DIETARY AND FECAL CONCENTRATIONS OF NITROGEN AND PHOSPHORUS IN PENNED WHITE-TAILED DEER DOES

LARRY D. HOWERY,[1] Department of Range and Wildlife Management, Texas Tech University, Lubbock, TX 79409
JAMES A. PFISTER, U.S. Department of Agriculture, Agricultural Research Service, Poisonous Plant Laboratory, Logan, UT 84321

Abstract: We evaluated fecal nitrogen (FN) and fecal phosphorus (FP) concentrations as indicators of different dietary nitrogen (DN) and dietary phosphorus (DP) levels fed to 11 penned, white-tailed deer does (*Odocoileus virginianus*) during summer 1985. We fed deer pelleted rations containing 2 levels of DN (2.64 and 1.18%) or DP (0.49 and 0.30%) during 2 consecutive, 16-day trials. We collected fecal pellets from each animal during the last 6 days of each trial. Pooled mean FN concentrations for corresponding high and low DN levels were as follows: total FN = 2.26 and 1.45% ($P = 0.003$), neutral detergent FN = 0.60 and 0.39% ($P = 0.019$), and metabolic FN = 1.67 and 1.06% ($P = 0.001$). Pooled mean FP concentrations for corresponding high and medium DP levels were as follows: total FP = 1.23 and 0.44% ($P = 0.002$), neutral detergent FP = 0.12 and 0.10% ($P = 0.022$), and endogenous FP = 1.11 and 0.33% ($P = 0.002$). Under controlled conditions FN and FP concentrations can be used to discern relatively large differences in DN and DP levels of white-tailed deer.

J. WILDL. MANAGE. 54(3):383–389

Nutrient levels of hand-collected forages have been used as indicators of dietary quality (Cook 1964), but this is generally an unreliable method for determining diet quality of free-ranging ungulates (Theurer et al. 1976) due to the apparent ability of ungulates to select the most nutritious forage available (Swift 1948). Esophageal fistulization is usually impractical for studying diet quality of free-ranging wild ungulates (Leslie and Starkey 1985) and, moreover, is unsuitable for DP assessment due to salivary phosphorus (P) contamination (Holechek et al. 1985). Blood samples require manual restraint or death of animals and, given the complex effects of homeostatic regulation of mineral metabolism, blood P concentrations may not be sufficiently sensitive to assess P status (Underwood 1981). The use of fecal nutrient levels to study diet quality may be a feasible noninvasive alternative to other techniques that require disturbance, stress, or death of wild ungulates (Leslie and Starkey 1985).

Researchers have used fecal nutrient levels to predict dietary nutrient levels in elk (*Cervus elaphus*) (Mould and Robbins 1981, Leslie and Starkey 1985), black-tailed deer (*Odocoileus hemionus columbianus*) (Leslie and Starkey 1985, Mubanga et al. 1985), white-tailed deer (Jenks et al. 1989, Leslie et al. 1989), moose (*Alces alces*) (Leslie et al. 1989), and domestic livestock (Belonje and Van den Berg 1980*a*,*b*; Holechek et al. 1982, 1985). The advantages (Leslie and Starkey 1987) and disadvantages (Hobbs 1987) of FN as an indicator of DN in free-ranging deer diets have been discussed, but little controlled research has been conducted to determine the utility of using fecal indices for nutrient assessment of wild ungulate diets, particularly for white-tailed deer. Leslie and Starkey (1987) argued for continued research toward refining the use of fecal indices to measure the quality of wild ungulate diets. We conducted a controlled study involving 2 consecutive feeding trials to determine whether FN and FP concentrations could be used to detect differences in DN and DP levels fed to penned, white-tailed deer does.

We thank C. Schreiner IV and the Y. O. Ranch employees of Mountain Home, Texas, for their kindness, cooperation, and generous use of study pens and other facilities. Critically constructive comments on the manuscript were provided by T. J. DeLiberto, S. Demarais, and F. C. Bryant. We are grateful to E. A. Howery for assistance with data collection and tabulation and to G. R. Scott and N. C. Jordan for lab assistance. Financial support was provided by the Caesar Kleberg Foundation for Wildlife Conservation and Texas Tech University. This is publication T-9-577 of The College of Agricultural Sciences, Texas Tech University, Lubbock.

[1] Present address: Range Science Department, Utah State University, Logan, UT 84322-5230.

METHODS

Trial 1

The study was conducted during summer 1985 in the Edwards Plateau Region of Texas (McMahan et al. 1984) on the Y. O. Ranch, Kerr County. We immobilized 12 female white-tailed deer (≥2 yr old) using powdered succinycholine chloride in a powder-charged dart gun (Liscinsky et al. 1969). Each deer received a color-coded ear tag for individual identification within the study pens and was treated with an insecticide to control ectoparasites; the dart wound was sprayed with a bactericide to prevent infection. We transported the animals to 4 adjacent study pens (70 × 30 m) and released them until there were 3 deer per pen. Each study pen contained a concrete building and tree canopy for shelter and shade. We offered a diet of alfalfa pellets ad libitum containing 2.64% N (16.5% crude protein) immediately after capture. All pelleted diets offered during this experiment were formulated by P & M Products Inc., San Antonio, Texas. Water also was provided ad libitum.

We fed deer daily at 0800 hours, and we observed them at least 6 hours per day for at least 18 days to accustom them to captivity, the pelleted diet, and the presence of the observer. We calculated daily ad libitum intake (kg/pen/day) by subtracting the mass of orts from the mass of feed offered on the previous day. Average intake (kg/pen/day) was determined during the adaptation period for each pen. This amount, plus 1 kg, was offered initially during the experimental trial. We analyzed experimental diets for (1) percent N (crude protein), Ca, P, and Mg (Horwitz 1980), (2) percent in vitro digestibility (Tilley and Terry 1963) using rumen inoculum from a Holstein steer fed alfalfa hay, and (3) percent fiber content (Goering and Van Soest 1970).

Trial 1 took place from 18 June to 3 July. We randomly selected 2 pens and fed deer high concentrations of DN (2.64% N or 16.5% crude protein), while deer in the other 2 pens were fed low concentrations of DN (1.18% N or 7.4% crude protein). Daily intake (kg/pen/day) was recorded as described above, and the feed offered was adjusted to ensure that animals received ad libitum intake each day. Deer adapted to the experimental diet during Days 1–10 of the trial. On Days 11, 13, and 15, each deer receiving high concentrations of DN was observed with binoculars until it defecated, after which fecal pellets were immediately collected in individual plastic bags and frozen at −20 C for later analyses. On Days 12, 14, and 16, each deer receiving low concentrations of DN underwent identical observation and fecal collection procedures. We collected at least 15 fecal pellets from the middle of the pellet group to avoid soil contamination.

We examined each fecal pellet included in the analyses under a 10× dissecting scope for soil particles which, if detected, were removed with a scalpel. Individual fecal samples from each deer were freeze-dried, ground to pass through a 1-mm screen, and analyzed for percent total FN content using the Kjeldahl method (Horwitz 1980). Neutral detergent extraction was used to isolate undigested fecal material of dietary origin (Mason 1971, Van Soest 1982). The neutral detergent fecal residue, termed neutral detergent FN, was analyzed for percent N using the Kjeldahl method (Horwitz 1980). Assuming that the metabolic fraction of fecal material was dissolved by the neutral detergent reagent, metabolic FN was calculated as the difference between total FN and neutral detergent FN (Van Soest 1982).

Our study design was unbalanced. One deer died before Trial 1 was underway and was not replaced. Fawning took place during Trial 1; consequently, deer were in 3 physiological conditions (nonpregnant, pregnant, and lactating) during both trials. Fawning (with 1 exception) occurred during adaptation periods; 1 deer fed low DN fawned immediately after the first fecal collection period and was not included in the analysis thereafter.

All data were converted to percent dry mass for statistical analyses. We analyzed data in a 2 × 3 × 3 factorial arrangement of a split-plot design with repeated measures with a general linear model for unbalanced data (SAS Inst., Inc. 1985). Diet, physiological condition, and fecal collection period were factors, and FN parameters (i.e., total FN, neutral detergent FN, and metabolic FN) were independent variables. Each pen represented 1 replication of DN level, thus, there were 2 replications of both experimental diets. Pen was nested within physiological condition and diet to test diet and physiological conditions effects and to test the diet × physiological condition interaction. Pen and fecal collection period were nested within physiological condition and diet to test period effects and

the interaction terms. If the F-test was significant at $P = 0.05$, multiple comparisons were made with the protected least significant difference (LSD) procedure.

Trial 2

Trial 2 took place from 3 July to 18 July, and methods were similar to Trial 1 with the following exceptions. Deer in 2 randomly-selected pens were fed high concentrations of DP (0.49%) while deer in the other 2 pens received medium concentrations of DP (0.30%). We refer to the above diets as high and medium DP only for purposes of experimental description, because precise DP requirements for deer are unknown (Davis and Johnson 1984). We analyzed individual deer samples of freeze-dried, ground fecal material for percent total FP content (Horwitz 1980). Neutral detergent extraction was used to isolate undigested fecal material of dietary origin (Van Soest 1982), and this residue, termed neutral detergent FP, was analyzed for percent P content (Horwitz 1980). Endogenous FP was calculated as the difference between total FP and neutral detergent FP (Van Soest 1982). Fecal phosphorus parameters were converted to a percent dry mass basis (i.e., total FP, neutral detergent FP, and endogenous FP) and analyzed as independent variables.

RESULTS

Trial 1.—Chemical analyses indicated that both diets fed during Trial 1 contained reasonably adequate nutrient levels given the short duration of this experiment except for the N concentration of low DN, the factor of primary interest for this trial (Table 1). We estimated individual intake (kg dry mass/deer/day) to be 1.32 and 1.15 kg for high and low DN, respectively.

Deer fed high concentrations of DN excreted higher total FN ($P = 0.003$) and neutral detergent FN ($P = 0.019$) concentrations than deer offered low concentrations of DN (Table 2). Total FN concentrations by deer fed high concentrations of DN ranged from 2.08 to 2.48%, compared to 1.31–1.62% by deer fed low DN. Mean neutral detergent FN concentrations by deer fed corresponding diets ranged from 0.49 to 0.66 and 0.27 to 0.51%, respectively. Total FN and neutral detergent FN concentrations were influenced by diet alone and were independent of fecal collection period ($P = 0.253$), physiological condition ($P = 0.189$), and interactions ($P = 0.312$).

Table 1. Chemical analyses of experimental diets fed to penned, white-tailed deer does (≥2 yr old), Y. O. Ranch, Texas, 1985.

Assay[c]	Diet[a,b] HDN	LDN	HDP	MDP
CP	16.52	7.39	16.79	16.78
P	0.53	0.18	0.49	0.30
Ca	1.39	0.23	1.02	1.38
Mg	0.19	0.09	0.15	0.15
NDF	41.37	52.69	47.40	50.38
ADF	36.98	36.14	38.39	38.08
IVD	66.96	55.19	55.76	57.05
Ca:P	2.62:1	1.28:1	2.08:1	4.60:1

[a] Percentage of dry mass.
[b] HDN = high dietary nitrogen (2.64%), LDN = low dietary nitrogen (1.18%), HDP = high dietary phosphorus, MDP = medium dietary phosphorus.
[c] CP = crude protein, P = phosphorus, Ca = calcium, Mg = magnesium, NDF = neutral detergent fiber, ADF = acid detergent fiber, IVD = in vitro digestibility.

Metabolic FN excretion was influenced both by diet ($P = 0.001$) and physiological condition ($P = 0.024$) within diets but was not dependent on fecal collection period ($P = 0.954$). Metabolic FN concentrations by deer fed high DN ranged from 1.46 to 1.89%, compared to 0.93–1.22% by deer fed low DN. Nonpregnant, pregnant, and lactating does fed high concentrations of DN excreted different metabolic FN concentrations ($P < 0.05$). Pregnant does receiving low concentrations of DN excreted less metabolic FN ($P < 0.05$) than lactating does on low concentrations of DN. There were no nonpregnant does that received low concentrations of DN for comparison.

Trial 2.—Chemical analyses revealed that both diets fed during Trial 2 were comparable for every dietary variable measured except DP, the factor of primary interest for this trial (Table 1). We estimated individual intake (kg dry mass/deer/day) to be 1.65 and 1.64 kg for high and medium DP, respectively.

Deer fed high concentrations of DP excreted higher total FP ($P = 0.002$) and endogenous FP ($P = 0.002$) concentrations than deer offered medium concentrations of DP (Table 3). Total FP concentration by deer fed high concentrations of DP ranged from 0.95 to 1.65%, compared to 0.32–0.69% by deer fed medium concentrations of DP. Mean endogenous FP concentrations by deer fed corresponding diets ranged from 0.84 to 1.40% and 0.19 to 0.50%, respectively. Total FP and endogenous FP con-

Table 2. Mean fecal nitrogen (FN) concentrations (% dry mass) of penned white-tailed deer does (≥2 yr old) fed high and low dietary nitrogen (DN) levels (Trial 1), Y. O. Ranch, Texas, 1985.

Diet[b] and item[c]	Pooled			Physiological condition: Nonpregnant[a]			Pregnant			Lactating		
	$\bar{x}$	SE	n	$\bar{x}$	SE	n	$\bar{x}$	SE	n	$\bar{x}$	SE	n
High DN												
TFN	2.26	0.03	15	2.25	0.05	6	2.17	0.02	3	2.32	0.06	6
NDFN	0.60	0.01	15	0.58	0.02	6	0.63	0.02	3	0.60	0.01	6
MFN[d]	1.67	0.02	15	1.67A	0.04	6	1.54B	0.007	3	1.72C	0.06	6
Low DN												
TFN	1.45	0.03	16				1.44	0.02	13	1.52	0.04	3
NDFN	0.39	0.01	16				0.40	0.01	13	0.35	0.04	3
MFN[d]	1.06	0.02	16				1.04D	0.02	13	1.17E	0.03	3

[a] There were no nonpregnant does fed LDN.
[b] Means involving DN main effects were different ($P \leq 0.019$) for TFN, NDFN, and MFN.
[c] High DN = high dietary nitrogen (2.64% DN = 16% crude protein), low DN = low dietary nitrogen (1.18% DN = 7% crude protein), TFN = total fecal nitrogen, NDFN = neutral detergent fecal nitrogen, MFN = metabolic fecal nitrogen.
[d] Means involving physiological condition main effects were different ($P = 0.024$) for MFN. Means with different letters within rows and columns of MFN are different ($P < 0.05$, least significant difference test) for all possible comparisons.

centrations were influenced by diet alone and were independent of fecal collection period ($P = 0.140$), physiological condition ($P = 0.473$), and interactions ($P = 0.140$).

Neutral detergent FP excretion was influenced by diet ($P = 0.022$); however, there was also a diet × physiological condition interaction ($P = 0.012$). Neutral detergent FP concentrations by deer fed high DP ranged from 0.06 to 0.20%, compared to 0.06–0.19% by deer fed medium DP. Neutral detergent FP concentrations were different ($P < 0.05$) between pregnant does fed high and medium concentrations of DP. However, there was no difference ($P > 0.05$) in neutral detergent FP excretion between nonpregnant or lactating does regardless of diet.

DISCUSSION

Trial 1

Total FN and neutral detergent FN concentrations were highly dependent on DN levels fed to deer. White-tailed deer maintained a relatively consistent FN excretion within diets regardless of physiological and temporal conditions. Other researchers have shown correlations between DN and FN levels for domestic (Holechek et al. 1982) and African (Arman et al. 1975) ungulates, and for elk and black-tailed deer (Mould and Robbins 1981, Leslie and Starkey 1985, Mubanga et al. 1985).

Verme and Ullrey (1972) stated that 16–17% dietary crude protein (2.6% DN) would satisfy the maximum needs of growing fawns and lactating does; 7% dietary crude protein (0.9–1.0% DN) has been suggested as the minimum level necessary to prevent impairment of deer rumen function (Dietz 1965). Because we estimated intake on both DN treatments to be >1 kg dry mass per deer per day, deer fed low DN apparently did not respond to a DN deficiency by decreasing intake and may have instead compensated for a short-term DN deficiency by recycling urea N (Van Soest 1982).

Forages containing soluble digestion inhibitors such as phenolics (e.g., tannins) can adversely affect FN correlations (Robbins et al. 1987*a*). This relationship is complex but is apparently due to precipitation of plant and microbial proteins and gastrointestinal enzymes in the gut and to reduction of apparent digestibilities of protein and cell solubles (Mould and Robbins 1981, Robbins et al. 1987*b*). Thus, deer that consume forage containing low DN levels and high phenolic levels may excrete relatively high total FN levels (Nelson et al. 1982) which could lead researchers to overestimate DN when using total FN under field conditions. The phenolic content of the pellets we used was unknown. Holechek et al. (1982) suggested that neutral detergent extraction may remove phenolic compounds from fecal material. Consequently, neutral detergent FN may more accurately reflect DN content under field conditions than either total FN or metabolic FN. In our study, neutral detergent FN concentration was independent of either physiological condition or fecal collection period and was influenced only by DN content.

Metabolic FN was sensitive to differences in

Table 3. Mean fecal phosphorus (FP) concentrations (% dry mass) of penned white-tailed deer does (≥2 yr old) fed high and medium dietary phosphorus (DP) levels (Trial 2), Y. O. Ranch, Texas, 1985.

Diet[a] and item[b]	Pooled			Physiological condition: Nonpregnant			Pregnant			Lactating		
	$\bar{x}$	SE	n	$\bar{x}$	SE	n	$\bar{x}$	SE	n	$\bar{x}$	SE	n
High DP												
TFP	1.23	0.04	18	1.31	0.17	3	1.26	0.05	11	1.06	0.02	4
NDFP[c]	0.12	0.01	18	0.10A	0.01	3	0.14B	0.01	11	0.10A	0.02	4
EFP	1.11	0.05	18	1.25	0.16	3	1.13	0.05	11	0.96	0.07	4
Medium DP												
TFP	0.44	0.02	15	0.45	0.02	6	0.44	0.03	3	0.42	0.05	6
NDFP[c]	0.10	0.009	15	0.11A	0.01	6	0.07C	0.001	3	0.12A	0.02	6
EFP	0.33	0.02	15	0.34	0.02	6	0.36	0.03	3	0.30	0.05	6

[a] Means involving DP main effects were different ($P \leq 0.022$) for TFP, NDFP, and EFP.
[b] High DP = high dietary phosphorus (0.49% DP), medium DP = medium dietary phosphorus (0.30% DP), TFP = total fecal phosphorus, NDFP = neutral detergent fecal phosphorus, EFP = endogenous fecal phosphorus.
[c] There was a DP × physiological condition interaction ($P = 0.012$) for NDFP. Means with different letters within rows and columns of NDFP are different ($P < 0.05$, least significant difference test) for all possible comparisons.

DN content but also was influenced by the animals' physiological condition within diets. Metabolic fecal material excreted by ruminants is dependent upon intake and physiological condition (Van Soest 1982). We could not determine the exact intake of individual animals, but our observations indicated ad libitum feeding. Moreover, each deer probably received adequate DN to meet metabolic demands during this short-term trial due to their ability to recycle urea N. Therefore, differences in metabolic FN concentrations within diets can apparently be attributed to variations in metabolic N regulation due to physiological condition rather than variations in intake.

Trial 2

Both total FP and endogenous FP concentrations were influenced by DP concentration and, like total FN and neutral detergent FN concentrations, were independent of physiological condition and fecal collection period. Both experimental diets in this trial probably contained adequate DP content for the short-term nutritional needs of deer. Dietary P requirements for gestating and lactating deer have not been quantified (Davis and Johnson 1984); however, Dietz (1965) and Short (1969) suggested that DP intake of less than 0.16% may adversely affect deer production. Additionally, deer probably were not subjected to a mineral imbalance given that the Ca:P ratios for both experimental diets (Table 1) were within limits considered acceptable for both deer (Short 1981) and domestic ruminants (Underwood 1981).

Researchers investigating domestic ruminants have shown total FP level to be highly correlated with DP level using either total FP output (g/day) or total FP concentration (% dry mass) (Cohen 1974; Belonje and Van den Berg 1980*a*,*b*; Holechek et al. 1985). Endogenous FP excretion level has also been shown to be highly correlated with an increase in DP intake in sheep (Braithwaite 1983, Scott et al. 1985).

MANAGEMENT IMPLICATIONS

Fecal nitrogen and fecal phosphorus concentrations may be useful for detecting differences in DN and DP concentrations fed to white-tailed deer does. However, because we examined only the short-term effects of fecal nutrient concentrations, we cannot comment on the long-term aspects of fecal nutrient excretion in relation to different dietary nutrient levels.

Several other problems must be addressed before this technique can be employed in the field. First, the complexing effect of phenolic compounds on FN output must be considered, as it may be the most paramount problem to solve before FN can be used as an effective indicator of DN under field conditions (Robbins et al. 1987*a*). Secondly, deer undergo a seasonal reduction in voluntary intake during winter months even when food is provided ad libitum in pens (Wheaton and Brown 1983) which would produce a lower total fecal output. Consequently, the use of fecal indices in the field during winter could result in an overestimation of dietary quality because low nutrient diets may produce high fecal nutrient concentrations (Belonje and Van den Berg 1980*b*) from deer that are voluntarily restricting intake. Finally, our

study was based on the analysis of fresh fecal material. However, deterioration of fecal material caused by environmental factors may temporally affect fecal nutrient content.

LITERATURE CITED

ARMAN, P., D. HOPCRAFT, AND I. M. MCDONALD. 1975. Nutritional studies on east African herbivores. 2. Losses of nitrogen in the feces. Br. J. Nutr. 33:265–276.

BELONJE, P. C., AND A. VAN DEN BERG. 1980*a*. The use of fecal analysis to estimate the phosphorus intake by grazing sheep. I. The use of pool instead of individual samples. Onderstepoort J. Vet. Res. 47:163–167.

———, AND ———. 1980*b*. The use of fecal analysis to estimate the phosphorus intake by grazing sheep. II. The repeatability of the technique and the influence of varying phosphorus intake. Onderstepoort J. Vet. Res. 47:169–172.

BRAITHWAITE, G. D. 1983. Calcium and phosphorus requirements of the ewe during pregnancy and lactation. 1. Calcium. Br. J. Nutr. 50: 723–736.

COHEN, R. D. H. 1974. The use of fecal and blood phosphorus for the estimation of phosphorus intake. Aust. J. Exp. Agric. Anim. Husbandry 14: 709–714.

COOK, C. W. 1964. Symposium on nutrition of forages and pastures: collecting forage samples representative of ingested material of grazing animals for nutrition studies. J. Anim. Sci. 23:265–270.

DAVIS, L. G., AND M. K. JOHNSON. 1984. Dietary phosphorus requirements of deer. Proc. Southeast. Assoc. Fish Wildl. Agencies 38:285–290.

DIETZ, D. R. 1965. Deer nutrition research in range management. Trans. North Am. Wildl. Nat. Resour. Conf. 30:274–285.

GOERING, H. K., AND P. J. VAN SOEST. 1970. Forage fiber analysis. U.S. Dep. Agric., Agric. Res. Serv., Agric. Handb. 379. 20pp.

HOBBS, N. T. 1987. Fecal indices to dietary quality: a critique. J. Wildl. Manage. 51:317–320.

HOLECHEK, J. L., M. L. GALYEAN, J. D. WALLACE, AND H. WOFFORD. 1985. Evaluation of fecal indices for predicting phosphorus status of cattle. Grass and Forage Sci. 40:489–492.

———, M. VAVRA, AND P. ARTHUR. 1982. Relationships between performance, intake, diet nutritive quality and fecal nutritive quality of cattle on mountain range. J. Range Manage. 35:741–744.

HORWITZ, W., EDITOR. 1980. Official methods of analysis of the Association of Official Analytical Chemists. 13th ed. Assoc. Off. Anal. Chem., Washington, D.C. 1018pp.

JENKS, J. A., D. M. LESLIE, JR., R. L. LOCHMILLER, M. A. MELCHIORS, AND W. D. WARDE. 1989. Effect of compositing samples on analysis of fecal nitrogen. J. Wildl. Manage. 53:213–215.

LESLIE, D. M., JR., J. A. JENKS, M. CHILELLI, G. R. LAVIGNE. 1989. Nitrogen and diaminopimelic acid in deer and moose feces. J. Wildl. Mange. 53:216–218.

———, AND E. E. STARKEY. 1985. Fecal indices to dietary quality of cervids in old-growth forests. J. Wildl. Manage. 49:142–146.

———, AND ———. 1987. Fecal indices to dietary quality: a reply. J. Wildl. Manage. 51:321–325.

LISCINSKY, S. A., G. P. HOWARD, AND R. B. WALDEISEN. 1969. A new device for injecting powdered drugs. J. Wildl. Manage. 33:1037–1038.

MASON, V. C. 1971. Some preliminary observations on the nature of factors influencing the excretion of nondietary fecal nitrogen by ruminant animals. J. Agric. Sci. Cambridge 76:157–166.

MCMAHAN, C. A., R. G. FRYE, AND K. L. BROWN. 1984. The vegetation types of Texas. Including cropland. Tex. Parks and Wildl. Dep. Bull. 7000-120. 40pp.

MOULD, E. D., AND C. T. ROBBINS. 1981. Nitrogen metabolism in elk. J. Wildl. Manage. 45:323–334.

MUBANGA, G., J. L. HOLECHEK, R. VALDEZ, AND S. D. SCHEMNITZ. 1985. Relationships between diet and fecal nutritive quality in mule deer. Southwest. Nat. 30:573–578.

NELSON, J. R., R. M. KOES, W. H. MILLER, AND B. B. DAVITT. 1982. Big game management on a nutritional basis--a new approach. West. Elk Workshop, Flagstaff, Ariz. 16pp.

ROBBINS, C. T., T. A. HANLEY, A. E. HAGERMAN, O. HJELJORD, D. L. BAKER, C. C. SCHWARTZ, AND W. W. MAUTZ. 1987*a*. Role of tannins in defending plants against ruminants: reduction in protein availability. Ecology 68:98–107.

———, S. MOLE, A. E. HAGERMAN, AND T. A. HANLEY. 1987*b*. Role of tannins in defending plants against ruminants: reduction in dry matter digestion? Ecology 68:1606–1615.

SAS INSTITUTE, INC. 1985. SAS User's Guide: statistics. SAS Inst., Inc., Cary, N.C. 584pp.

SCOTT, D., F. G. WHITELAW, W. BUCHAN, AND L. A. BRUCE. 1985. The effect of variation in phosphorus intake on salivary phosphorus secretion, net intestinal absorption, and fecal endogenous phosphorus excretion in sheep. J. Agric. Sci. Cambridge 105:271–277.

SHORT, H. L. 1969. Physiology and nutrition of deer in southern upland forests. Pages 14–18 *in* L. K. Halls, ed. White-tailed deer in the southern forest habitat: proceedings of a symposium. U.S. For. Serv., South. For. Exp. Stn., New Orleans, La.

———. 1981. Nutrition and metabolism. Pages 98–127 *in* O. C. Wallmo, ed. Mule and black-tailed deer of North America. Univ. Nebraska Press, Lincoln.

SWIFT, R. W. 1948. Deer select the most nutritious forage. J. Wildl. Manage. 12:109–110.

THEURER, C. B., A. L. LESPERANCE, AND J. D. WALLACE. 1976. Botanical composition of the diets of livestock grazing native ranges. Univ. Ariz. Agric. Exp. Stn. Tech. Bull. 233, Tucson. 19pp.

TILLEY, J. M. A., AND R. A. TERRY. 1963. A two-stage technique for in vitro digestion of forage crops. J. Br. Grassland Soc. 18:104–111.

UNDERWOOD, E. J. 1981. The mineral nutrition of livestock. Commonw. Agric. Bur., London. 180pp.

VAN SOEST, P. J. 1982. Nutritional ecology of the ruminant. O & B Books, Inc., Corvallis, Oreg. 374pp.

VERME, L. J., AND D. E. ULLREY. 1972. Feeding and nutrition of deer. Pages 275–291 *in* D. C. Church, ed. Digestive physiology and nutrition of ruminants. Vol. 3. Practical nutrition. O & B Books, Inc., Corvallis, Oreg.

WHEATON, C., AND R. D. BROWN. 1983. Feed intake and digestive efficiency of south Texas white-tailed deer. J. Wildl. Manage. 47:442–450.

Received 28 August 1989.
Accepted 27 February 1990.
Associate Editor: Brooks.

EFFECT OF EXPOSURE ON NITROGEN AND FIBER CHARACTERISTICS OF WHITE-TAILED DEER FECES

JONATHAN A. JENKS, Oklahoma Cooperative Fish and Wildlife Research Unit, Department of Zoology, Oklahoma State University, Stillwater, OK 74078
RODERICK B. SOPER, Department of Zoology, Oklahoma State University, Stillwater, OK 74078
ROBERT L. LOCHMILLER, Department of Zoology, Oklahoma State University, Stillwater, OK 74078
DAVID M. LESLIE, JR., U.S. Fish and Wildlife Service, Oklahoma Cooperative Fish and Wildlife Research Unit, Department of Zoology, Oklahoma State University, Stillwater, OK 74078

Abstract: We collected feces from a captive herd of white-tailed deer (*Odocoileus virginianus*) to determine the effect of time of exposure under laboratory conditions on fecal nitrogen (FN) concentration and the effect of time of exposure under natural conditions on FN and fiber characteristics of feces. No differences were found in FN when pellet groups were exposed to laboratory conditions for ≤12 days ($P = 0.99$). The FN concentration also did not differ in pellet groups that were exposed to natural conditions (except when sheltered from rainfall greater than about 1 cm) in Oklahoma for ≤24 days ($P = 0.94$) during September and October. Neutral detergent fiber (NDF) and acid detergent fiber (ADF) of pellet groups placed under these conditions also remained similar with different times of exposure (NDF, $P = 0.30$; ADF, $P = 0.90$). These results suggest that feces collected ≤24 days postdefecation can be used to estimate FN, fecal NDF, and fecal ADF.

J. WILDL. MANAGE. 54(3):389–391

Fecal indices can be useful tools for assessing nutritional characteristics of populations of wild ruminants. Feces have been used to assess food habits (Leslie et al. 1984) and index nutrient status (Hodgman and Bowyer 1986, Leslie et al. 1989). When evaluating fecal components, fresh feces are collected (Leslie et al. 1984, Morgantini and Hudson 1985) presumably because of decreased nutrient concentrations in weathered feces. However, individuals of some deer populations (e.g., at low density) cannot be observed defecating, and estimates of time since defecation may be inaccurate. We examined the effect of time of exposure on FN of deer feces that were maintained under laboratory conditions for 12 days to determine if FN was stable under controlled conditions. We also examined the effect of time of exposure on FN, NDF, and ADF of feces that were maintained under natural conditions for 24 days to determine if environmental weathering affected nutrient concentrations.

Our research was funded by the U.S. Fish and Wildlife Service, Oklahoma Cooperative Fish and Wildlife Research Unit, Oklahoma Agricultural Experiment Station, and Oklahoma State University. A. A. Kocan supplied feces from a captive herd maintained by the College of Veterinary Medicine, Oklahoma State University. We thank D. M. Engle, R. L. Gillen, F. T. McCollum, J. R. Schuette, D. J. Soper, and G. A. Jenks for their helpful comments on this manuscript. This is Journal Article Number J5739 of the Oklahoma Agricultural Experiment Station.

MATERIALS AND METHODS

In April 1987, 5 fecal groups were collected immediately after defecation from a captive herd of white-tailed deer that were maintained