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Herbage selection, intake and digestibility in grazing beef cattle

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The objectives of this study were to measure voluntary herbage intake in kg of dry matter (DM) per day and in proportions of plant species and components (leaf, stem, dead material) of nonlactating Angus cows under grazing conditions and compare DM herbage intakes to intakes of the same cows when they were nursing their calves. Twenty nonlactating Angus cows (50 ± 12 mo of age, 525 ± 55 kg weight) were selected from a larger herd to create 4 groups of 5 cows with average DM intakes that ranged from 11 to 15 kg/d during lactation. The cows were allocated for 28 d as a group on the pasture that contained 5540 kg DM/ha as tall fescue (*Festuca arundinacea*), bermudagrass (*Cynodon dactylon* var. Tifton-85), red clover (*Trifolium pratense*) and other plants. Pasture composition was measured by visual appraisal and manual separation of pasture clippings. Daily allocations provided approximately 2.5 kg DM/100 kg BW. Each cow was individually fed 0.82 kg supplement DM daily that contained 498 mg of the *n*-alkane dotriacontane (C32) and 448 mg hexatriacontane (C36) during the last 14 d. Fecal grab samples were collected from each cow during the last 5 d. Grazing intake (8.92 ± 1.5 kg DM/d) was calculated for each cow from C32 intake and ratios of tritriacontane (C33):C32 in feces and did not differ ($P = 0.97$) among cow groups. Individual cow intakes during lactation and after weaning, during grazing, were not correlated. Measured sward and calculated intake proportions of tall fescue (0.58 and 0.65), bermudagrass (0.38 and 0.33), and red clover (0.02 and 0.01) indicated cows selected slightly more tall fescue and less bermudagrass and red clover than was on offer. Manual separations of sward and calculated intake proportions of dead material and stem (0.89 and 0.95), green leaf (0.10 and 0.02) and other material (0.01 and 0.04) were similar. *N*-alkanes provided credible calculations of intake by grazing cows. Intakes of lactating cows did not predict their intake after weaning.

1. Introduction

Approximately one-half of the energy input for beef production from conception to slaughter is used for maintaining the breeding female (Ferrell and Jenkins, 1982). Improving efficiency of beef production through selection of breeding females requires information on the individual grazing cow's selection of herbage from the sward, voluntary intake, and apparent dry matter (DM) digestibility. Various techniques and approaches have be used to measure these components in grazing situations, including sampling of herbage on offer before and after grazing, internal or external markers, and inference from production parameters, such as weight gain and milk production (Macoon et al., 2003; Undi et al., 2008). Calculated intakes using *n*-alkanes, as internal and external

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markers are not significantly different from measured intakes in cattle fed hay (Unal and Garnsworthy, 1999; Ferreira et al., 2004; Chavez et al., 2011) or intakes determined by other indirect methods with grazing cattle (Undi et al., 2008). Their use as markers provides the opportunity to measure selection, intake, and digestibility in grazing cattle (Molina et al., 2004; Smit et al., 2005; Ferreira et al., 2007).

The objectives of this study were use the *n*-alkane technique to measure voluntary herbage intake in kg of dry matter (DM) per day and in proportions of plant species and components (leaf, stem, dead material) of nonlactating Angus cows under grazing conditions and compare DM herbage intakes to intakes of the same cows when they were nursing their calves.

2. Materials and methods

Procedures were reviewed and approved by the Animal Care and Use Committee of North Carolina State University. The experiments were conducted at the Upper Piedmont Research Station, Reidsville, NC (36°23′16.04″N 79°41′54.54″W).

A study was conducted from January to June 2011 to evaluate DMI of a group of 120 purebred Angus cows averaging 525 kg of BW and 49 months of age during the lactation period. Cows were allocated in pens equipped with electronic recognition Calan doors system (American Calan, Northwood-NH) and received a fescue grass hay-based diet (DM:90%; CP:10%; NDF:52%; TDN:58% and EM:2.09 Mcal/kg DM). The DMI during lactation period was measured as the difference between the fescue hay offered (kg DM/d) and the orts (kg DM/d). From this group, 20 cows were selected to create 4 intake groups of 5 cows ranging from 11 kg to 15 kg of DMI/d. The intake groups formed had the following age, BW and DMI: group 1 (38 months 486 kg; 10.85 kg/d), group 2 (48 months; 514 kg; 12.45 kg/d), group 3 (48 months; 492 kg; 13.14 kg/d) and group 4 (65 months; 608 kg; 15.08 kg/d). During the non-lactation period (from July to August), the group of 20 cows (previously selected during lactation phase) was allocated to graze as a herd for 28 d (14 d on an adaptation field and 14 d on the test field) for alkane DMI evaluation. The mouth, tongue and teeth of the cows were examined to verify absence of injuries or abnormalities. The cows were weighed and body condition score recorded at start and end of the experiment. The test field was 0.68 ha, and visual appraisal of randomly placed 0.25 m^2 quadrats by 3 persons indicated that the composition of the sward was 58% tall fescue (*Festuca arundinacea*), 38% bermudagrass (*Cynodon dactylon* var. Tifton-85), 2% red clover (*Trifolium pratense*) and 2% other plants. Samples from 0.25 m^2 quadrats clipped to the soil surface were collected before the experiment to estimate the 5540 kg of herbage DM/ha of the field.

2.1. Pasture allocation, alkane dosing, and sample collection

Based on the sampling information and on visual characteristics of the test field, daily allocations of field area were calculated to provide 2.5 kg DM/100 kg BW, approximately 12 kg/DM/d for each cow. A temporary electrified fence was used to control access to the allocation, with no restriction to access to areas previously grazed. Water was available ad libitum. Each cow was individually fed 0.82 kg of supplement DM daily. The daily protocol was to separate the cows at 0630 h to allow individual feeding and consumption of supplement, and collection of a fecal sample from each cow. Oliván et al. (2007) found that alkane concentrations in fecal grab samples collected at 0830 h, the time of daily dosing alkanes to cattle, were representative of alkane concentrations in total fecal collections. Fecal samples were collected in aluminum plans, covered with lids, and stored frozen for later analysis. Each day, 2 or 3 quadrats were clipped and collected from the pasture allocation to be provided. Then the electrified fence was moved, and the cows were allowed access to the new allocation at approximately at 0900 h. The following morning, 3 to 4 quadrats were clipped and collected from the same pasture allocation.

Herbage from the quadrats was stored in a refrigerator until samples from each allocation were composited, and then divided into subsamples. The first subsample was analyzed for determination of DM, nutrient composition and alkane composition and the second subsample was manually separated in green leaf, stem, dead material, seed head, and other material. The supplement for each cow contained dotriacontane (C32) and hexatriacontane (C36). The alkanes were dissolved in warm heptane and sprayed on soy hulls as they were turning in a paddle mixer. Alkanes were sprayed on the hulls to provide 1.197 g of C32 and 1.079 g C36/kg soyhulls DM. After drying for several days at room temperature to evaporate the heptane, the soy hulls were mixed 1:1 with ground corn. Each cow received 0.45 kg of that mixture which was hand-mixed with 0.45 kg of pelleted corn-gluten feed before feeding. There were orts in 6 of the 280 supplement feedings; those orts were collected, but later deemed insignificant (they were 50 g or less at collection, which included salivary contamination) and ignored in calculations of intake.

2.2. Sample analysis

Feed, orts, and fecal samples were dried to a constant weight at 55 °C to determine DM content. Analysis for alkane concentrations were done as described by Chavez et al. (2011), except fecal samples were ground through a 1 mm screen instead of a 0.5 mm screen. Feedstuff nutrient content (Table 1) was determined by the samples sent to the North Carolina Department of Agriculture and Consumer Services, Raleigh NC. Herbage and supplement samples were analyzed for analytical DM and ash (methods 930.15; 942.05; Association of Official Analytical Chemists (AOAC), 2006), total N (LECO Trucmac Determinator; LECO Corp., St Joseph, MI), individual minerals (Ca, P, Mg, Cu, Zn) (method 985.01; Association of Official Analytical Chemists (AOAC), 2006), neutral detergent fiber (NDF) and acid detergent fiber (ADF) (Ankon Technology methods 6 and 5; Fairport, NY, solutions as Van Soest et al., 1991).

2.3. Calculations and statistical analyses

Herbage DM intake (DMI) was calculated daily from fecal and supplements concentrations of alkanes using

Table 1
Chemical compositions of supplement offered and pasture clippings before and after grazing during the trial.

Item	g/kg DM								mg/kg DM	
	OM	CP	NDF	ADF	TDN	Ca	P	Mg	Cu	Zn
Pre-grazing	928	112	594	323	655	6	3	2	5	28
Post-grazing	924	113	592	340	525	6	3	2	5	29
Supplement	924	96	380	227	674	16	3	2	5	27

Eq. (1) (Mayes et al., 1986):

$$\text{Daily herbage intake, kg/DM} = \left(\frac{F_i}{F_j} \times (S \times S_j) - S \times S_j\right) - \left(H_i - \frac{F_i}{F_j} \times H_j\right) \quad (1)$$

where F_i is the Fecal odd-chain alkane concentration, mg/kg; F_j is Fecal concentration of even-chain alkane, mg/kg; S is supplement, kg/d; S_j is concentration of even-chain alkane in supplement, mg/kg; S_i is concentration of odd-chain alkane in supplement, mg/kg; H_i is concentration of odd-chain alkane in herbage, mg/kg; H_j is concentration of even-chain alkane in herbage, mg/kg. The measured daily dose of C32 was 504 mg C32/cow and 454 mg C36/cow, which included 6 mg of C32 and 6 mg of C36 in the corn gluten feed pellets. The odd-chain alkanes used for intake calculations were C31 (hentriacontane) and C33 (tritriacontane), because they were present in higher concentrations in the diet. Herbage contained 181.3, 9.7, and 86.2 mg/kg DM of C31, C32, and C33, respectively. The alkane C36 was zero in herbage. Herbage intake was calculated from the content of *n*-alkane pairs C31:C32, C33:C32 and C33:C36 in herbage and fecal samples. Fecal output was calculated as a proportion of ingested C36 that was recovered in feces. Concentrations of heptacosane (C27), octacosane (C28), nonacosane (C29), triacontane (C30), C31, C33 and pentatriacontane (C35) in plant separations and feces (Table 2) were used in the non-negative least squares (NNLS) algorithm described by Dove and Moore (1995) to determine the composition of herbage consumed by each cow. Two simulations using the NNLS procedure were done to estimate the botanical composition based on plant species and parts of plants (leaf, stem, dead or senescent material and others) for the different intake groups. For all approaches the NNLS analysis included fecal concentrations of C29, C28, C29, C30, C31, C32, C33, and C35. Zero alkanes were entered in the algorithm as zero. Indigestibility of alkanes C31 or less was estimated as 0.93, indigestibility of C32 and C33 was estimated at 0.93, and indigestibility of C35 was estimated at 0.95. Differences among cows in fecal alkane ratios and NNLS predictions were detected in a one-way analysis of variance using daily fecal samples within cows as the error term and Duncan's test if $P < 0.15$.

Alkane and pellet composition, fecal concentration, body traits and intake within groups were statistically analyzed according to a completely randomized design, applying the Duncan test for means comparison when means differed ($P < 0.05$). The effect of sampling day on fecal concentrations of alkanes was tested with the PROC GLM procedure of SAS in a model that had day and cow as main effects tested against residual mean squares. Sample days were averaged within cows and fecal alkane concentrations, intake, and digestion dependent variables were tested with the PROC GLM procedure of SAS in a model that contained cow and intake group as main effects tested against residual mean squares. Paired-t comparisons within alkane ratios measured intake during lactation and herbage intake were made to determine if the difference between measured and estimated variables differed from zero. Pearson correlations were applied to determine correlations among the parameters evaluated.

Table 2
N-alkane concentrations (mg/kg DM) in herbage, feces and botanical separations.

Composition	*N*-alkane[a] (mg/kg DM)								
	C27	C28	C29	C30	C31	C32	C33	C35	C36
Herbage	28	13	65	16	181	10	86	12	ND[b]
Feces	27	6	103	22	309	127	161	28	103
Botanical separation (components and plant species)									
Leaf	13	2	38	12	204	5.6	70	ND	ND
Stem	10	4	23	4	62	2.4	43	6	ND
Dead	14	3	56	11	173	9.2	81	7	ND
Other[b]	133	20	164	27	324	ND	287	65	ND
Fescue stem	ND	ND	30	ND	99	ND	32	ND	ND
Fescue leaf	8	ND	49	11	233	ND	42	ND	ND
Clover leaf	7	ND	46	ND	74	ND	9	ND	ND
BG leaf	11	7	37	ND	46	ND	32	9	ND
Clover stem	9	ND	61	ND	46	ND	ND	ND	ND
BG stem	ND	ND	19	ND	35	ND	51	26	ND
Clover seed	55	27	320	53	607	26	69	ND	ND
BG seed	259	29	222	33	393	34	446	124	ND

[a] Heptacosane (C27), octacoxane (C28), nonacosane (C29), triacontane (C30), hentriacontane (C31), dotriahexatriacontane (C32), tritriacontane (C33), and hexatriacontane (C36).
[b] Inflorescence, weeds, etc; 3 ND=not detected.

3. Results

Over the 14 d of trial, there were no supplement refusals, except for two cows whose refusals were less than 2% (20 g) of supplement offered. One cow had minor foot injuries, but no significant variations were observed in her data.

3.1. Alkane concentrations and intake calculations

Herbage DMI calculated from fecal ratios of C31/C32, C33/C32, and C33/C36 (Table 3) differed ($P < 0.01$) from each other. In our study, we assumed similar recoveries of alkane pairs (Table 3); a lesser fecal recovery of C31 vs. C32 or C33 vs. C36 would reduce the calculated DMI, and a greater recovery of C33 vs. C32 would increase calculated DMI. For purposes of calculating apparent digestibility, DMI of plant parts or herbage separations, DMI as a proportion of BW, or comparison of intake to nutrient requirements, we used the average calculated DMI of the 3-alkane pairs (Table 3). There was no difference ($P > 0.05$) in herbage DMI among groups, indicating that DMI measured in electronic gates during lactation did not correlate with grazing intakes after weaning. Comparison of calculated intake of CP, TDN, Ca, and P to

Table 3
Dry matter intake (supplement, herbage, herbage proportions) and digestibility measured in beef cows from different intake groups during the grazing period.

Items	Intake group				SE	P=
	1	2	3	4		
Herbage intake (kg DM/d)						
C31/C32 alkane ratio	8.07	7.83	8.09	7.88	0.5	0.98
C33/C32 alkane ratio	8.79	8.87	8.8	9.21	0.66	0.97
C33/C36 alkane ratio	8.50	8.33	8.45	8.68	0.61	0.98
Average of alkane ratios	8.45	8.34	8.44	8.59	0.59	0.99
Herbage intake (g DM/kg BW)	17.3	16.3	17.1	14.3	0.09	0.09
Supplement intake (kg DM/d)	0.82	0.82	0.82	0.82		
Herbage plus supplement (kg DM/d)	9.27	9.16	9.26	9.71	0.58	0.99
Herbage plus supplement (g/kg BW)	19.0	17.9	18.8	15.7	0.09	0.06
Digestibility (g/g of DM)	0.497	0.517	0.517	0.496	0.019	0.76
Digestible DMI (kg/d)	4.63	4.74	4.77	4.68	0.33	0.99
Herbage proportions (kg/kg DM[1])						
Leaf	0.010	0.013	0.072	0.002	0.011	0.01
Stem	0.257	0.372	0.278	0.437	0.058	0.14
Dead	0.712	0.586	0.583	0.535	0.061	0.25
Other	0.020	0.030	0.067	0.026	0.025	0.56
Herbage proportions (kg/kg DM[2])						
Fescue leaf	0.096	0.089	0.172	0.072	0.022	0.02
Fescue stem	0.598	0.569	0.48	0.561	0.022	0.01
BG leaf	0.010	0.022	0.015	0.003	0.008	0.36
BG stem	0.254	0.269	0.277	0.27	0.016	0.78
BG seedhead	0.037	0.042	0.045	0.064	0.011	0.38
Clover stem	0.003	0	0	0	0.001	0.47
Clover seedhead	0.004	0.008	0.011	0.030	0.014	0.55

Table 4
Fecal concentration of alkane[a] (mg/kg DM) in the feces of beef cows from different intake groups during the grazing period.

Items	Intake group				SE	P=
	1	2	3	4		
C27	25.0	27.6	29.5	27.0	2.4	0.63
C28	2.8	7.4	8.6	5.4	1.9	0.33
C29	102.9	105.5	104.4	99.2	3.3	0.58
C30	20.8	22.1	23.8	21.6	1.6	0.62
C31	310.0	307.8	326.2	293.1	11	0.25
C32	127.1	127.5	131.9	121.2	7.8	0.81
C33	158	162.5	164.4	159.2	4.4	0.73
C35	25.8	28.4	28.3	29.1	1.7	0.56
C36	102	106.9	105.4	98.4	7.6	0.86

[a] Heptacosane (C27), octacoxane (C28), nonacosane (C29), triacontane (C30), hentriacontane (C31), dotriahexatriacontane (C32), tritriacontane (C33), and hexatriacontane (C36); 2-Fecal alkane concentrations adjusted for indigestibility: 0.9 (C27, C28, C29, C30); 0.93 (C31, C33); 0.95 (C35).

the cow's requirements for maintenance (Table 5) indicated that the calculated intake was more than adequate to meet requirements, and provide nutrients to support weight gain.

The visual plant species evaluation presented the following botanical composition: 58% tall fescue; 38% bermudagrass; 2% red clover and 2% others. Manual separation of pasture samples showed the DM of pasture on offer was 89% stem or senescent material (mostly tall fescue and bermudagrass stem), 10% green leaf, and 1% other material.

Concentration of C31 was relatively low in stem, greater in leaf and dead and, greatest in other portion (Table 2). Concentrations of C27, C29 and C35 were relatively greater in the classification 'other' than in the other types of separation. The alkane C35 was zero in leaf or stem separations. Concentration of C28 was greatest in stem and other, and zero in leaf. Among plants species and components, concentrations of C31 were greatest in clover and bermudagrass seedhead, followed by tall fescue leaf and stem (Table 2).

Concentrations of C27, C28 and C30 were low or zero in all components except bermudagrass and clover seedhead. Concentrations of C33 were relatively low in clover leaf and seedhead, medium in fescue and bermudagrass leaf and stem, greatest in bermudagrass seedhead. The alkane C35 was found only in bermudagrass components. The alkane C34 (data not shown) was zero in analysis of plant separations or components, and was used as a recovery standard in analysis.

Fecal alkane ratios that differed among cows were 27/29 ($P<0.10$), 27/31 ($P<0.12$), 27/35 ($P<0.08$), 29/31 ($P<0.01$), 29/33 ($P<0.14$), 29/35 ($P<0.01$), 31/33 ($P<0.01$), and 31/35 ($P<$ 0.01). Therefore, the most important determinants of differences among cows in predicted intake of plant separations or components are sources of C31 (fescue plant, leaves and stems, bermudagrass seedhead, red clover seedhead, and the herbage separation other) and C33 and C35 (bermudagrass seedhead and the herbage separation other). Red clover and bermudagrass seedhead are very high in C31, but contributed very little to the amount of kg DM on offer. The relatively low concentrations of C27, C28 and C30 and the fact that C35 was found only bermudagrass (Table 2) precluded use of these alkanes for intake calculations; however, the variation among plant separations and plant components enhanced the capacity of the NNLS to predict composition of

Table 5
Daily nutrient of the beef cows during the grazing period and total requirements for maintenance according to NRC (1996).

Item	Intake group			
	1	2	3	4
Supplement intake (kg DM/d)	0.82	0.82	0.82	0.82
CP (g)	108.00	108.00	108.00	108.00
TDN (g)	553.00	553.00	553.00	553.00
Ca (g)	13.00	13.00	13.00	13.00
P (g)	7.00	7.00	7.00	7.00
Grazing intake (kg DM/d)	8.79	8.87	8.86	9.25
CP (g)	984.00	994.00	993.00	1036.00
TDN (kg)	5.76	5.81	5.80	6.06
Ca (g)	53.00	53.00	53.00	56.00
P (g)	26.00	27.00	27.00	28.00
Total intake (kg DM/d)				
CP (kg)	1.09	1.10	1.10	1.14
TDN (kg)	6.31	6.36	6.35	6.61
Ca (g)	66.00	66.00	66.00	69.00
P (g)	33.00	34.00	34.00	35.00
Total/NRC (1996) requirements for maintenance				
CP (g)	1.77	1.79	1.78	1.85
TDN (g)	1.42	1.43	1.43	1.49
Ca (g)	4.39	4.42	4.42	4.57
P (g)	2.79	2.81	2.81	2.91

ingested herbage. The only NNLS predictions of plant components that differed ($P \leq 0.15$, this criterion was used to reduce probability of type 2 error) among cows were fescue leaf ($P < 0.02$). Herbage separations that differed ($P \leq 0.15$) among cows were leaf ($P < 0.05$), stem ($P < 0.07$) and dead material ($P < 0.04$). Herbage DMI differed ($P < 0.01$) among cows, as did intake of fescue leaf, fescue stem, bermudagrass stem ($P < 0.02$), and intake of leaf ($P < 0.06$) and stem ($P < 0.03$). Duncan's means separations ($P \leq 0.15$) partitioned the differences among cows into 6 to 9 groups, except for leaf or 'other' intake, which were separated into 2 groups. Six of the 20 cows were identified as members the group with the lowest or greatest value for a given intake response; cow A069 had the greatest herbage DMI, and the greatest intake of fescue stem and dead material from the mixed herbage. Cow W084 the greatest intake of Ffescue leaf or leaf from the mixed herbage, and the least intake of bermudagrass stem or stem from the mixed herbage. Cow A043 had the greatest intake of 'other' and the least intake of dead material from the mixed herbage. Three other cows had the least herbage DMI (cow W009), least fescue leaf intake (cow A016) or greatest intake of bermudagrass stem (Cow 7121). With exception of cow 7121, these cows were younger and weighed less the average for the herd. Correlations of cow physical traits and intake variables indicated that cow BW was positively correlated with age ($r=0.71$, $P < 0.05$), BCS ($r=0.78$, $P=0.05$), electronic gate intake ($r=0.59$, $P < 0.05$), grazing intake ($r=0.41$, $P=.10$), fescue stem ($r=0.46$, $P < 0.05$), bermudagrass stem ($r=0.44$, $P=0.10$) and stem from mixed herbage intake ($r=0.72$. $P < 0.05$) and negatively correlated with fescue leaf ($r=-0.38$, $P=0.10$) and Leaf ($r=-0.42$, $P=0.10$) intake. Fecal concentrations of alkanes from plant sources or supplement (C32 and C36) did not differ ($P > 0.05$) among cow groups; overall means are in Table 4. There was no effect of intake groups ($P=0.22$), sampling day ($P=0.07$) or the interaction intake group $\times$ sampling day ($P=0.55$) on recovery of C34 as an internal standard. Recovery of C34 added at the beginning of chemical analysis for alkanes ranged from 84% to 88%.

3.2. Comparison of methods to estimate grazing intake

The disappeared herbage DM (pre minus post-grazing data from clipped quadrats) for the last 8 d of evaluation was 9.7 kg of DM/cow/d, which was greater than intake measured by alkane concentrations (Table 3). As stated before, for accurate DMI estimations using the *n*-alkane technique, the natural and dosed *n*-alkane must show similar fecal recoveries. In our study, the best correlation between measured (intake during lactation) and estimated intake was obtained with the alkane ratio C33/C32 ($r=0.10$) and a consistent ratio of dosed to natural alkanes in feces for the intake groups (data not shown) with lower discrepancy between maximum and minimum values. The C31/C32 estimator also presented a lower CV (coefficient of variation), but the correlation with measured intake was low (0.03). The total DMI in pasture (herbage plus supplement) estimated by the C33/C32 alkane ratio was an average of 9.7 kg/d.

4. Discussion

4.1. Alkane concentrations and intake calculations

Smit et al. (2005) likewise found differences in DMI calculated with C31/C32 vs. C33/32 fecal alkane ratios in grazing, lactating dairy cows, but intakes calculated with C31/C32 or C33/C32 ratios were similar in lactating cows fed freshly-cut herbage (Molina et al., 2004). They also found DMI calculated from pre- and post-grazing sward clippings and intake calculated from milk production and NEl was similar to intake calculated with C33/C32 fecal ratios in one year's data and similar to C31/C32 in another year. In general, indigestibility, or fecal recovery, of alkanes increases with chain length (Mayes et al., 1986; Oliván et al., 2007); for intake calculations, it is important that the even and odd-chain alkanes used in the calculation have known and (or) similar fecal recoveries and pattern of excretion (Oliván et al., 2007). Thus, the errors associated with incomplete fecal recoveries will be accounted for, or cancelled out, in the equation used to estimate intake (Ferreira et al., 2004).

Vance et al. (2012) compared intake of lactating dairy cows using electronic gate system and grazing conditions. The heavier cows ate more from the electronic gates than lighter cows, but grazing intake was similar for all cows. The authors concluded that cows fed via electronic gate system are likely to have an increased rate of eating, probably caused by the constant feed offering in a restricted allowance space. The patterns of alkane concentration for plant components (Table 2) were similar to those previously reported (Dove and Mayes, 1996; Dove et al., 1996; Bugalho et al., 2004). However, our study provides additional information on the alkane concentration for separation of herbage on offer into leaf, stem, senescent material (dead) and other. Odd-chain alkanes represented more than 90% of the total alkanes (Table 2). Dove et al. (1996) and Laredo et al. (1991) found that plant species accounted for from 80 to 85% of the variation in alkane concentrations among plant parts.

4.2. Comparison of methods to estimate grazing intake

The method used for DM disappearance may have overestimated DMI because herbage was clipped to the ground in quadrats for both pre and post grazing samples. The calculations of disappeared DM considered that all the content inside the square was offered (on pre grazing samples) and the difference, considered as the consumed. However, the material consumed by the cows was not similar as the sampled, because the post-grazing material (mostly dead material) may have had a higher DM content than herbage actually consumed.

Smit et al. (2005) evaluated grazed dairy cows on individual swards of perennial ryegrass and compared DMI estimated from sward cuttings, from net energy requirements and milk yield and from alkanes dosed twice daily for two years. Year one DMI across methods ranged from 16.2 to 18.2 kg/d and the range among methods was 12% of the mean. Year 2 DMI ranged from 15.3 to 18.6 kg/d and the range among methods was 19% of the mean. In year one, the ranking of intake methods was C31/C32 > sward cuttings = C33/C32 = NE calculation. In year 2, the ranking was sward cutting = 31/32 > 33/32 > net energy calculations, indicating that time (year) affected the comparison of methods.

Moore (1996) recommended that for individual intake estimations, the techniques based on the use of markers are suitable for estimates of intake by individual animals. For groups of animals or pasture the predictions based on disappearance of herbage mass are more appropriate.

Chaves et al. (2006) found that intake in 10 grazing heifers from calculated from the fecal C31/C32 alkane ratio was less than DMI predicted by an equation using forage composition and animal requirements. Based on response to treatments in the experiment, the authors concluded that fecal C31/C32 alkane ratio underestimated intake. Undi et al. (2008) compared DMI of grazing steers over 3 yr and found that DM intake measured by C31/C32 fecal alkane ratio was less than DM intake predicted by an equation using BW and weight gain and greater than DM intake predicted by an equation using W0.75 and NEm. All of these methods predicted DMI that were appreciably less than DMI measured by sward clippings inside and outside of protected cages in the pasture.

Kosloski et al. (2014) reported higher ruminal DM digestibility for C32 and C33 *n*-alkanes than acid detergent fiber and sulfuric acid detergent lignin methods. Mann and Stewart (2003) calculated DMI from fecal C33/C32 concentrations and concluded that in the morning fecal samples the actual intake was underestimated by 11% (5.61 kg), while herbage intake calculated from alkane concentrations in the afternoon fecal samples overestimated actual intake by 8% (6.81 kg).

Despite the diurnal variation on alkane pattern, these authors found similar values for actual intake (6.28 kg), (measured by electronic gates) and herbage intake estimated by the alkane ratio C33/C32 (6.81 kg).

Our study aimed determine whether or not DMI measured intake by electronic gates can be extrapolated for grazing conditions, at least to rank individual intake of cows grazing as a herd. Cows selected for the study were in the final of lactation curve (in the pre-weaning phase) during the electronic gate evaluation, thus, the energy requirements expended in this phase likely influenced DMI.

5. Conclusions

Individual intake of cows during lactation did not predict grazing intake of cows post-weaning. The proportions of grass species and anatomical components of herbage on offer from pasture clippings agreed well with proportional intake of those components predicted by herbage and fecal concentrations of *n*-alkanes. Concentrations of *n*-alkanes in pasture clippings and feces predicted differences among individual cow's selection of grass species and anatomical components of herbage on offer.

Conflicts of interest statement

None.

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