Using Eastern Gamagrass to Limit Weight Gains by Replacement Dairy Heifers: 2. Measuring Excreta and Digestibility On a Whole-Pen Basis

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ABSTRACT

Previously, research efforts that attempted to make whole-pen measurements of excreta output were complicated by organic bedding materials. New research pens equipped with sand-bedded freestalls offered potential for refinement of whole-pen collection methods, largely because sand-bedded freestall systems contain no organic bedding. Our research objective was to evaluate novel procedures for quantifying excreta produced from whole pens of replacement dairy heifers. This study was conducted on a subset of heifers used in a larger production-scale study evaluating eastern gamagrass [EGG; *Tripsacum dactyloides* (L.) L.] haylage that was incorporated into a total mixed ration comprised of corn silage and alfalfa haylage at rates of 0, 9.2, 18.4, or 27.6% of total dietary DM (EGG0, EGG9, EGG18, and EGG27, respectively). The EGG0 diet also was offered on a limit-fed basis (LF). Eighty Holstein dairy heifers were blocked by weight (heavy, 424 ± 15.9 kg; light, 324 ± 22.4 kg), and then assigned to 10 individual pens containing 8 heifers/pen. One pen per block was assigned to each of the 5 research diets, and whole-pen collections were conducted twice for each pen. Under the conditions framed by our experimental design, pooled SEM for the excreta output of DM and OM were 98 and 84 g/heifer/day, respectively. For DM excretion, this represented about 1/3 of the SEM reported for previous whole-pen collections from bedded-pack housing systems. Subsequent calculations of DM and OM digestibilities indicate that the whole-pen evaluation system detected linear ($P \leq 0.027$) trends associated with the inclusion rate of EGG. This research technique facilitated excreta collection and estimation of diet digestibility coefficients on multiple animals simultaneously, thereby mitigating the need for individual animal measurements. The approach is viable, but requires collections of multiple pens for statistical analyses, as well as thorough homogenization of large volumes of manure.

INTRODUCTION

Previously, several studies (Bjelland et al., 2011; Kruse et al., 2010; Hoffman et al., 2007) included whole-pen collections designed to determine excretions of nutrients on a whole-pen basis, rather than by traditional individual-animal methods. Within this context, the recovery and subsequent analysis of excreta on a whole-pen basis has been complicated by use of organic bedding materials; therefore, the soiled bedding following the collection period contained organic components from bedding materials, as well as excreta (urine and feces). Generally, these raw manure components had to be separated quantitatively by weighing and analyzing the organic bedding materials prior to the collection period. Subsequently, excreta had to be quantified by differences in DM weights and/or nutrient loads before (bedding alone) and after a 48-h collection period (bedding plus excreta; Hoffman et al., 2007). This approach also requires a dedicated collection pen, which is potentially disruptive to routine day-to-day heifer behaviors.

Our newly constructed (USDA-ARS) research pens located at the University of Wisconsin Marshfield Agricultural Research Station (Marshfield, WI) are equipped with sand-bedded freestalls and offered an opportunity for improvement and refinement of whole-pen methods of excreta collection. Potentially, the primary advantage of the sand-bedded freestall system within small pens (8 heifers/pen) designed for replicated research trials is the absence of organic bedding. Theoretically, sand is entirely recovered as ash following combustion. On this basis, any contamination of the alley manure by sand should be correctable using ash as an internal marker. Another advantage of our updated facilities is the addition of locking headgates along a drive-through feed alley; this additional animal-handling equipment permits quick collection of fecal samples from each heifer within the pen, as well as easy generation of a composite whole-pen fecal sample that is uncontaminated by bedding materials.

In theory, many nutrient concentrations in excreta, such as P or fiber components, can be determined directly (or reasonably approximated) from fecal samples, and then multiplied by the gross excreta weight from each pen to determine specific nutrient loads from a pen of heifers over a 48-h period. This approach also has clear limitations, such as the inability to prevent volatilization of N (Hoffman et al., 2007), thereby necessitating that some potential results be evaluated on an apparent basis. Furthermore, sensitive determination of specific nutrient loads within the excreta, coupled with daily intake measurements, potentially permits calculation of digestibility coefficients. These method refinements are important for researchers lacking facilities for digestibility evaluations within individual animals, and offer the additional benefit of minimal intrusion into normal animal routines. Our objective for this project was to assess the efficacy of these procedural refinements in conjunction with a large-scale production trial evaluating multiple inclusion levels of EGG haylage within the diets of replacement dairy heifers (Coblentz et al., 2012).

METHODS

1. Remove all excreta from pens (1a), and install dividers on gates (1b) to prevent cross contamination of excreta and/or sand from adjacent pens.

2. Disconnect automated alley scrappers, allow manure to accumulate normally for 48 h (2a), and then weigh contents of each pen in a manure spreader fitted with load cells (2b).

3. Discharge (3a), thoroughly mix, and rigorously sample (3b) manure contents from each pen.

4. Obtain daily diet samples and voluntary intakes (whole-pen basis) by heifers (4a), as well as composite fecal samples from each pen (4b).

Calculations

To calculate the amount of excreta within each pen, and to correct for contamination of excreta by sand, ash was used as an internal marker, based on the following series of calculations:

$$SPREADER_{DM} = \text{wet manure recovered (kg)} \times (\%\ DM_{spreader}/100) \text{ (Equation 1)},$$

$$\text{and } SPREADER_{ASH} = SPREADER_{DM} \times (\%\ ASH_{spreader}\ /100) \text{ (Equation 2)}.$$

Within Equations 1 and 2, $SPEADER_{DM}$ and $SPREADER_{ASH}$ are equal to the total respective weights (kg) of DM and ash within each spreader load (pen); similarly, $DM_{spreader}$ and $ASH_{spreader}$ represent laboratory-derived concentrations of DM and ash for each spreader load.

Subsequently, $SPREADER_{ASH}$ can then be set equal to its individual contributions from sand and excreta by:

$$SPREADER_{ASH} = [SAND_{DM} \times (\%\ ASH_{sand}/100)] + [(EXCRETA_{DM}) \times (\%\ ASH_{excreta}/100)] \text{ (Equation 3)},$$

where $SAND_{DM}$ and $EXCRETA_{DM}$ are unknowns and represent the weights (kg) of sand and excreta DM, respectively. In addition, ASH_{sand} and $ASH_{excreta}$ were determined by laboratory analysis and represent respective concentrations of ash within sand bedding and composite fecal samples obtained directly from heifers by rectal palpation.

Equation 3 can be rewritten such that there is only one remaining unknown by substituting $SPREADER_{DM} - SAND_{DM}$ for $EXCRETA_{DM}$, thereby yielding:

$$SPREADER_{ASH} = [SAND_{DM} \times (\%\ ASH_{sand}/100)] + [(SPEADER_{DM} - SAND_{DM}) \times (\%ASH_{excreta}/100)] \text{ (Equation 4)}.$$

After solving Equation 4 for $SAND_{DM}$ (kg), $EXCRETA_{DM}$ (kg) then can be calculated by simple difference ($SPREADER_{DM} - SAND_{DM}$).

Table 1. Whole-pen collection characteristics for heifers consuming diets with serial additions of EGG or limit-fed (LF) a blended alfalfa/corn silage diet. Gross manure wet weights represent 48 h of collection from pens containing 8 dairy heifers.

Treatment	Gross Manure Weight (wet)	$DM_{spreader}$[1]	$SPREADER_{DM}$[2]	$ASH_{spreader}$[3]	$SPREADER_{ASH}$[4]	$ASH_{excreta}$[5]	$SAND_{DM}$[6]	$EXCRETA_{DM}$[7]
	kg	%	kg DM	% of DM	kg	% of DM	-------- kg DM --------	
Diets[8]								
EGG0	863	48.9	442	84.9	385	16.4	383	59
EGG9	851	43.4	400	81.2	341	14.5	338	61
EGG18	981	43.2	492	81.1	430	13.5	430	62
EGG27	762	39.4	306	78.7	246	16.0	241	66
LF	697	43.3	312	82.4	264	18.8	259	54
SEM	179.2	4.33	135.8	3.58	133.2	0.88	135.7	1.6
Contrasts[9]	----------	----------	----------	----------	*P > F*	----------	----------	----------
i	0.416	0.931	0.531	0.829	0.568	0.002	0.564	0.001
ii	0.994	0.187	0.789	0.286	0.767	0.105	0.768	0.036
iii	0.831	0.160	0.613	0.261	0.591	0.584	0.588	0.009
iv	0.572	0.843	0.607	0.855	0.610	0.023	0.603	0.630

[1] $DM_{spreader}$, concentration of DM within each spreader load of manure.

[2] $SPREADER_{DM}$, weight of manure within each spreader load (pen) expressed on a DM basis (kg DM/load).

[3] $ASH_{spreader}$, concentration of ash (% of DM) within each spreader load of manure.

[4] $SPREADER_{ASH}$, weight of ash (kg) within each spreader load (pen) expressed on a DM basis.

[5] $ASH_{excreta}$, concentration of ash (% of DM) determined from composite fecal samples obtained from each heifer within a given pen.

[6] $SAND_{DM}$, weight of sand within each spreader load (pen) expressed on a DM basis (kg DM/load).

[7] $EXCRETA_{DM}$, weight of excreta within each spreader load (pen) expressed on a DM basis (kg DM/load).

[8] Abbreviations: EGG0 = alfalfa haylage/corn silage diet containing no EGG offered for ad-libitum intake; EGG9 = alfalfa haylage/corn silage diet containing 9.2% EGG offered for ad-libitum intake; EGG18 = alfalfa haylage/corn silage diet containing 18.4% EGG offered for ad-libitum intake; EGG27 = alfalfa haylage/corn silage diet containing 27.6% EGG offered for ad-libitum intake; and LF = EGG0 diet offered at 85% of intake for EGG0.

[9] Contrasts: i) all ad-libitum diets (EGG0, EGG9, EGG18, and EGG27) vs. LF; ii) EGG0 vs. all diets containing EGG (EGG9, EGG18, and EGG 27); iii) linear effect of serial addition of EGG; and iv) quadratic effect of serial addition of EGG.

Table 2. Intakes, fecal excretions, and apparent digestibilities determined from whole-pen collections of manure. Intakes and excretions are expressed on a per heifer basis.

Treatment	DM Intake	DM Excretion	DM Digestibility	OM Intake	OM Excretion	OM Digestibility
	kg/day	kg/day	g/kg	kg/day	kg/day	g/kg
Diets[1]						
EGG0	9.67	3.67	619	8.95	3.06	657
EGG9	9.35	3.84	590	8.64	3.27	622
EGG18	9.13	3.84	578	8.43	3.32	605
EGG27	9.33	4.11	559	8.61	3.45	597
LF	8.33	3.37	594	7.71	2.72	645
SEM	0.420	0.098	16.4	0.390	0.084	16.1
Contrasts[2]						
i	0.044	0.001	0.694	0.047	< 0.001	0.184
ii	0.423	0.036	0.037	0.401	0.010	0.021
iii	0.524	0.009	0.019	0.489	0.006	0.018
iv	0.541	0.620	0.775	0.546	0.602	0.412

[1] Abbreviations: EGG0 = alfalfa haylage/corn silage diet containing no EGG offered for ad-libitum intake; EGG9 = alfalfa haylage/corn silage diet containing 9.2% EGG offered for ad-libitum intake; EGG18 = alfalfa haylage/corn silage diet containing 18.4% EGG offered for ad-libitum intake; EGG27 = alfalfa haylage/corn silage diet containing 27.6% EGG offered for ad-libitum intake; and LF = EGG0 diet offered at 85% of intake for EGG0.

[2] Contrasts: i) all ad-libitum diets (EGG0, EGG9, EGG18, and EGG27) vs. LF; ii) EGG0 vs. all diets containing EGG (EGG9, EGG18, and EGG 27); iii) linear effect of serial addition of EGG; and iv) quadratic effect of serial addition of EGG.

CONCLUSIONS

Based on the results of this and several other recent studies, the concept of whole-pen estimates of excreta output appears viable. For the present study, the use of sand-bedded freestalls permitted use of ash as an internal marker to mathematically separate quantities of bedding and excreta within the gross recovery of pen manure. It is unclear whether other procedural adjustments, such as installing bedding mattresses, which potentially reduces or eliminates sand in the recovered manure, could further improve the sensitivity of the excreta output measurement, but this type of option should be considered for future work. Under the conditions described in this study, the practical limitation of this technique is adequate homogenization of sand and excreta within manure samples collected from each pen. We found that homogenization was best facilitated by discharging pen contents through a beater-type manure spreader, and by further mixing with a skid-steer loader. Since all calculations are based on concentrations of ash, rigorous sampling after homogenization is essential.

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