ENERGY REQUIREMENTS OF MULE DEER FAWNS IN WINTER

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Abstract: **Maintenance energy requirement of tame mule deer *(Odocoileus hemionus hemionus)* fawns of similar age and body weight was determined under winter conditions in north central Colorado by subjecting test groups to 4 levels of energy intake. Twenty-five digestion trials were carried out to evaluate the experimental diet in 2 winters. In the 1st winter 3 lots of fawns were used. The 1st was fed ad libitum, the second 75% and third 50% of the pretreatment ad libitum intake. In the 2nd winter one lot was fed ad libitum and another was fed 25% of ad libitum. A linear regression of metabolizable energy intake and corresponding body weight gain or loss indicated that the maintenance requirement was.158 kcal of metabolizable energy per $W_{kg}^{0.75}$/day in 2 winters of study.**

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Energy requirements of wild ruminants in their natural environment are poorly understood. Quantitative determination of range carrying capacity for deer is dependent on knowledge of seasonal energy needs and seasonal supplies of energy in range forage. With mule deer this knowledge is especially critical in areas with cold winter climates. Heat conservation and compensatory adjustment of caloric intake in relation to cold stress are important factors in determining the capacity of forage to maintain deer.

Physiological evidence from domestic and wild ungulates suggests that the young are the most vulnerable of all age classes to nutritional deficiencies. In the case of deer, fawn mortality during winter is highest due to their relatively high metabolic rate, less favorable surface area to weight ratio, and presumably depleted body fat reserves (Ritzman and Benedict 1930, Ritzman and Colovos 1943, McEwan 1970, Wesley et al. 1970, Nordon et al. 1970, Silver et al. 1969, Thompson et al. 1973, Moen 1967, Holter et al. 1977). A better understanding of the post-weaning maintenance energy requirements of fawns during winter would provide a portion of the basic biological information requisite for an assessment of range carrying capacity for mule deer.

The primary objective of this experiment was to estimate the digestible (DE) and metabolizable (ME) energy requirements for maintenance of mule deer fawns in winter (January through March) by using body weight change as an index to energy equilibrium.

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METHODS

The study was conducted principally at the Junction Butte Deer Research Center, 3 km south of Kremmling, Colorado. This location was chosen to obtain measurements from deer subjected to winter climate typical of that where wild deer periodically experience severe nutritional stress. Climate, topography, vegetation, and winter mortality of deer in the general area, Middle Park, were discussed by Gilbert et al. (1970) and Wallmo and Gill (1971).

Data were collected during 2 winters in order to assess winter maintenance requirements. Fawns used in these trials were hand-reared and trained for digestion experiments at the Foothills Campus of Colorado State University, Fort Collins. Rearing procedures generally followed those outlined by Reichert (1972).

For the 1st winter trial (1974), 12 fawns were acclimatized to the Junction Butte environment 13 days prior to the start of actual feeding trials. Mean weight and age of the 12 fawns at the beginning of the experiment were 39.4 (SE ± 1.6) kg and 211 (SE ± 2.5) days, respectively. During acclimatization fawns received the pelleted diet ad libitum (Table 1) which they had been receiving for 5 months prior to this experiment. During this period mean ad libitum dry matter intake was determined for the ensuing trial. The 12 fawns were ranked from lightest to heaviest and allotted into 4 successive trios so that weights of deer within a trio were as similar as possible. One member of each trio was randomly selected to receive ad libitum amounts of the pelleted feed (treatment A), a 2nd random member to receive 75 (treatment B) and 3rd 50% (treatment C) of the mean ad libitum pretrial intake. Daily intake for each deer was calculated by weighing orts to the nearest gram. Snow was provided ad libitum to each deer as a water source. This feeding regime continued for 10 weeks (18 January-28 March).

The experimental design accommodated 3 treatments (energy intake levels) with replicates of 4 deer per treatment. The spread in energy intake and associated body weight change was used as an

Table 1. Composition analysis of experimental pelleted ration.

Ingredient	Weight %
Barley, pulverized	10.0
Corn, pulverized	30.0
Milo, pulverized	5.0
Oats, pulverized	7.5
Wheat middlings	6.5
Beet pulp, shredded	2.5
Brewers grain	35.0
Dicalcium phosphate	1.0
Molasses, cane	2.5
Vitamin A, D, E premix	0.002
Trace mineral package (Mg, Zn, I, Fe, Co, Cu)	0.005
Analysis	
Dry matter	*90.59*
Crude protein[a]	19.34[b]
Ether extract[a]	2.84
Ash[a]	7.86
Cell wall constituents[a]	52.82
Acid-detergent fiber[a]	13.58
Lignin[a]	3.58[b]
Gross energy" kcal/g	4.60
Apparent in vivo dry matter digestibility[a] (ADMD)	72.07
Apparent digestible energy[a] kcal/g	3.45
Apparent metabolizable energy[a] kcal/g	3.05

[a] Dry matter basis.
[b] Percentages for crude protein.. .lignin total 100

index to estimate the DE and ME maintenance requirements (Lambdurne and Reardon 1962; Ullrey et al. 1969, 1970). Linear regression analyses were used to estimate feed requirements for maintenance by solving for X (average daily DE or ME intake/$W_{kg}^{0.75}$/day) when Y (average daily body weight gain or loss) equals zero. Fawns were randomly assigned to 1 of 18 individual isolation pens to control effects of pen variability. Each pen measured 3.0 x 9.1 m and consisted of woven wire sides and dirt floors denuded of vegetation. A 3.0 x 3.0-m wooden roof partially covered each pen.

Methodology for the 2nd winter trial (1975) was similar to that of 1974. However, due to the shortage of fawns only 2 treatments were tested in 1975, but the low energy diet was more restrictive than in 1974. Deer in treatment A (7 deer) were fed ad libitum, while those in treatment D (6 deer) were fed 25% of this amount. Four sets of twins were used in this experiment and when weights of twins were similar, 1 fawn from each set was assigned to a different treatment. Mean weight and age of the fawns at the beginning of this trial was 38.0 (SE ± 1.7) kg and 200.5 (SE ± 5.5) days, respectively*

In 1974, all fawns were placed in digestion cages (Cowan et al. 1969) immediately following the winter experiment. A 3-day adjustment to the cage was allowed, followed by a 7-day total fecal and urine collection. In 1975, fecal and urine collection was similar to 1974 except that 1 fawn from each treatment was rotated into 1 of 2 digestion cages every 10 days during the course of the experiment. This was done primarily to examine the effect of deteriorating physical condition on digestibility. Thus 25 fecal and urine balance trials were completed over a 2-winter period.

Total feces and urine were collected and weighed once a day for 7 days and aliquots were preserved for analysis. Feces were stored in moisture-proof bags and frozen. Urine was acidified with H_2SO_4 during collection. Total daily urine output for each deer was diluted to a predetermined weight in grams by the addition of water. Urine was then mixed, filtered through 2 layers of cheesecloth, and sampled. Aliquots measuring 10% of the total volume of each day's collection were cornposited in a screw-cap jar.

Feed and feces were analyzed for dry matter, gross energy, crude protein, ether extract, and ash. Gross energy of the urine was determined after freeze-drying in a manifold style freeze dryer (Virtus Co., Inc. Gardiner, New York). Energy lost in methane production was estimated from values measured for white-tailed deer (*Odocoileus virginianus*) fawns on a similar diet (Thompson et al. 1973).

All fawns were weighed at the beginning of the feeding trial and at weekly intervals thereafter. The trained fawns were walked through a specially designed holding chute consisting of a platform scale situated beneath a wooden floor. Body weights were taken at the same time each week and recorded to the nearest 0.10 kg. Average daily change in body weight over the entire experiment was calculated for each deer by subtracting the final weight from pretrial weight and dividing by the total number of days on the trial.

Weather conditions were monitored during both winter experiments. Daily temperature, humidity, and wind speed were recorded continuously with a 'I-day hygrothermograph and anemometer located immediately adjacent to the isolation pen-digestion cage complex. Daily and weekly means were calculated by sampling weather conditions from these instruments every 2 hours over a 24-hour period.

RESULTS

Feed Intake and Utilization

For the IO-week trial of 1974, mean ad libitum dry matter intake for the fawns in treatment A was 998.0 (SE ± 22.0) g/day. Food intake for this group of fawns remained relatively constant throughout the winter experiment. Fawns in treatment B and C consumed all feed provided (829.0 and 529.0 g, respectively) each day of the trial. Apparent in vivo dry matter digestibility (ADMD) of the experimental ration was 72.1 (SE ± 1.3) percent. Digestibility of this ration did not differ ($P > 0.05$) between levels of intake (treatments). Dietary gross energy was

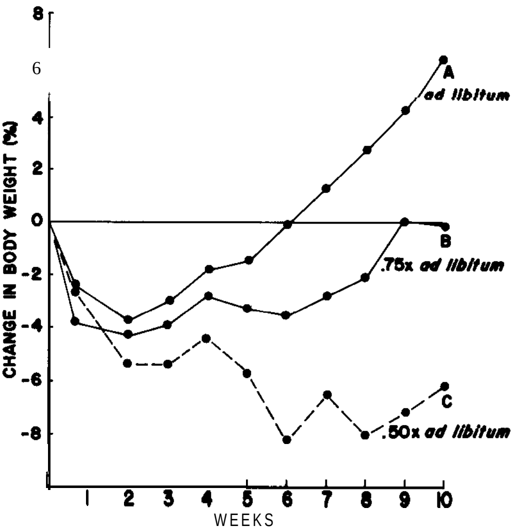

Fig. 1. Mean weekly weight change (percent) compared to initial weight of fawns on 3 different levels of dietary energy, 1974 experiment.

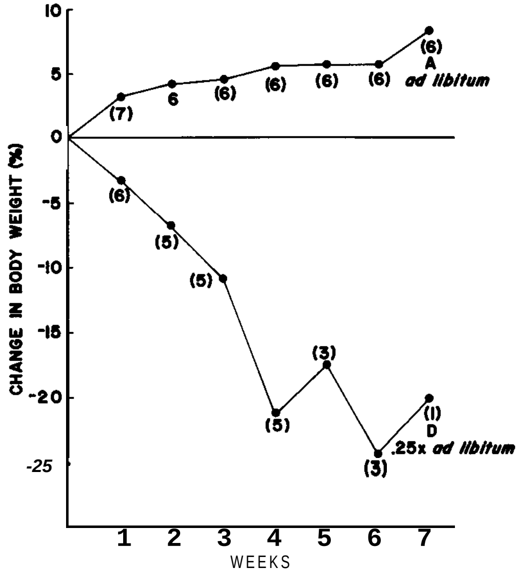

Fig. 2. Mean weekly weight change (percent) compared to initial weight of fawns on 2 different levels of dietary energy, 1975 experiment.

75.0% digestible while the percent of DE available for metabolism was 88.2.

In 1975, mean ad libitum intake for the treatment A fawns was 987.0 (SE ± 15.4) g/day. This level of intake was not different (P > 0.05) from the ad libitum intake of the fawns from the previous winter trial. As in 1974, ad libitum intake did not differ (P > 0.05) between deer in treatment A or between weeks during the trial. Treatment D fawns consumed all of their 240 g each day of the 'experiment. Food utilization by the fawns in 1975 was not different (P > 0.05) from the 1974 fawns. Apparent in vivo dry matter digestibility of the experimental ration was 69.3 (SE ± 1.5) percent. Gross energy intake was 71.6% digestible. The digestible energy that was metabolizable was estimated to be 87.0%. None of these values differed significantly from those of the previous year.

Progressive nutritional stress did not appear to impair ability of the fawns to digest the experimental ration. One fawn (#15) had lost 25% of its pretrial body weight before entering the digestion cage but showed a 73.5% ADMD. Another fawn (#29) apparently died of starvation 1 day after leaving the digestion cage but its ADMD of the ration was 71.3%. Body weight loss of this fawn was *28%.*

Body Weight Change

Mean weight changes for fawns in treatments A, B, and C in 1974 after 10 weeks were +2.4 kg (SE ± 0.6) (6.3%), -0.08 kg (SE ± 0.2) (−0.7%), and -2.6 kg (SE ± 1.1) (−6.2%), respectively. At the end of the trial, mean change in body weight was different (P < 0.01) between treatments (Fig. 1).

In 1975, all fawns in treatment A gained weight during the 7-week trial (Fig. 2). Mean gain was 3.3 kg (SE ± 0.6) (8.3%). Treatment D fawns exhibited a linear decrease in body weight over time.

Table 2. Linear regression equations relating mean daily energy intake (x) and average body weight gain or loss (y); and calculated feed requirements for maintenance (y = 0) for the 1974, 1975, and combined experiments.

Year	Sample size	Regression equation[a]	Correlation (r)	Maintenance[b] requirement kcal/$W_{kg}^{0.75}$/day
1974	12	$\hat{y} = 0.000848(x) - 0.149659$	.87*	176 DE[c]
1974	12	$\hat{y} = 0.000961(x) - 0.149661$	.87*	156 ME[d]
1975	13	$\hat{y} = 0.002195(x) - 0.394860$	.89*	180DE
1975	13	$\hat{y} = 0.002523(x) - 0.394870$	.89*	157ME
1974-75	25	$\hat{y} = 0.002011(x) - 0.361766$	.87*	180DE
	25	$\hat{y} = 0.002292(x) - 0.361527$	.87*	158ME

[a] Body weight gain ($\hat{y}$) = β (energy intake) − 1.
[b] Maintenance requirements were calculated by solving for x (average daily feed intake) when y (average daily body weight gain or loss) equals zero.
* Significant ($P < 0.05$).
[c] Digestible energy.
[d] Metabolizable energy.

By the end of the 7-week trial, 4 of the 6 fawns had died, apparently of starvation. Two fawns died after 28 days and 2 after 42 days on the experimental level of feeding. Mean weight loss of the dead fawns was **11.0** kg (SE ± 0.50) or 32.7%. The 2 surviving fawns in this treatment lost 16.0 and 13.7% body weight, respectively. An apparent increase in body weight for treatment D was indicated during the 4th and 6th week of the trial, but was due to a reduction in sample size as a result of the death of 2 fawns during each of these weeks and not a real weight gain (Fig. 2).

Maintenance Requirements

Estimates for maintenance intake were based on average daily DE and ME intake and the corresponding daily weight changes of the fawns over the entire experiments (Table 2). Digestible energy of ME intake at which the resulting curve crosses zero (body weight equilibrium) is the estimated apparent maintenance requirement.

Overall DE and ME intake levels required for body weight equilibrium were similar for both winters. Digestible energy maintenance requirements for 1974 and 1975 were 176 and 180 kcal/$W_{kg}^{0.75}$/day, respectively. Estimated ME maintenance requirements were 156 and 157. Slopes of these equations were not different ($P > 0.05$) between years. Fawns of similar age and weight were used for both winter experiments and fed the same ration under similar experimental conditions. Therefore, a regression equation based on the daily intake and corresponding body weight change of 25 fawns from both winter trials was used to derive combined DE and ME maintenance requirements of 180 DE kcal/$W_{kg}^{0.75}$/day and 158 ME kcal/$W_{kg}^{0.75}$/day (Fig. 3).

Weather Conditions

Mean temperature for the 1974 winter experiment was -8 C (SE ± 0.6). Temperatures ranged from a maximum of 11 C to a minimum of -29 C. Average wind velocity was 3.6 meters per second (m/s) (SE ± 1.4) and relative humidity was 70% (SE ± 1.5). Windchill was calculated from mean temperature and wind velocities according to the formula provided by Siple and Passe1 (1945). Mean windchill was estimated to be 1,058 kcal/m^2/hour or a still air equivalent of -15 C.

Measured weather parameters for the 1975 experiment were similar to the previous winter. Temperatures ranged from 2 C to -30 C and averaged − 13 C (SE ± 0.6). Average wind velocity was 3.6 m/s (SE ± 0.4) and relative humidity was 73% (SE ± 0.9). Mean wind chill was calculated to be 1,187 kcal/m²/hour or a still air equivalent of -20 C.

DISCUSSION

Average maintenance energy requirement of fawns in this experiment was 158 kcal ME/$W_{kg}^{0.75}$/day. This quantity of caloric intake is needed to maintain body weight equilibrium and includes the unquantified cost of activity and thermoregulation inherent in this experimental design. This value is approximately 1.75 times the fasting metabolism value of 90 kcal/$W_{kg}^{0.75}$/day reported for white-tailed deer fawns in a thermoneutral environment (Silver et al. 1969) and 21% higher (158 vs. 125) than their estimated January and March ME maintenance requirements (Thompson et al. 1973).

Additional energy cost associated with activity and thermoregulation could not be controlled or monitored under the conditions of this experiment but may be inherent in the energy budget estimated for these fawns.

The isolation pens allowed considerable freedom of movement which may have added to maintenance'cost. No rigorous estimate of energy expenditure can be given but an estimate or rather a guess can be made from existing literature. Brownlee (1954) suggested a maximum activity cost of 10% of fasting energy expenditure for young well-fed animals in a pen. Clapperton (1961) used a treadmill built inside a respiration chamber to study the energy expended by sheep walking at different speeds on the level and up gradients. Results of his experiment indicated that under extreme amounts of exercise, energy expenditure increased 20%. Under more normal conditions the additional expenditure was less than 10%.

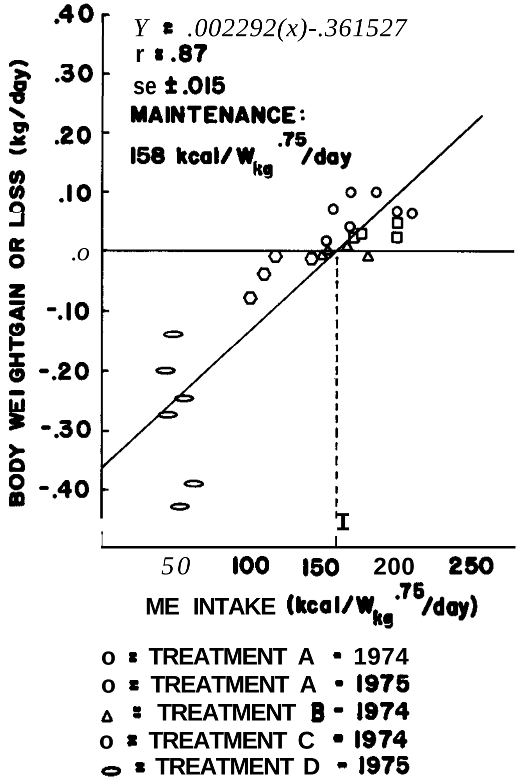

Fig. 3. Regression of average daily body weight gain or loss on average daily metabolizable energy intake, 1974, 1975, and combined experiments.

Weather measurements recorded for this experiment, together with cold tolerance data from white-tailed deer (Silver et al. 1959, Moen 1968, Holter et al. 1975), suggest that the fawns in these trials were subjected to a "critical hypothermal environment" for much of the experiment. Holter et al. (1975) found that the comfort zone for adult northern white-tailed deer in winter was between 5 and 20 C, assuming negligible wind and moisture. Mule deer fawns in this study experienced temperatures of approximately − 11 C and winds of 3.6 m/s or a still air equivalent of -17 C. Combined field and simulation data for deer in winter obtained by Moen (1968) suggest that fawns on a starvation diet would reach a negative energy equilibrium at air temperatures approaching 0 C and wind velocity of 0.2 to 0.4 m/s, while the same deer on a full diet could withstand exposure to -40 C and wind velocity of 3.6 m/s. Similar results pertained in this experiment. Fawns on full diets maintained or slightly gained body weight during the winter, while fawns on restricted rations lost weight at varied rates with the most extreme loss exhibited by fawns on the lowest intake.

In addition to activity and thermoregulation, quality of ingested forage could affect maintenance requirements. Maintenance requirements estimated for our fawns were based on a highly metabolizable concentrate (3.0 ME kcal/g). Assuming that the efficiency values described by Blaxter (1962) are applicable to deer consuming native forage with an ME value of 2.0 ME kcal/g (Wallmo et al. 1977), the equivalent ME maintenance requirement could be increased to 173 kcal/$W_{kg}^{0.75}$/day. However, for ruminants exposed to environmental conditions below their critical temperature, heat loss due to microbial fermentation and metabolism would be used to help maintain body temperature. Deer consuming lower quality diets could theoretically have a slightly lower critical temperature providing the extra total ME of this diet was available and consumed.

The extent to which the results of these trials can be extrapolated to free-ranging mule deer fawns remains speculative. Energy requirements determined from penned animals probably underestimate the requirements for free-ranging animals because unrestrained deer are presumably more active, exposed to more inclement weather, and consume forages of lower digestibility. Energy values obtained from this study are at best a 1st approximation of the energy budget of fawns in winter. Additional experimentation is needed to elucidate the complex interaction of animal nutrient requirements and the fluctuating supply of those nutrients in range forage.

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