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Post-extraction algal residue in beef steer finishing diets: I. Nutrient utilization and carcass characteristics☆

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A B S T R A C T

In Part I of a two-part study, an experiment was conducted to determine effects of post-extraction algal residue (PEAR) inclusion on nutrient utilization and carcass characteristics in finishing steers. Eighteen Angus × Hereford steers (initial body weight = 549 ± 38.8 kg) were randomly assigned to one of three treatments for the last 35 days prior to harvest: PEAR added to the ration at 1.0 kg organic matter (OM)/day (PEAR), or 1.0 kg OM/day glucose infused ruminally (GR) or abomasally (GA). The basal diet consisted of a standard finishing ration with additional roughage provided in the diet to prevent sudden changes in intake as a result of infusion treatments. Greater dry matter intake (DMI) was observed for PEAR (13.0 kg/d) than GR (10.3 kg/d; $P < 0.05$); DMI for steers receiving GA (11.2 kg/d) was intermediate and not different from either PEAR or GR ($P \geq 0.14$). Intake of digestible energy (DE) was similar among treatments ($P = 0.45$) and averaged 36 Mcal/d as was digestible OM intake which averaged 8.8 kg/d ($P = 0.51$). Digestion of gross energy (GE) was 72.9, 82.6, and 80.9% for PEAR, GA, and GR, respectively ($P < 0.01$). Digestion of neutral detergent fiber (NDF) was substantially less (55.7%) for PEAR than GA (75.4%) and GR (75.0%; $P < 0.01$). Steers fed PEAR had greater marbling scores (Mt^{20}) than GA (Sm^{63}) and GR (Sm^{52}; $P = 0.01$). Accordingly, USDA Quality Grade was greater for PEAR than GA and GR ($P = 0.01$; Ch^{40}, Ch^{21}, and Ch^{17}, respectively). There was no difference in USDA Yield Grade or hot carcass weight (HCW) between treatments ($P \geq 0.66$). In Part II, flavor and fatty acid composition of beef cuts from carcasses used in this study were assessed, and results are addressed in a separate publication.

1. Introduction

Inclusion of co-products such as cottonseed meal, soybean meal, or distillers' grains as sources of protein or energy in cattle diets is a well-accepted practice; Drewery [1] showed that cattle consumed and utilized post-extraction algal residue (PEAR) as affectively as conventional protein supplements. The co-product, PEAR, originates from biofuel production from algal biomass and is a potential feedstuff for beef cattle.

Currently, biofuel production from micro-algae is not cost-competitive with other fuel sources [2]. However, development of a market for PEAR would aid in cost recovery, allowing biofuel from micro-algae to be more cost-competitive with other renewable fuel sources. After oil is extracted from algae, more of the original biomass remains as PEAR than was removed as oil (> 50% of biomass) [3]; achieving meaningful level of biofuels from algae would thus produce a substantial amount of PEAR. With 10.7 million cattle on feed [4], the U.S. feedlot sector is an appealing market of substantial size for PEAR. Placement of distillers' grains in finishing rations demonstrates an acceptance of a competitive biofuel co-product and provides a means to enhance biofuel and beef sustainability.

Technical advancements in algae production have yielded a second-generation PEAR with improved nutrient composition; it contains less ash (12.2 vs 45.5%) and more protein (33.8 vs 17.9% crude protein (CP)) than first-generation PEAR [5]. However, PEAR has not, to our knowledge, been evaluated as a component of beef cattle finishing diets. Our objectives in Part I of this study were to evaluate the effects of PEAR provision on nutrient utilization in cattle consuming finishing diets, and its effects on carcass performance.

Abbreviations: PEAR, post extraction algal residue; CP, crude protein; OM, organic matter; GR, glucose infused ruminally; GA, glucose infused abomasally; DM, dry matter; NDF, neutral detergent fiber; ADF, acid detergent fiber; FAME, fatty acid methyl esters; DMI, dry matter intake; GE, gross energy; DE, digestible energy; ME, metabolizable energy; NEm, net energy for maintenance; NEg, net energy for gain; HCW, hot carcass weight

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2. Materials and methods

This research was conducted according to experimental protocols approved by the Institutional Animal Care and Use Committee at Texas A & M University.

2.1. Data and sample collection

Eighteen Angus × Hereford steers (initial body weight = 549 ± 38.8 kg) were used in a one-way, completely randomized, three-treatment experiment designed to evaluate the effects of PEAR on nutrient utilization as compared to infusion of glucose ruminally or abomasally. Treatments included PEAR hand mixed into the diet (1.0 kg organic matter (OM)/day; PEAR), and ruminal (GR), or abomasal (GA) infusion of 1.0 kg OM/day glucose. Glucose treatments were selected for use in this study to prevent addition of flavor influencing compounds which would have been added in the diet had the treatments been balanced for starch or protein. The carcasses from steers in this study were further evaluated in Part II by Morrill et al. [6] for differences in flavor and fatty acid composition of beef as a result of PEAR inclusion compared to glucose infused steers. Further, at the time of study design, it was unknown whether PEAR would be digested ruminally or post-ruminally, thus glucose was infused into the rumen or abomasum. Algal biomass (*Chlorella* sp.) was grown photosynthetically in an open pond, flocculated, dewatered, spray dried, and oil was extracted with a methylpentane solvent to produce the PEAR used in this experiment.

Steers were adapted to housing and feeding protocols for 5 days. Steers were housed in individual pens within a continuously lighted barn, and were provided ad libitum access to fresh water and feed. Prior to beginning the study, steers were adapted to a finishing diet comprised of dry rolled corn (42.3%), ground milo (18.0%), cottonseed hulls (13.5%), grass hay (10.0%), molasses (6.7%), cottonseed meal (5.4%), vitamin/mineral premix (2.3%), urea (0.9%), and limestone (0.9%; Tables 1 and 2). We recognize that this diet contained a higher proportion of roughage than seen in typical United States feedlot diets, but additional roughage was necessary to prevent sudden changes in intake in steers administered glucose treatments. For the duration of the study, the same finishing diet was fed daily at 0600 h and offered at 130% voluntary intake of the previous day. Steers assigned to the PEAR treatment also received PEAR hand mixed into the finishing diet at 0600 h. Infusion treatments were applied to ruminally cannulated steers continuously through an anchored infusion line into the rumen (GR) or abomasum (GA).

Throughout the 35-day feeding period, steers received their respective treatments. For the first 3 days, treatments were administered at increasing levels (0.25 kg OM/day increments) to prevent sudden intake changes. Sampling for nutrient utilization occurred on day 27 through day 31.

Intake was measured on day 27 through day 30; calculations of intake were made from observations of intake and orts. Finishing diet, supplement (PEAR and glucose), and orts were collected on day 27 through day 30 to correspond with fecal samples collected day 28 through day 31 for determination of digestions. Feed refusals were collected and weighed prior to feeding at 0600 h and a 200 g sample was retained for analysis. Finishing diet, and PEAR samples were composited across days on an equal weight basis. Ort samples were composited within steer across days.

Titanium dioxide was used as an external marker to estimate fecal production for calculations of digestions; 10 g/day were hand mixed into the diet prior to feeding on day 21 through day 31. Concentration of titanium in orts was used to determine individual animal intake of titanium. Fecal samples were collected prior to initiation of feeding titanium (day 20) to determine baseline titanium levels (0.03% ± 0.02). On day 28 through day 31 fecal samples were collected every 8 h, with sample time advancing 2 h each day so that 12 samples were obtained over a 4-day collection period. Fecal samples collected during the feeding of titanium were composited and frozen at −20 °C until analysis. Prior to analysis, each sample was allowed to thaw, was thoroughly mixed, and a representative subsample was collected for analysis.

At the end of the nutrient utilization sampling period, harvest of steers began on day 34 and continued through day 36. Harvest day was assigned at random within treatment and rumen cannulation status. On the day of harvest, steers were transported 9 km to the Texas A & M University Rosenthal Meat Science & Technology Center (College Station, TX), where the cattle were harvested by humane, industry standard procedures. Prior to harvest, steers with ruminal cannulae had ruminal contents manually evacuated to prevent carcass contamination during harvest; PEAR steers were fasted for 18 h prior to slaughter. At 48 h post-harvest, carcasses were graded according to USDA standards

Table 1
Chemical composition of finishing diet and post-extraction algal residue (PEAR)[a].

Item	Finishing diet	PEAR[a]
DM, %	92.6	93.3
	% of Dry Matter	
OM	94.3	87.8
CP	13.7	33.8
Ether extract	3.40	3.91
Acid hydrolysis fat	3.97	6.13
ADF	17.40	n.d.
NDF	33.57	n.d.
Macrominerals, %		
Ca	1.31	0.08
P	0.35	0.54
K	0.93	0.64
Mg	0.23	0.09
Na	0.30	3.16
S	0.21	0.74
Microminerals, ppm		
Al	121.6	2880.0
Co	0.83	0.83
Cu	15.85	54.70
Fe	165	3540
Mn	84.3	61.1
Mb	0.89	0.88
Zn	98.9	164.0

[a] PEAR = post-extraction algal residue (*Chlorella* sp.)

Table 2
Comparison of fatty acid composition of finishing diet and post-extraction algal residue (PEAR)[a].

Item	Finishing Diet	PEAR[a]
Fatty Acid, g/100 g FAME[b]		
14:0	0.26	0.72
14:1	0.05	0.41
16:0	17.32	26.19
16:1	0.29	1.99
18:0	2.36	4.12
18:1c9	21.30	37.89
18:1c11	0.65	5.32
18:2	48.63	4.47
18:3	4.85	5.03
20:0	0.03	n.d.[c]
20:1	0.14	0.62
20:2	0.03	0.32
20:4	0.27	0.28
20:5	0.26	0.36
22:0	0.32	0.84
24:0	0.10	n.d.
22:6	0.10	0.11

[a] PEAR = post-extraction algal residue (*Chlorella* sp.)
[b] FAME = fatty acid methyl esters.
[c] n.d. = not detected.