Comparison of In Vivo and In Vitro Dry Matter Digestibility of Mule Deer Forages

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Highlight: In vivo digestibility percentages from mule deer (*Odocoileus hemionus*) digestion-balance trials were usually higher than in vitro determinations obtained from the same experimental forage species. Linear regression analysis suggested a correction factor could be applied to in vitro estimates to make them more nearly correspond to in vivo dry matter digestibility values. Forages with in vitro digestibility values below 35% often varied markedly from in vivo estimates. It raises the question whether deer consume species lower than this in digestibility given reasonable choice.

Digestibility and chemical composition are the major components of forage nutritive values (Barnes 1965). Chemical analyses are routinely and inexpensively obtained, but digestibility percentages, as determined by animal feeding trials, are both laborious and costly. In vitro methods of forage assessment are rapid and inexpensive, but the relationship between in vitro and in vivo estimates is essentially unknown for deer forages (Short 1966; Wilson 1969) and little is known about shrubs generally (Newman and McLeod 1973). This study was designed to provide information on the agreement among values derived by the two methods for selected mule deer foods from the Great Basin and Arizona chaparral and desert habitats.

Methods

In vitro digestibilities (dry matter disappearance) were determined for numerous forage species from the Three Bar Experimental Area in central Arizona (Urness 1973). A two-stage in vitro technique (Tilley and Terry 1963) as modified by Alexander and McGowan (1961) was used. Hand-clipped plant samples, composited from at least 15 different plants, were prepared for artificial rumen fermentation by oven drying (100°C) and grinding through a Wiley mill with a 16-mesh per centimeter screen. Triplicate half-gram samples were analyzed and digestibility percentages were derived by averaging the three samples provided that the high and low values were within 5 percentage points of the mean. Rumen liquor inocula were obtained from deer killed in the same area from which the plant samples were collected. The deer were obtained within 10 days of plant collections.

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The work done in Arizona was sponsored by the U.S. Forest Service, Rocky Mountain Forest and Range Exp. Sta., Tempe, maintained in cooperation with Arizona State University. Central headquarters for the station is at Fort Collins, Colorado.

Acknowledgement is due the Phoenix Zoo, which provided deer, facilities, and assistance by the staff. Sample collections were provided by wildlife management students at Arizona State University, station personnel and many others. The in vitro tests on Great Basin species were made on materials remaining from standard digestion trials under Utah Federal Aid Project W-65-R. We are especially grateful to J. Malechek for his help in interpretation of nutritional parameters.

Manuscript received March 29, 1976.

In vivo digestibility trials were subsequently completed for seven of the same species. These forages ranged from high to low in vitro dry matter digestibility. Although in vivo and in vitro analyses were not run on the same forage samples, attempts were made to duplicate plant phenological development and season of use in the compared forages. Two other species (*Rhus ovata* and *Cercocarpus betuloides*) were refused by deer in feeding trials although these shrubs were conspicuously present in diets of free-ranging deer. Two species were run twice for a total of nine completed trials. Forage samples were collected every 2–5 days and stored in a walk-in cooler at 3°C until being fed.

Three adult female mule deer were used in 8 trials, but only two deer were maintained on false mesquite (*Calliandra eriophylla*) because of difficulty in collecting sufficient amounts for a complete trial. The animals were confined in screen-bottomed cages similar to those previously described (Smith 1950; Dietz et al. 1962; Bissell et al. 1955). Fresh material of individual forage species was fed for 7 to 10 days before fecal collections were begun, approximating the 9-day conditioning period recommended by Mautz (1971). Total fecal output and green weight intake were then recorded for a 10-day trial period. Green weight intake was corrected for moisture loss by use of forage samples placed outside the cages. These samples upon oven drying at 100°C to constant weight (usually 24 hours) also provided the dry matter percentage of the forage offered.

Daily fecal collections were oven-dried and green weight intake (weight offered minus weight of orts and mean moisture loss) was converted to oven-dried intake. The mean difference between OD intake and OD fecal output provided a percentage of apparent digestibility. Animal weight loss or gain was not recorded, although this would have been a valuable statistic, because excessive animal handling was not permitted. The does used were desert mule deer, a small race, and weighed about 36 kg.

To obtain additional data points, forage samples remaining from in vivo trials reported earlier from Utah by Smith (1952, 1957) were fermented in vitro. Inoculum source was from rumen-fistulated mule deer browsing during early spring on foothill pastures containing bitterbrush (*Purshia tridentata*), big sagebrush (*Artemisia tridentata*), serviceberry (*Amelanchier utahensis*), and several grasses and forbs.

Results

Jojoba (*Simmondsia chinensis*) and desert ceanothus (*Ceanothus greggii*) samples were similar in both trials, with moderate fiber and dry matter differences probably a result of the variability in growing conditions between years (Table 1). Samples of filaree (*Erodium cicutarium*) were dissimilar in that in vitro trials were run on small rosette plants in 1967, whereas tall robust plants were fed in vivo in 1971. These differences were not reflected in mean digestibilities, however. Mesquite beans (*Prosopis juliflora*) fed in vivo were somewhat drier than those analyzed in vitro; the reverse was true for false mesquite leaves. Wright buckwheat (*Eriogonum wrightii*) and artemisia (*Artemisia ludoviciana*) were least constant between years in

Table 1. Comparative values (%) for Arizona mule deer forages tested for digestibility by in vivo and in vitro methods.

Species	Plant part	Method	Plant collection date	Seasonal dietary composition	Protein	Acid detergent fiber	Dry matter	Mean digestibility (and range)	Mean oven-dry intake (grams/day)
Jojoba	Leaves+twigs	in vivo	1-71	20	12	28	49	48(42-52)	285[3]
		in vitro	1-68		11	25	44	41	
Jojoba	Leaves	in vivo	3-71	23	11	25	50	48(42-51)	313[3]
		in vitro	3-67		11	29	44[1]	45	
Filaree	Whole plant	in vivo	4-71	10	14	35	20	67(66-68)	910[3]
		in vitro	3-67		22	24	17	66	
Mesquite	Fruit	in vivo	8-71	29	15	33	44	60(58-60)	801[2]
		in vitro	7-67		17	35	39	54	
False mesquite	Whole plant	in vivo	10-71	71	16	42	48	51(49-52)	897
		in vitro	10-67		13	38	59	33	
Desert ceanothus	Leaves	in vivo	1-72	4	11	32	50	55	397
		in vitro	1-68		10	30	55[1]	45	
Wright buckwheat	Whole plant	in vivo	2-72	13	9	52	63	45(41-47)	593[3]
		in vitro	3-67		7	41	55	19	
Wright buckwheat	Whole plant	in vivo	1-73	33	11	43	60	38(34-44)	875
		in vitro	1-68		6	52	66	16	
Artemisia	Whole plant	in vivo	12-72	6	11	38	51	47(45-50)	672
		in vitro	12-67		8	35	39	37	

[1]Dry matter percentage is for leaves plus twigs.
[2]Value is voluntary intake.
[3]Values are close estimates of voluntary intake.

comparative nutrient levels.

Except for mesquite beans, forage on offer was completely consumed during one or more days of each trial by one or more deer, so strict determinations of voluntary intake (VI) were not possible. Close approximations of VI, however, were obtained for jojoba, filaree, eriogonum (February–April period), and artemisia. Consumption of false mesquite and desert ceanothus did not approach VI levels.

Acid detergent fiber content is usually consistently and inversely related to digestibility (Van Soest 1966). Two-thirds of the forage samples fed in digestion-balance trials were higher in fiber than those run in vitro, yet mean in vivo digestibility was usually higher than in vitro percentages. This might occur because (1) the artificial rumen technique (Tilley and Terry 1963) does not duplicate all enzymatic and mechanical functions found in ruminant digestive systems; (2) oven drying forages at 100°C appears to reduce in vitro digestibility by increasing content of lignin-like substances (Van Soest 1965). Drying may also create physical impediments to microbial attack in some plant materials. For example, eriogonum became cottony and almost impervious to wetting when dried and mechanically ground.

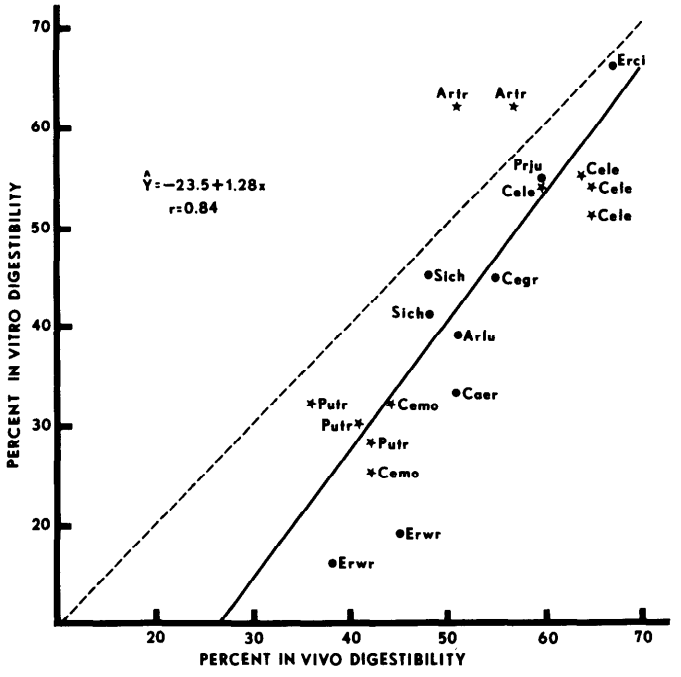

Fig. 1. *In vivo and in vitro dry matter digestibility values are compared for selected mule deer forages from central Arizona (circles) and northern Utah (stars). Abbreviations for plant names are:* Artr = *Artemisia tridentata,* Arlu = *A. Ludoviciana,* Caer = *Calliandra eriophylla,* Cegr = *Ceanothus greggii,* Cele = *Cercocarpus ledifolius,* Ccmo = *C. montanus,* Erci = *Erodium cicutarium,* Erwr = *Eriogonum wrightii,* Prju = *Prosopis juliflora,* Putr = *Purshia tridentata,* Sich = *Simmondsia chinensis.*

Differences between deer in their ability to digest the same forages were narrow or wide depending on plant species (Table 1). digestibility of desert ceanothus was particularly variable with more than 20 percentage points separating the high and low in vivo values. The low values came from one deer, the only individual yielding in vivo percentage lower than in vitro values in the Arizona trials.

If in vivo and in vitro digestibility percentages were identical, they would describe a 45° line when plotted as in Figure 1.

Table 2. Comparative dry matter digestibilities (%) for Utah mule deer forages from in vivo and in vitro analyses.

Species[1]	Plant part	In vitro dry matter digestibility	In vivo dry matter digestibility[2]
Big sagebrush	Leaves+twigs	62	57
		62	51
Curl-leaf mountainmahogany	Leaves+twigs	54	65
		51	65
		55	64
		54	60
True mountainmahogany	Twigs	25	42
		32	44
Bitterbrush	Leaves+twigs	32	36
		28	42
		30	41

[1]Big sagebrush (*Artemisia tridentata*), curl-leaf mountainmahogany (*Cercocarpus ledifolius*), true mountainmahogany (*C. montanus*), and bitterbrush (*Purshia tridentata*).
[2]Smith, 1952, 1957.

Except for sagebrush, our in vivo digestibilities (apparent) were higher than in vitro digestibilities. This result is just the opposite from that reported by Robbins et al. (1975). They attributed the lower in vivo values to metabolic fecal excretion (MFE) and reported almost identical values between in vivo and in vitro methods when MFE was taken into account, although it is not clear from their paper how MFE values were determined. Presumably the differences are due to the methods of in vitro analysis. That is, the Tilley and Terry (1963) in vitro results are considerably lower than those from fermentation followed by neutral detergent extraction of the fermentation residue (Van Soest et al. 1966). Robbins et al. (1975) analyzed composited browse diets rather than individual forage species which might have masked some differences as well.

The regression equation relating all in vitro to in vivo digestibilities ($Y = -23.51 + 1.28X$) had a highly significant correlation coefficient ($r = .84$). Thus, even though we compared dried vs fresh material and analyzed some forages during different years, we determined a strong relationship between in vivo and in vitro values. In some cases the differences between in vivo and in vitro trials using different plant materials were greater than any of those using identical materials (Utah data). However, in other cases the differences were less.

There are too few data points available from this study to develop a comprehensive correction equation for in vitro digestibility estimates. Moreover, such an equation would likely have limited application to diets at other locations. We conclude, however, that the two-stage artificial rumen method provides estimates of apparent digestibility that are reasonably accurate, albeit conservative, for deer forages that are digested 35%, the lowest value observed, or more in vitro.

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