeding 60% algae meal increased NDF digestibility by approximately 13% over the control lambs. Similarly, the NDF content of the high algae meal diet increased 15% compared to the control diet. This enhancement of NDF digestibility could be associated with the highly digestible nature of the NDF in soyhulls. Increasing algae meal in place of corn may be lessening the negative associative effects of corn on fiber digestion driving this increase in NDF digestion as algae meal increases in the diet. Further research will be required to determine the effects of algae meal on ruminal pH as well as the contribution to total tract digestion from distinct sites within the gastrointestinal tract.

Increasing digestibility of ether extract as algae meal increased in the diet may simply reflect the differences in the concentration of fat in each dietary treatment. The original microalgae is grown in a heterotrophic fermentation process and contains at least 80% oil. This oil is then extracted and utilized to produce biofuels, chemicals, human nutritionals, and cosmetics for skin and personal care. The residual oil that was not extracted then ends up in the algae meal. Soyhulls only contain 2.6% ether extract according to the NRC and therefore likely contribute minimally to the total fat of the algae meal. The algae meal utilized in the present study contains 7.54% fat which can be assumed to be majorly contributed by the algae itself, thus it is no surprise that the total ether extract content of the diet increases as the inclusion of algae meal increases.

The CP digestibility of soyhulls is decreased in some cases due to protein damage from heat processing, though that was not measured in this study. Also, due to increased passage rates, soyhulls tend to escape rumen degradation and become subject to hindgut fermentation, which can

inflate fecal CP values and decrease apparent N digestibility. This may help explain why even though all diets were similar for total N there were changes in both lamb N digestibility and N balance. So, even though the algae meal is providing a source of N, since this fibrous feedstuff is potentially passing from the rumen at an accelerated rate, the cellulolytic microbial population may not be able to effectively utilize the available N.

In conclusion, the results of this study suggest that algae meal is highly digestible by ruminants and will be readily consumed by lambs when included at up to 60% of the diet DM. The nutrient digestibility data suggest that algae meal could potentially replace portions of corn or

soyhulls and serve as a viable component of feedlot diets. Considering that both algae and soyhulls constitute algae meal it will be challenging to determine if the effects on intake and digestibility are driven solely by the algae, the soyhulls, or perhaps a complimentary effect of the two. From a nutritional standpoint algae meal offers an attractive combination of protein, fiber, and fat. Stimulation of DMI may allow algae meal to serve an important role in backgrounding and receiving cattle diets when intakes are of the utmost importance. The outlook for algae meal is good, however, additional research will be required to determine where this feedstuff may be best utilized in the livestock industry.

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Table 1. Ingredient composition of lamb digestibility diets (% DM basis).

Ingredient, % DM	Treatment				
	Control	15% Algae	30% Algae	45% Algae	60% Algae
Corn	60.00	45.00	30.00	15.00	-
Wet corn gluten feed	25.00	25.00	25.00	25.00	25.00
Hay	10.00	10.00	10.00	10.00	10.00
Algae meal	-	15.00	30.00	45.00	60.00
Corn dried distillers grains ¹	1.44	1.44	1.44	1.44	1.44
Limestone	2.10	2.10	2.10	2.10	2.10
Salt	0.31	0.31	0.31	0.31	0.31
Ammonium chloride	0.50	0.50	0.50	0.50	0.50
Lasalocid ²	0.015	0.015	0.015	0.015	0.015
Vitamin A, D, and E premix ³	0.10	0.10	0.10	0.10	0.10
Trace mineral premix ⁴	0.54	0.54	0.54	0.54	0.54

¹Carrier for micro-ingredients.

² Provided Lasalocid at 25g/909 kg of diet DM.

³ Contained 900,000 IU of Vitamin A, 225,000 IU of Vitamin D, and 180 IU of Vitamin E per kg of premix.

⁴ Provided per kilogram of diet DM: 500 mg of Mg (magnesium sulfate), 30 mg of Zn (zinc sulfate), 25 mg of Mn (manganese sulfate), 0.6 mg of I (calcium iodate), 0.22 mg Se (sodium selenite), and 0.2 mg of Co (cobalt carbonate).

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Table 2. Analyzed composition of lamb diets (% DM basis).

	CON ¹	Algae meal				SEM	CON vs Algae	<i>P</i> -value		
		15%	30%	45%	60%			Linear	Quadratic	Cubic
Dry matter	66.28	68.38	70.62	71.73	72.59	0.383	<0.001	<0.001	0.02	0.75
NDF	25.20	29.73	33.01	35.13	40.20	1.195	<0.001	<0.001	0.99	0.28
ADF	9.66	13.09	16.05	18.29	22.09	0.714	<0.001	<0.001	0.99	0.38
Ether extract	2.89	3.29	3.91	4.38	4.76	0.169	<0.001	<0.001	0.77	0.56
Nitrogen	1.76	1.81	1.75	1.80	1.79	0.029	0.33	0.54	0.79	0.62
Crude protein	10.98	11.30	10.96	11.25	11.18	0.180	0.33	0.54	0.79	0.62

¹Corn based control diet.

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Table 3. Lamb digestibility calculations (% DM basis).

	Control	Algae meal				SEM	Con vs Algae	<i>P</i> -value		
		15%	30%	45%	60%			Linear	Quadratic	Cubic
Lambs (n)	10	10	10	10	10					
DMI, lbs/d	2.23	2.54	2.85	2.62	2.75	0.598	0.01	0.01	0.09	0.43
DM digestibility, %	75.1	73.3	69.8	68.0	67.5	0.70	<0.001	<0.001	0.11	0.20
OM digestibility, %	76.4	74.5	70.7	68.9	68.1	0.69	<0.001	<0.001	0.12	0.20
NDF digestibility, %	37.5	44.8	44.7	44.9	50.7	1.70	<0.001	<0.001	0.68	0.03
ADF digestibility, %	39.9	46.9	44.7	43.5	48.1	1.92	0.01	0.04	0.61	0.02
Ether extract digestibility, %	83.5	87.0	87.9	87.9	89.5	1.20	0.002	0.002	0.31	0.27
N digestibility, %	68.5	67.0	61.8	59.1	59.3	0.95	<0.001	<0.001	0.11	0.03