FOOD AND ENERGY USE BY CAPTIVE COYOTES

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Abstract: **Four eastern coyotes (*Canis latrans* var.) were fed white-tailed deer (*Odocoileus virginianus*), showshoe hare (*Lepus* americanus), and laboratory mice (*Mus musculus*) to determine their digestion of dry matter, nutrients, and partitioning of dietary gross energy. Dry matter digestibility of the deer diet (96.8%) was higher ($P < 0.05$) than of the hare (81.5%) or mouse (83.2%) diets. The digestible energy value of deer (5.69 kcal/g dry matter) differed ($P < 0.05$) from the other diets, and metabolizable energy values of the deer and mouse diets (4.99, 5.07 kcal/g dry matter) were greater ($P < 0.05$) than that of the hare diet (4.01 kcal/g dry matter). The prey required to fulfill the minimum energy demands at the metabolizable level of a 12.9-kg coyote was estimated to be 8 deer, 105 hares, or 4,800 mice per year.**

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The coyote is one of the most widespread mammalian predators in North America. From approximately 1920 to 1960, the coyote expanded its distribution into the northeastern United States (Hilton 1978). This range expansion has aroused interest in the Northeast concerning the impact coyotes have on endemic prey. Food habit studies (G. 0. Koons, unpubl. manuscript, 1972; Hamilton 1974; Richens and Hugie 1974; Hilton 1976) have determined the prey consumed by coyotes in this region.

To evaluate coyote-prey relations, information on the energy and nutrient requirements of coyotes is needed. Shield (1972) determined the standard metabolic rate of coyotes. Other researchers have determined the food consumption rates of coyotes in captivity (Fitch 1948, Gier 1975, Hilton 1978) and estimated those of free-ranging coyotes (Wagner and Stoddart 1972, Gier 1975, Hilton 1978). These investigations, however, did not quantify parameters such as digestion efficiency and partitioning of dietary energy and nutrients by coyotes.

Our study was designed to determine the nutrient and energy value of common prey species fed to captive coyotes. Specific objectives were to (1) determine the composition of prey species utilized by coyotes, (2) determine the digestion of dry matter and nutrients by coyotes, and (3) describe the partioning of dietary energy by captive coyotes.

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METHODS AND MATERIALS

Four eastern coyotes (2 females) were used in this study. These animals were part of a litter of 7 taken from a den in Aroostook County, Maine, when approximately 12 days old. Their growth and development was reported by Hilton (1976). The coyotes were transported to the University of New Hampshire when approximately 9 months old, housed in

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an enclosed shelter, and maintained on a diet of commercial dog chow and white-tailed deer carcasses prior to the period of study.

The coyotes were placed in collection cages (1.9 x 0.6 x 1.1 m) that allowed limited activity and separate collection of feces and urine. Coyotes were placed in cages 14 days before the start of the study and cages were contained in the same enclosure where the animals had been housed for the previous 2 months. Photoperiod and temperature approximated natural conditions. Ambient temperature ranged from -7 to 32 C during the feeding trials. Feeding trials were conducted from 31 March to 27 April 1976.

Diets (prey) were selected for evaluation based on use by coyotes and availability. Food habit studies in Maine (Richens and Hugie 1974, Hilton 1976), New Hampshire (G. 0. Koons, unpubl. manuscript, 1972), and New York (Hamilton 1974) indicated that white-tailed deer, snowshoe hare, and small mammals (cricetine and microtine rodents) are frequently consumed prey. Three white-tailed deer were obtained from the New Hampshire Fish and Game Department. The hide, bones, and gastrointestinal tract were removed from each deer because we felt that these portions would not be consumed readily by the captive coyotes. Large fat deposits also were removed to aid in processing. All remaining muscles and viscera were ground into a homogeneous mixture. Snowshoe hares were obtained by trapping in New Hampshire and in Nova Scotia. Frozen carcasses were cut into pieces (lo-100 g) on a band saw and combined. Because a sufficient supply of small mammals could not be obtained from the wild, laboratory mice *(Mus musculus)* were used. Mice were reared in captivity on a diet of commercial lab chow. Whole carcasses were fed to the coyotes.

The estimated daily rations of each diet were packaged and frozen at -16 C. Rations were removed from the freezer and thawed prior to feeding each day. Powdered multiple vitamins were added to all feed to prevent deficiencies.

Design of the experiment was an augmented Latin Square. Diets were assigned to the 4 animals for 3 consecutive trials. Data were evaluated by the analysis of variance using the method of fitting constants in an incomplete block design and orthogonal comparisons. Significance was assigned at $P < 0.05$.

Each feeding trial ran for 9 days. The initial 4 days served to adjust the coyotes to their respective diets and allowed estimation of daily consumption rates. The remaining 5 days served as the collection period. During this time animals were fed a known amount of their diets. Water was provided ad libitum. All orts (uneaten food), feces, urine, and a representative sample of each day's ration were collected and frozen. Coyotes were weighed at the beginning and end of each collection period to determine the mean trial weight.

Moisture content of the feed was determined in duplicate by drying samples to a constant weight in a convection oven at 60-70 C. All orts and feces were dried to a constant weight. Feed, orts, and feces were then homogenized separately in a Wiley mill. The proximate nutrient content of each was determined at the University of New Hampshire Analytical Services Laboratory using standard procedures outlined by Horwitz (1975). Energy content of the feed, orts, and feces was determined using a Parr adiabatic calorimeter and standard procedures. Nitrogen content and specific gravity of urine were determined on a fresh basis.

Table 1. Composition of white-tailed deer, snowshoe hare, and laboratory mice fed to 4 captive coyotes.

Component	White-tailed deer	Snowshoe hare	Laboratory mice
Dry matter (DM) (% as fed)	28.1	35.2	34.5
Cross energy (kcal/g DM)	5.90	4.97	6.00
Ash (% DM)	4.3	14.9	10.0
Crude protein (% DM)	80.5	70.1	53.8
Ether extract (% DM)	14.1	12.0	32.0
Crude fiber (% DM)	0.5	0.4	0.2
Nitrogen-free extract (% DM)	1.0	2.6	4.0

Gross energy of urine was determined from dried samples.

RESULTS AND DISCUSSION

Diet Composition

The gross energy content of the 3 diets ranged from 4.97 to 6.00 kcal/g (Table 1) for the hare and mouse diets, respectively. White-tailed deer had the lowest ash (mineral) content due to deboning prior to feeding. Crude protein content ranged from 80.5% of dry matter in deer to 53.8% in mice. Ether extract (fat) was higher in laboratory mice than in deer or hare. Crude fiber and nitrogen-free extract (carbohydrates) were low in all diets.

Nutrient composition of lean deer meat reported by Watt (1968) was similar to the composition reported in this study. Davison et al. (1978), however, reported higher ether extract (25.0%) and lower crude protein (69.9%) values for white-tailed deer meat and viscera. These differences may be due to sample treatment, since the deer were collected during the same season. The composition of snowshoe hare reported by Davison et al. (1978) included lower ether extract (3.7%) and higher nitrogen-free extract content (7.1%) than observed in this study (Table 1). The composition of laboratory mice differed from that of meadow voles (*Microtus pennsylvanicus*), white-footed mice (*Peromyscus leucopus*), and short-tailed shrews (*Blarina brevicauda*) as reported by Davison et al. (1978). The ash, crude protein, ether extract, crude fiber, and nitrogen-free extract of meadow voles (14.0, 59.8, 15.5, 1.7, 9.0% of dry matter), white-footed mice (13.4, 58.9, 14.6, 0.6, 12.7%), and short-tailed shrews (15.1, 66.6, 8.9, 0.6, 9.8%) varied from laboratory mice. The high ether extract content of laboratory mice was probably a result of captive rearing.

Consumption Rates.-Daily dry matter intake per unit metabolic weight ($W^{0.75}$) did not vary significantly between diets (Table 2). Golley et al. (1965) reported similar results in consumption rates of bobcats (*Lynx rufus*) fed poultry, cottontail rabbits (*Sylvilagus floridanus*), and

Table 2. Daily intake ($\bar{x} \pm$ SD) of dry matter (DM) and gross energy (GE) of 3 diets fed to 4 captive coyotes.[a]

Trait	White-tailed deer	Snowshoe hare	Laboratory mice
DM intake/body $W^{0.75}$ (g/kg)	26.3 ± 3.6	31.2 ± 1.4	36.4 ± 6.1
Digestible DM intake/body $W^{0.75}$ (g/kg)	25.5 ± 3.3	25.5 ± 1.6	30.3 ± 5.0
GE intake/body $W^{0.75}$ (kcal/g)	B155.5 ± 21.2	B155.5 ± 7.1	A218.0 ± 36.6

[a] Within a row, means preceded by different letters are different ($P < 0.05$).

Table 3. Percent apparent digestibility ($\bar{x} \pm$ SD) of dry matter and nutrients of 3 diets fed to 4 captive coyotes.[a]

Trait	White-tailed deer	Snowshoe hare	Laboratory mice
Dry matter	A96.8 ± 0.6	B81.5 ± 1.9	B83.2 ± 0.9
Crude protein	A98.3 ± 0.4	B90.0 ± 2.1	C87.9 ± 0.8
Ether extract	A97.2 ± 0.5	B95.7 ± 0.9	A97.3 ± 0.2

[a] Within a row, means preceded by different letters are different ($P < 0.05$).

deer. Daily gross energy intake, however, was greater ($P < 0.05$) on the mouse diet than on the deer and hare diets.

Digestibility of Nutrients

Digestion of dry matter, crude protein, and ether extract varied among diets (Table 3). Dry matter digestibility was highest for deer ($P < 0.05$) and appeared to be inversely related to the ash content of the diet.

Digestion of ether extract was higher ($P < 0.05$) for mouse and deer diets than for the snowshoe hare diet. Coyotes selectively consumed those portions of snowshoe hare with a high fat content. The digestion of ether extract of hare by coyotes was greater than that observed for hare consumed by fishers (*Martes pennanti)* (80.9%, Davison et al. 1978), but similar to that observed for cottontail rabbits consumed by badgers (*Taxidea tams)* (97.6%, Jense 1968). Fishers digested ether extract of small mammals (91.5%, Davison et al. 1978) less efficiently than coyotes digested ether extract of laboratory mice.

Digestibility of crude protein varied ($P < 0.05$) among all 3 diets, being highest for deer (98.3%) and lowest for mice (87.9%) (Table 3). Digestion of crude protein of white-tailed deer (93.5%), snowshoe hare (92.6%), and small mammals (78.9%) by fishers (Davison et al. 1978) differed from this study. Badgers digested crude protein of cottontail rabbits (79.0%, Jense 1968) less efficiently than coyotes digested the crude protein of snowshoe hare (90.0%). Female coyotes had a significantly higher digestion of crude protein (92.9%) than males (91.2%). Sexual differences in protein digestion were not found in the literature, although Moors (1977) reported female weasels *(Mustela nivalis)* having a significantly higher assimilation of dietary energy than males.

Digestion of crude fiber and nitrogen-free extract are not included in this study because of the consumption of wood from the collection cages by coyotes during the feeding trials. The wood passed through undigested and small quantities were observed in the feces. While the

Table 4. Daily intake and partition of dietary nitrogen ($\bar{x} \pm$ SD) by 4 captive coyotes fed white-tailed deer, snowshoe hare, and laboratory mice.[a]

Trait	White-tailed deer	Snowshoe hare	Laboratory mice
Daily N intake, $(NI)/W^{0.75}$ (g/kg)	3.4 ± 0.5	3.5 ± 0.2	3.1 ± 0.5
Fecal N (%NI)	C1.7 ± 0.4	B1O.1 ± 2.1	A12.1 ± 0.8
Urine N (%NI)	81.8 ± 13.9	57.9 ± 20.7	68.8 ± 15.5
Tissue N (%NI)	16.4 ± 13.8	32.1 ± 19.2	19.1 ± 16.2
Daily digestible $N/W^{0.75}$ (g/kg)	3.3 ± 0.4	3.2 ± 0.2	2.8 ± 0.5

[a] Within a row, means preceded by different letters are different ($P < 0.05$).

Table 5. Partition ($\bar{x} \pm$ SD) of dietary gross energy (GE) by 4 captive coyotes fed white-tailed deer, snowshoe hare, and laboratory mice.[a]

Trait	White-tailed deer	Snowshoe hare	Laboratory mice
Daily GE intake/body $W^{0.75}$ (kcal/kg)	**B155.5 ± 21.2**	B155.5 ± 7.1	A218.0 ± 36.6
Fecal energy/GE (%)	C3.2 ± 0.6	**All.9 ± 1.0**	B9.6 ± 0.4
Urine energy/GE (%)	A12.2 ± 1.5	**B7.6 ± 2.7**	B6.0 ± 1.2
Digestible energy/GE (%)	A96.8 ± 0.6	C88.2 ± 1.0	B90.5 ± 0.4
Metabolizable energy/GE (%)	A84.6 ± 1.1	**B80.6 ± 2.5**	A84.5 ± 1.6
Digestible energy/dry matter (kcal/g)	**A5.69 ± 0.07**	C4.38 ± 0.05	B5.43 ± 0.02
Metabolizable energy/dry matter (kcal/g)	**A4.99 ± 0.06**	B4.01 ± 0.12	A5.07 ± 0.09
Digestible energy intake/$W^{0.75}$ (kcal/kg)	**B150.50 ± 19.87**	B137.00 ± 7.62	A197.25 ± 33.51
Metabolizable energy intake/$W^{0.75}$ (kcal/kg)	**B131.50 ± 17.90**	B125.00 ± 5.16	A184.50 ± 33.2

[a] Within a row, means preceded by different letters are different ($P < 0.05$).

amount of wood was minimal and deemed not to have an appreciable effect on other nutrients, the extremely low carbohydrate content of the diets was greatly altered by this extraneous ingestion of fiber.

Daily nitrogen intake per unit metabolic weight did not vary among diets (Table 4). Coyotes apparently compensated for the lower nitrogen content of hares and mice by consuming greater quantities of them than of deer. This resulted in a positive nitrogen balance on all diets. The efficiency of conversion of dietary nitrogen to tissue (tissue nitrogen/nitrogen intake) did not vary among diets.

Partitioning of Dietary Energy

Energy lost in feces and urine varied ($P < 0.05$) among diets (Table 5). Digestible energy (percent of gross energy) of white-tailed deer (98.9%) was greater than that of hare (88.2%) or mice (90.5%). These values are within the range observed for other carnivores including the least weasel (*Mustela rixosa*) (90%, Golley 1960), mink (M. *vison*) (92%, Roberts and Kirk 1964), weasel (90%, Moors 1977), fisher (89%, Davison et al. 1978), badger (91%, Jense 1968), arctic fox (*Alopex lagopus*), (95%, Underwood 1971) and red fox (*Vulpes vulpes)* (91%, Vogtsberger and Barrett 1973; 89%, Litvaitis and Mautz 1976).

Metabolizable energy (percent gross energy) of snowshoe hare (80.6%) was lower ($P < 0.05$) than that of deer (84.6%) or mice (84.5%). The metabolizable energy values of snowshoe hare (76.7%) and small mammals (73.9%) fed to fisher (Davison et al. 1978) were lower than observed for hare and mice in this study. Litvaitis and Mautz (1976) reported the metabolizable energy of deer (87.9%) fed to a red fox to be greater than in this study, while the metabolizable energy of snowshoe hare (76.1%) was less than in this study.

Shield (1972) estimated the standard metabolic rate of coyotes to be 7.38 ml O_2/kg minute. If 4.686 kcal are expended per liter 0, consumed (Maynard and Loosli 1969), the daily minimum energy expenditure of a 12.9 kg coyote would be 94.47 kcal/$kg^{0.75}$. To fulfill this requirement at the metabolizable level, the coyote would need to ingest 18.9 g of dry deer meat and viscera, 23.6 g of snowshoe hare, or 18.6 g of laboratory mice/$kg^{0.75}$ daily. The annual ingestation rate for a 12.9 kg coyote would be 167 kg (fresh weight) of deer meat and viscera (about 8 deer), 166 kg of snowshoe hare (about 105 hares), or 134 kg of laboratory mice (about 4,800 mice). This is a con-

servative estimate since it does not consider activity or heat losses during assimilation (heat increment). Gessaman (1973:4) discussed several studies that estimated that free-ranging animals require approximately 3 times the energy of the standard metabolic rate. Therefore the above consumption rates should be considered with these limitations.

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