DIETARY HUSBANDRY OF CAPTIVE WHITE-TAILED DEER (*ODOCOILEUS VIRGINIANUS*) IN THE NORTHERN USA AND CANADA MUST CONSIDER EFFECTS OF DAYLENGTH, AGE, AND GENDER ON TISSUE ENERGY RESERVES

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Abstract

The effects of age, season, and gender on live body weights, lipogenesis and lipolysis in subcutaneous and perirenal adipose tissues, and weight and fat (ether extract) concentrations of skeletal muscles and viscera were studied in 48 captive white-tailed deer (*Odocoileus virginianus*) fed a complete diet ad libitum. Food intake, rates of lipogenesis, and accumulation of fat in skeletal muscle and viscera increased in relation to declining daylength from mid-June to late fall. Although many deer lost body weight during winter, tissue fat reserves supplied sufficient energy to prevent morbidity and mortality. These and other data indicate that, if food intake had been restricted during the summer and fall period of fat accumulation, morbidity and death losses might be expected during winter and early spring.

Introduction

Voluntary intake of a nutritionally adequate diet tends to be regulated by the demand for energy. Ideally, daily energy intake should equal (or exceed during growth) daily energy loss. However, in the wild ecosystem occupied by free-ranging white-tailed deer (*Odocoileus virginianus*) in Michigan, daily energy supplies differ widely from season to season, both in quantity and quality. Further, food accessibility may be limited by deep snow in winter. Successful occupation of this ecosystem requires adaptive behavioral and metabolic adjustments that will ensure individual survival and perpetuation of the species. Behavioral observations have revealed that in midwinter, when digestible food is in short supply, white-tailed deer seek shelter under evergreens, such as in a white cedar swamp, to interpose an insulating conifer canopy between their warm bodies and the cold sky, thus limiting heat and energy loss. Mobility decreases and metabolic rate declines.[4,6] These are useful responses because the search for food during this season tends to result in more energy lost than energy acquired. Nevertheless, basal metabolic functions continue, and with limited digestible food intake, much of the energy for these must come from stored energy reserves. As a consequence, it is critical that supplies of food be adequate during other seasons to build energy reserves sufficient to deal with the exigencies of winter weather. The development and magnitude of those reserves in relation to daylength, age, and gender is the subject of this report.

Materials and Methods

Data on live body weights (BW) and fat (ether extract [EE]) concentrations of skeletal muscle and viscera were obtained from 25 white-tailed does and 23 white-tailed bucks when killed at approximate ages of 7, 9, 13, 15, or 17 months. Lipogenesis and lipolysis rates in perirenal and subcutaneous adipose tissue also were determined at these times.[1] The deer were born in captivity between May 8 and July 12, with 94% born between May 11 and June 19. During the study, they were housed (5 deer of one sex per group) in 9- by 18-m outdoor pens, without vegetation and sheltered from wind by snow fence on the north and west sides, at the Houghton Lake Wildlife Research Station, Houghton Lake, MI (44.4º north latitude, 84.7º west longitude). The deer were fed a complete pelleted diet (Tables 1 and 2) ad libitum in roofed feed shelters.

At data collection, the deer were rendered insensible with a captive-bolt pistol and were exsanguinated by severing the carotid arteries and jugular veins. Perirenal and subcutaneous adipose tissues were removed immediately for *in vitro* determination of lipogenesis and lipolysis as described by Abbott et al.[1] The thoracic and abdominal viscera were removed, the gastrointestinal tract emptied of its contents, and the total viscera were weighed, ground, and mixed prior to sampling for analysis. After removing the skin, all skeletal (except facial) muscles were separated from the skeleton, weighed, ground, and mixed prior to sampling for analysis. Analyses for dry matter (DM) and EE were performed on these samples by AOAC procedures.[3]

All data were statistically analyzed by the mixed procedure of SAS Version 8.01 (SAS Institute, Inc., Cary, NC) to examine fixed effects of age and gender on lipogenesis, lipolysis, BW, and weight of muscle and viscera, and to examine fixed effects of age, gender, and BW on EE concentration in muscle and viscera expressed as % of BW. Bonferroni adjustment was used for multiple comparisons.

Results and Discussion

Lipogenesis in subcutaneous (sc) and perirenal (pr) adipose tissue (expressed as nanomoles of $^{3}H_2O$ incorporated *in vitro* per 100 mg tissue in 2 hr) from white-tailed does is shown in Table 3. Because the deer were born mostly in May and June, the effects of age and season of sampling were confounded. However, lipogenesis declined ($P<0.05$) in both sc and pr adipose tissue from December 7 (7-mo-old does) to a low on February 19 (9-mo-old-does), followed by increases ($P<0.05$) to June 24 (13-mo-old does), August 25 (15-mo-old does), and November 3 (17-mo-old does) in sc adipose tissue. Lipogenesis in pr adipose tissue increased ($P<0.05$) from February 19 to June 24 and August 25, but the mean value was numerically (but not significantly) lower on November 3.

The pattern of lipogenesis in adipose tissue from white-tailed bucks (Table 4) was similar to that from does, but the magnitude of change was not as great. Although not statistically significant, some decline was seen from December 19 (7-mo-old bucks) to February 6 (9-mo-old bucks), with little change to June 26 (13-mo-old bucks). Lipogenesis increased ($P<0.05$) about eight- and ten-fold in sc and pr adipose tissue, respectively from February 6 to October 31 (17-mo-old bucks). Lipolysis in sc and pr adipose tissue (expressed as µmoles of glycerol released *in vitro* per 100 mg tissue in 2 hr) did not vary significantly between tissues, genders, or sampling periods, and means ranged from 3.8 to 15.0.

Patterns of change in BW, muscle and viscera weights, and muscle and viscera EE concentrations as % of BW are shown in Table 5 for does and Table 6 for bucks. Mean BW trended downward from December to February in both genders, trended upward somewhat to June, and then appreciably to late October or early November. Mean BW of 7-mo-old (Dec 7) and 13-mo-old does (Jun 26) was significantly ($P<0.05$) lower than that of 17-mo-old does (Nov 3). Mean BW of 9-mo-old does (Feb 19) was lower ($P<0.05$) than that of both 15-mo-old (Aug 25) and 17-mo-old does. Mean BW of 7-mo-old (Dec 19) and 9-mo-old bucks (Feb 6) was significantly ($P<0.05$) lower than that of 15-mo-old (Aug 27) and 17-mo-old bucks (Oct 31). Differences in weights of skeletal muscle and viscera exhibited the same patterns, and these BW and tissue patterns appear to be a consequence of the increases in lean body mass characteristic of growth plus the influence of season on accumulation and utilization of body fat (energy) stores. Ether extract concentrations in muscle and viscera as % of BW were lowest in June and highest in mid to late fall in both genders.

Because the deer were penned in groups, it was not possible to measure individual food consumption. However, average daily food consumed by does (food intake by bucks was not measured) from November 14 to February 19 (7 to 9 mo-of-age; n = 15) was 1.10 kg, from February 19 to June 24 (9 to 13-mo-of-age; n = 10) was 1.28 kg, and from June 24 to November 3 (13 to 17 mo-of-age; n = 5) was 2.17 kg. Mean body weights of does were 28.4, 28.5, 38.6, and 54.5 kg on November 14, February 19, June 24, and November 3, respectively.

The deer in this study were all relatively young and were still growing. However, the markedly elevated food intake by does from mid-June throughout summer and fall not only supported an increase in lean body mass (characteristic of growth) but was associated with a very significant increase in rate of lipogenesis and accumulation of body fat stores. Earlier research suggested that both food intake and the rate and extent of fat synthesis were regulated, at least in part, by daylength, presumably via the pineal gland.[1] Other research on free-ranging white-tailed fawns near Chicago, IL found that the composition of winter weight loss ranged from 12% water, 84% fat, 4% protein, and 0.5% ash during early winter to 73% water, 0.3% fat, 25% protein, and 2% ash during early spring. Calculated metabolizable energy derived from tissue catabolism during these periods was 7.7 and 1.1 mcal/kg of bled, ingesta-free body weight loss, respectively.[7] Thus, if food of sufficient quantity and quality were not available for generation of fat stores, either in the wild or in captivity during the critical summer and fall preparation for winter (when daylength is diminishing), morbidity or mortality during mid to late winter would be likely. Ensuring an adequate food supply in a wild ecosystem is a difficult management problem and often beyond human control. However, when white-tailed deer (and possibly other cervids)[2,5] are kept in captivity in a northern temperate environment, the ecological adaptations described above are of direct relevance to their dietary husbandry.

Conclusion

It is particularly important that there be no food restriction in late summer and fall so that captive white-tailed deer might survive the exigencies of their winter environment.

***Acknowledgments*:** We thank M.J. Abbott, M.E. Allen, D.J. Baer, C.L. Bennett, C.R. Brockway, W.S. Budde, E.S. Carlson, K.A. Carter, R.D. Earle, P.D. Friedrich, D.P. Moran, W.V. Rumpler, L.D. Schrader, J.R. Terry, B.E. Watkins, and others who assisted in gathering these data, and J.P. Steibel and N.M. Bello for assistance with statistical analysis.

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Table 1. Formula of complete pelleted diet fed to white-tailed deer.

Ingredient	Percentage
Corn cob byproduct	35.00
Soybean meal w/o hulls, solvent extracted	24.00
Corn grain, ground	18.61
Wheat middlings	10.00
Alfalfa meal, dehydrated	5.00
Sugarcane molasses	5.00
Soybean oil	1.00
Sodium chloride	0.50
Limestone, ground	0.40
Vitamin E premix	0.20
Selenium premix	0.10
Trace mineral premix	0.03
Vitamin A premix	0.01
Vitamin D premix	0.001
Mold inhibitor	0.15
Total	100.00

Table 2. Calculated composition (DM basis) of pelleted diet fed to white-tailed deer.

Item	Amount
Dry matter, %	90.7
Crude protein, %	19.0
Neutral-detergent fiber, %	40.3
Acid-detergent fiber, %	20.8
Calcium, %	0.41
Phosphorus, %	0.39
Magnesium, %	0.22
Sodium, %	0.28
Potassium, %	1.37
Iron, mg/kg	208
Copper, mg/kg	15
Manganese, mg/kg	45
Zinc, mg/kg	53
Iodine, mg/kg	1
Cobalt, mg/kg	1
Vitamin A, IU/kg	3650
Vitamin D_3, IU/kg	350
Vitamin E, IU/kg	110

Table 3. Lipogenesis[a] in subcutaneous (sc) and perirenal (pr) adipose tissue in does.

Approx age	*n*	Season	Sc lipogenesis	Pr lipogenesis
7 mo	5	Dec 7	108 ± 17.7[b]	62 ± 11.4[d]
9 mo	5	Feb 19	9 ± 6.9[c]	1 ± 0.6[c]
13 mo	5	Jun 24	256 ± 118.4	245 ± 116.0[e]
15 mo	5	Aug 25	661 ± 103.8	1264 ± 333.7
17 mo	5	Nov 3	1515 ± 725.6	616 ± 329.2

[a]Least squares means ± SEM in nanomoles ^3H_2O incorporated per 100 mg tissue in 2 hr.
[b]Significantly (P<0.05) different from 9 and 17-mo-old does.
[c]Significantly (P<0.05) different from 13, 15, and 17-mo-old does.
[d]Significantly (P<0.05) different from 9 and 15-mo-old does.
[e]Significantly (P<0.05) different from 15-mo-old does.

Table 4. Lipogenesis[a] in subcutaneous (sc) and perirenal (pr) adipose tissue in bucks.

Approx age	*n*	Season	Sc lipogenesis	Pr lipogenesis
7 mo	5	Dec 19	30 ± 8.6	61 ± 8.9
9 mo	5	Feb 6	20 ± 8.0[b]	17 ± 2.8[c]
13 mo	4	Jun 26	21 ± 32.3	18 ± 33.3[b]
15 mo	5	Aug 27	162 ± 57.7	144 ± 64.6
17 mo	4	Oct 31	167 ± 37.4	186 ± 39.9

[a]Least squares means ± SEM in nanomoles ^3H_2O incorporated per 100 mg tissue in 2 hr.
[b]Significantly (P<0.05) different from 17-mo-old bucks.
[c]Significantly (P<0.05) different from 15 and 17-mo-old bucks.

Table 5. Doe body, muscle, and viscera weights, and muscle and viscera EE as % of BW.[a]

Approx			Body wt	Muscle		Viscera	
age	*n*	Season	kg	Wt, kg	EE, % of BW	Wt, kg	EE, % of BW
7 mo	5	Dec 7	34.5 ± 2.48[b]	14.2 ± 1.17[b]	7.1 ± 0.57[d]	5.0 ± 0.38[b]	3.7 ± 0.39[d]
9 mo	5	Feb 19	30.1 ± 2.48[c]	12.4 ± 1.17[c]	3.2 ± 0.65	3.5 ± 0.38[c]	1.9 ± 0.45
13 mo	5	Jun 24	38.9 ± 2.48[b]	15.9 ± 1.17[b]	1.7 ± 0.51	5.0 ± 0.38[b]	1.0 ± 0.35
15 mo	5	Aug 25	45.6 ± 2.48	18.3 ± 1.17	2.9 ± 0.49	5.9 ± 0.38	1.6 ± 0.34
17 mo	5	Nov 3	54.5 ± 2.48	22.1 ± 1.17	4.4 ± 0.59	8.1 ± 0.38	2.3 ± 0.41

[a]Least squares means ± SEM.
[b]Significantly (P <0.05) different from 17 mo.
[c]Significantly (P <0.05) different from 15 and 17 mo.
[d]Significantly (P <0.05) different from 9, 13, and 15 mo.

Table 6. Buck body, muscle, and viscera weights, and muscle and viscera EE as % of BW.[a]

Approx age	n	Season	Body wt kg	Muscle Wt, kg	Muscle EE, % of BW	Viscera Wt, kg	Viscera EE, % of BW
7 mo	5	Dec 19	39.9 ± 2.48[b]	18.0 ± 1.17[b]	5.5 ± 0.50[c]	6.0 ± 0.38[b]	3.3 ± 0.39[c]
9 mo	5	Feb 6	37.0 ± 2.48[b]	16.5 ± 1.17	3.7 ± 0.53[d]	5.6 ± 0.38[b]	2.9 ± 0.37[d]
13 mo	4	Jun 26	44.9 ± 2.77	18.6 ± 1.31	1.1 ± 0.54	5.7 ± 0.43[b]	0.8 ± 0.38
15 mo	5	Aug 27	56.8 ± 2.48	23.9 ± 1.17	1.9 ± 0.64	7.7 ± 0.38	1.1 ± 0.44
17 mo	4	Oct 31	58.6 ± 2.77	25.1 ± 1.31	3.3 ± 0.72	9.0 ± 0.43	2.2 ± 0.50

[a]Least squares means ± SEM.
[b]Significantly ($P < 0.05$) different from 15 and 17 mo.
[c]Significantly ($P < 0.05$) different from 13 and 15 mo.
[d]Significantly ($P < 0.05$) different from 13 mo.