CONDITION OF BLACK-TAILED DEER FAWNS FROM OAK WOODLAND AND CHAPARRAL HABITAT TYPES

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Abstract. The physical condition of 20 resident Columbian black-tailed fawns (*Odocoileus hemionus columbianus*) from oak woodland and chaparral areas was evaluated during spring and fall, using a series of physical parameters: whole and field dressed weight, mandible and femur length, blood urea nitrogen level (BUN) and packed cell volume (PCV) of the blood, rumen fill, volatile fatty acids (VFA) in rumen fluid, and fat content of femur marrow and muscle tissue. The plant species composition of rumen contents was also determined. The physical condition of oak woodland fawns appeared better than that of chaparral fawns, as indicated by significantly higher ruminal VFA, BUN, femur marrow fat and muscle tissue fat levels in animals from the oak woodland. Femur marrow fat was accurately and consistently determined using a modified Babcock acid digestion procedure. Fat and dry matter content of femur marrows were highly correlated. Seasonal differences in the diet of oak woodland fawns were observed, while chaparral fawns relied heavily on browse both in spring and fall. Based on age estimates from eye lens and body weights, fawns in the oak woodland were born 18 days earlier than those in chaparral.

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INTRODUCTION

A wild animal is a product of its environment. The health of the animal reflects the quality of the environment. Therefore, it is reasonable to assess habitat quality by measuring the health and condition of animals produced by that habitat. In big game management, this concept has found application in such measures as kidney fat index and bone marrow fat content. However, few workers have compared the utility of various condition measures for assessment of deer habitat quality in California.

This paper compares several parameters related to the physical condition of Columbian black-tailed deer resident in chaparral and oak woodland plant communities. The objectives of this study were:

1. To compare the physical condition of fawns from chaparral and oak woodland habitat types during spring and fall using a series of indices.

2. To examine the sensitivity and relative utility of various physical condition indices for deer in the north coastal region of California.

3. To test the feasibility of a modified Babcock acid digestion procedure for determining femur marrow fat levels.

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PROCEDURES

Study Areas

This study was conducted on and adjacent to the University of California's Hopland Field Station located in southeastern Mendocino County. The 5,300-acre research facility ranges in elevation from approximately 600 to 3,000 ft. The predominant vegetation is oak woodland consisting mainly of blue oak (*Quercus douglasii*), white oak (*Q. lobata*), black oak (*Q. kelloggii*), live oak (*Q. wislizenii*) with an understory of annual grasses and forbs. At higher elevations, the oak woodland type gives way to chaparral consisting mostly of chamise (*Adenostoma fasciculatum*), buckbrush (*Ceanothus cuneatus*), scrub oak (*Q. dumosa*), live oak (*Q. wislizenii*), and manzanita (*Arctostaphylos* spp.). This area is characterized by a limited availability of grasses and forbs.

For this study, an oak woodland area at lower elevation on the field station (1,300 to 2,000 ft) was selected for comparison with a chaparral area on public land north of the station at 2,400 to 3,500 ft elevation. These were the same areas studied by Longhurst and Connolly (1970) and Book et al. (1972). A buffer zone about 1-1/4 miles wide separated the two study areas. Studies of marked animals have shown that deer on the Hopland Field Station have home ranges approximately 3/4 mile in diameter (Longhurst and Connolly, 1970). Thus, we concluded that separate deer populations were involved in the two study areas.

Table 1. Nutritionally-related parameters for 11-month old deer collected in oak woodland and chaparral habitats at Hopland Field Station, April 1973. Five animals were collected from each habitat type.

	Oak Woodland			Chaparral			
Parameter	Mean	S.D.[1]	C[2]	Mean	S.D.	C	Significance[3]
Whole weight (lbs.)	44.0	8.13	18%	48.9	4.22	9%	NS
Field dressed weight (lbs.)	32.2	5.91	18%	35.5	2.69	8%	NS
Length of femur (cm)	18.9	1.11	6%	19.6	0.78	4%	NS
Length of mandible (cm)	15.9[4]	0.87	5%	15.2[4]	0.60	4%	NS
BUN (mg%)	25.6	13.50	53%	17.4	4.70	27%	NS
PCV (%)	44.0	3.40	7%	40.0	2.30	6%	NS
Femur marrow fat (%)	13.0	6.17	47%	19.1	13.50	71%	NS
Femur marrow dry matter (%)	27.5	12.70	46%	35.4	10.40	29%	NS
Muscle tissue fat (%)	4.1	1.79	44%	2.0	0.31	16%	5%
Rumen fill (%)	7.5	1.21	16%	8.9	1.48	17%	NS
Total VFA (mg/100 ml)	1212	250	21%	921	249	27%	NS
VFA energy (Kcal/100 ml)	51	11.40	22%	38	11.0	29%	NS
Acetic: Propionic	2.7	0.60	22%	3.6	0.50	14%	10%

[1] S.D. = Standard deviation

[2] C= Coefficient of variation = $\frac{S.D.}{Mean}$ x 100

[3] NS = No significant difference between oak woodland and chaparral.

5%, 10% = difference between oak woodland and chaparral significant at 5% or 10% level, respectively

[4] One mandible broken during collection - sample size = 4.

Animal Collections

This study concentrated on fawns since this age class appears most sensitive to forage conditions (Anderson et al., 1974). Within each habitat type, five fawns were collected in spring (April, 1973) and five in fall (October, 1973). In all, 20 animals were collected. It was not possible to distinguish male from female at long range, so the deer were taken without regard to sex. Cowan and Wood (1955) reported no significant differences in the early growth of male and female fawns to at least 135 days old on a high plane of nutrition. Thus, data obtained in this study for fawns of both sexes were analyzed together. The animals were shot while foraging during morning or evening hours. The deer collected in spring were approximately 11 months of age while those taken in fall were about 5 months old. All were judged normal in appearance.

Necropsy Procedures

The animals were killed with head or neck shots from a scope-sighted rifle. As soon as possible after shooting, a blood sample was drawn by heart puncture into a syringe containing anticoagulant (sodium heparin). The animals were then bled via brisket puncture and additional blood samples collected in open vials. These samples were allowed to clot so that serum could be decanted off in the laboratory. The animals were then transported to the laboratory where the following measurements and samples were obtained:

1. Body weight. Whole and field dressed (all viscera removed) weights were taken to the nearest 0.1 lb. on a standard spring-type scales.

2. Skeletal measurements. Lengths of mandibles and femurs were measured to the nearest 0.1 cm with a steel ruler. Mandible length was taken from the point of eruption of incisors to the posterior angle, holding the ruler parallel with the molariform teeth.

3. Eye lens weight (fall collections only). Eyes were removed and preserved in 10% formalin for at least 14 days. Lenses were extracted and weighed using the technique described by Longhurst (1964). Age of fawns was estimated using a regression model developed by Connolly (unpublished data) with body and eye lens weights as estimating variables. The equation was designed for fawns from birth to 6 months of age having lens weights between 130-300 mg. Birth dates were calculated from age estimates and collection dates.

4. Blood urea nitrogen (BUN). The serum was withdrawn from clotted whole blood samples and frozen until collections were completed. BUN analyses were made by the Animal Science Department, University of California, Davis, using an auto-analyzer.

5. Packed cell volume (PCV). Blood drawn into plastic, disposable syringes containing sodium heparin was placed in Wintrobe tubes for standard PCV determination (Schalm, 1961).

6. Rumen fill. The ruminoreticulum (R-R) was weighed full, emptied, washed, wrung dry and weighed empty. These weights were taken to the nearest 10 g. The difference between full and empty weights was recorded as the weight of the R-R contents. The weight of R-R contents was expressed as a percentage of the whole body weight to obtain a standard rumen fill value.

7. Volatile fatty acid (VFA) content of rumen fluid. Rumen fluid was strained through cheese cloth into a 13 x 100 mm tube containing a pellet of metaphosphoric acid and frozen for later analysis. VFA levels were determined on an Aerograph 204 gas-liquid chromatograph

Table 2. Nutritionally related parameters for five-month old deer collected in oak woodland and chaparral habitats at Hopland Field Station, October 1973. Five animals were collected from each habitat type.

	Oak Woodland			Chaparral			
Parameter	Mean	S.D.[1/]	C[2/]	Mean	S.D.	C	Significance[3/]
Whole weight (lbs.)	33.0	4.86	15%	31.5	7.78	25%	NS
Field dressed weight (lbs.)	23.9	3.60	15%	22.4	5.46	24%	NS
Length of femur (cm)	17.5	1.54	9%	17.0	1.31	8%	NS
Length of mandible (cm)	13.4[4/]	0.45	3%	13.3[4/]	1.36	10%	NS
BUN (mg%)	14.5	5.20	36%	7.4	4.70	62%	5%
PCV (%)	50.0	8.70	17%	46.0	7.30	16%	NS
Femur marrow fat (%)	31.4	12.80	41%	7.8	5.67	73%	1%
Femur marrow dry matter (%)	44.4	6.50	15%	29.4	9.70	33%	5%
Muscle tissue fat (%)	2.79	1.63	58%	2.24	1.11	50%	NS
Rumen fill (%)	11.3[5/]	2.60	23%	8.5	5.58	66%	NS
Total VFA (mg/100 ml)	622	77.40	12%	570	166	29%	NS
VFA energy (Kcal/100 ml)	26	2.90	11%	21	5.60	27%	10%
Acetic: Propionic	3.5	0.50	14%	3.5	0.90	26%	NS

1/ S.D. = Standard deviation

2/ C = Coefficient of variation = $\frac{\text{S.D.}}{\text{Mean}} \times 100$

3/ NS = No significant difference between oak woodland and chaparral.

1%, 5%, 10% = Difference between oak woodland and chaparral significant at 1%, 5% or 10% level, respectively.

4/ Two mandibles broken during collection - Sample size = 3

5/ One rumen measurement lost - sample size = 4.

equipped with a 12 x 0.125 inch (O.D.) stainless steel column containing Porapak Q, 80-100 mesh, and a hydrogen flame ionization detector with nitrogen as the carrier gas at 36 ml/minute. This combination resolved acetic (C_2), propionic (C_3) and butyric acids, but did not resolve valeric (C_5) or caproic (C_6) acids. Since valeric and caproic acids comprise only a small fraction of total VFA, no attempt to quantify these higher acids was made. The chromatograph charted the VFA concentrations on an automatic recorder as a series of peaks depicting the retention time of the various acids. The amount of each acid was then calculated manually from peak heights on the charts. The amounts of individual acids (C_2, C_3, C_4) were summed to obtain total VFA concentrations. Caloric value of VFA was calculated using the energy values given by Weast (1968).

8. Femur marrow fat. Both femurs were removed. The bones were cracked open and the entire marrow removed with the aid of a spatula. Fresh weight was recorded and the marrow then frozen in a capped vial until analysis. Fat was determined using the modified Babcock acid digestion procedure described by Salwin et al. (1955). Since all marrows weighed less than 9 g, the fresh weight rather than the standard 9 g aliquot was used for fat determinations. While one marrow from each animal was analyzed for fat, the other marrow was dried in an oven to determine dry matter content.

9. Muscle tissue fat. The psoas major was removed intact, weighed immediately, and frozen until needed for analysis. Fat was determined using the solvent extraction method described by Hammarstrand (1966). The modified Babcock procedure used for marrow analysis could not be used for muscle tissue, as it does not provide sufficient accuracy at the low fat levels encountered.

10. Plant species composition of rumen contents. One-pint samples of mixed rumen contents were preserved in 10% formalin for analysis by the Food Habits Section, Wildlife Investigations Laboratory, California Department of Fish and Game.

Data were analyzed by standard statistical procedures.

RESULTS

Results for each of the parameters are presented in the same order that they are described. Although well-defined trends are obvious in data for several parameters, some of these differences are not significant as a result of the small sample size. Sample size was restricted by deer collection permit limitations. The data for all nutritionally related parameters are summarized in Tables 1 and 2.

Body Weight

Whole and field dressed weight data indicated no significant difference between oak woodland and chaparral fawns. It is noteworthy that body weight trends indicate chaparral fawns experienced favorable conditions for weight gain prior to the spring collection period, while oak woodland fawns experienced greater weight gain prior to the fall period. Judging from the coefficients of variations, whole weights and field dressed weights appeared equally variable.

Skeletal Measurements

Mandible and femur lengths were less variable than body weights, but the differences between fawns from the two areas were not significant.

Table 3. Mean values for eye lens weight, estimated age and birth dates for fawns collected in oak woodland and chaparral habitats at Hopland Field Station, October 1973.

	Oak Woodland	Chaparral
Mean lens weight	261 mg	242 mg
Standard deviation	2.82	10.6
Coefficient of variation[1/]	1%	4%
Estimated age[2/]	137 days	119 days
Estimated birth dates	May 11-26	May 19-June 16

1/ Coefficient of variation = $\frac{\text{standard deviation}}{\text{Mean}} \times 100$

2/ Age estimated using the equation:

$$\text{Age in days} = .883\ (\text{lens weight in mg}) + .704\ (\text{body weight in pounds}) - 116.78$$

Eye Lens Weight

Lens weights were not measured as a nutritional indicator, but to compare the ages of fawns sampled in the two study areas. Lenses from oak woodland fawns were significantly heavier (1% level) than lenses from chaparral animals in the October period (Table 3). The resulting age estimates showed fawns from the oak woodland to be about 18 days older, on the average, than fawns from the chaparral. The relatively uniform age of oak woodland fawns reflects a higher degree of estrous synchrony among does in this area than in the chaparral. This difference may indicate better nutritional conditions in the oak woodland at the time of ovulation.

Blood Urea Nitrogen

Data obtained during April indicate no significant differences in BUN levels between oak woodland and chaparral fawns. However, BUN levels were significantly higher (5% level) in oak woodland animals collected during October (Table 2).

Packed Cell Volume

No significant differences in PCV were noted between fawns from the oak woodland and chaparral areas during either season. There was a tendency for oak woodland fawns to have slightly higher levels. The 5-month old fawns collected during the fall had higher PCV levels than the 11-month old animals collected during spring. This difference was thought to represent the greater hematopoietic ability of the younger fawns.

Rumen Fill

Rumen fill, expressed as a percent of the whole carcass weight, showed no significant differences between fawns from the oak woodland and chaparral areas. The mean value obtained during April is higher in chaparral animals, indicating lower forage quality in this area, as fawns must eat more of a less nutritious forage.

However, mean values obtained during October indicated oak woodland fawns had higher rumen fill values. The dry, heavy ingesta observed in oak woodland fawns during the fall was the result of the abundance of acorns in the diet. Short et al. (1969b) reported similar findings for white-tailed deer in Texas. Although nutritious, acorns are retained in the rumen due to large particle size and slow ruminal microbe adjustment to the high starch content. Delayed breakdown of the ingesta, rather than low forage quality, was thought to be responsible for the relatively high rumen fill values of oak woodland fawns during the fall.

Volatile Fatty Acids

Analysis of rumen fluid samples produced data for acetic, propionic and butyric acids, the primary rumen fermentation products. Total VFA, caloric value and acetic : propionic acid ratios were calculated from the chromatograph data. Although the mean values for total VFA in oak woodland samples were higher than for chaparral samples, the differences were not statistically significant. Caloric values did not differ significantly during the spring, but oak woodland samples were significantly higher (10% level) during the fall collection period. Acetic : propionic acid ratios were significantly higher in chaparral samples during spring, a reflection of lower forage quality. Means obtained for the fall samples did not differ significantly.

Table 4. Principal food items eaten by deer in the study areas during April and October 1973, as determined by rumen analyses. Five deer were collected in each habitat type.

Common Name	Scientific Name	Percent in contents (by volume) April		Percent in contents (by volume) October	
		Oak woodland	Chaparral	Oak woodland	Chaparral
Oak acorns	*Quercus* spp.[1/]	--	--	54%	tr.[2/]
Oak leaves	*Quercus* spp.	16%	58%	16	75%
Mountain-mahogany	*Cercocarpus betuloides*	--	5	--	tr.
Chamise	*Adenostema fasciculatum*	tr.	23	tr.	tr.
Wedge-leaf ceanothus	*Ceanothus cuneatus*	--	6	--	4
Grass	Gramineae	12	4	25	tr.
Forbs	Misc. forbs	33	2	4	tr.
Bur clover	*Medicago hispida*	15	tr.	--	--
Filaree	*Erodium* spp.	16	1	--	--
Clover	*Trifolium* spp.	6	tr.	--	--
Chaparral pea	*Pickeringia montana*	--	--	--	20
Other trace items		2	1	1	tr.
Totals		100%	100%	100%	100%
General forage class:					
Browse		17%	92%	74%	99%
Grass		12	4	25%	tr.
Forbs		71	4	tr.	tr.
		100%	100%	100%	100%

1/ Primarily *Q. lobata*, *Q. kelloggii* and *Q. wislizenii* in oak woodland and *Q. wislizenii* and *Q. dumosa* in chaparral.

2/ tr. = Trace items present in amounts less than 1%.

Femur Marrow Fat

Femur marrow fat and dry matter levels appeared higher in chaparral fawns than in oak woodland fawns during April. The differences, however, were not significant. The mean femur fat level of oak woodland fawns was significantly higher (1% level), as was the dry matter content (5% level), than that of chaparral fawns during fall (Table 2). Regression analysis of these data indicate a high degree of correlation (r = .88) between marrow fat and dry matter contents. The relationship is expressed by the equation % fat = 1.16 (% dry matter) - 23.16.

To compare the accuracy of the Babcock acid digestion method of marrow fat analysis with a standard chloroform-methanol solvent extraction method, additional femurs were collected from deer taken for other purposes at Hopland. Comparable samples from five marrows were analyzed by each method. The results from the two methods were highly correlated (r = .99) although the Babcock procedure produced values averaging 5.3% higher than the solvent extraction method. The explanation offered for this higher average value is that this acid digestion resolves total fat including neutral fats, phospholipids, fatty acids, and cholesterol. Solvent extraction of fat from animal tissue may not remove total fat. This high degree of correlation indicates that the modified Babcock method used in this study is reliable.

Muscle Tissue Fat

The mean value for muscle tissue fat of oak woodland fawns was significantly higher (5% level) than that of chaparral fawns during April (Table 1). Although the mean value for oak woodland animals was also higher during fall, this difference was not significant. Higher fat levels in oak woodland fawns were thought to reflect less nutritional stress on animals in this area.

Plant Species Composition of Rumen Contents

Food habits of fawns collected in the two study areas during spring and fall are summarized in Table 4. The diet of oak woodland fawns included a higher percentage of grasses and forbs during both seasons. The abundance of acorns in the diet of oak woodland fawns during fall is certainly noteworthy.

DISCUSSION

Of the parameters measured in this study, BUN, VFA, and femur marrow and muscle tissue fat appeared most useful as significant differences between fawns from oak woodland and chaparral areas were documented. Body weight, skeletal measurements, PCV, and rumen fill failed to show significant differences. Limitations of these parameters were recognized as were those of the small sample sizes. Field dressed weight and skeletal measurements are commonly used for evaluating condition in all age classes. Although skeletal measurements have been reported to be more reliable indicators of growth than body weights in wild ungulates (Klein, 1964), in this study no significant differences appeared in such measurements. Estimated birth dates indicated that oak woodland fawns averaged approximately 18 days older than chaparral fawns. This finding indicates the advantage of using nutritional parameters not directly related to age.

Since limited information is available on blood values of black-tailed deer, the usefulness of these measures as condition indices is uncertain. Torell (1971) found that BUN levels in sheep were directly related to forage quality. The extremely low BUN levels in chaparral fawns during fall were thought to reflect a diet low in protein. The data for PCV indicated no significant difference between oak woodland and chaparral fawns. The higher levels observed during the fall were expected, as PCV is inversely related to age in most mammalian species.

The use of rumen fill as a measure of forage quality and animal condition appears questionable. Church (1969) indicated that the physical nature of feed is the dominant factor controlling the passage rate of digesta from the rumen. The values observed for oak woodland fawns during fall tend to support this concept as high rumen fill values were evident despite an apparently nutritious diet. Short et al. (1969a) recognized total food consumption, time after feeding, forage digestibility, and physical nature of food items as variables influencing the rumen fill measurement in white-tailed deer. No differences were apparent in rumen fill samples taken during morning and evening.

Rumen fluid VFA data indicated significant differences in the quality of forage consumed by fawns on the contrasting study areas. Caloric value and acetic : propionic acid ratios appear to identify variations more readily than total VFA measurement. Expression of VFA data in the form of acid ratios is a commonly used method for comparing individual animals (Church, 1969). Allo et al. (1973) found that high roughage diets produced large amounts of acetic acid (C_2) in deer and sheep. As in the case of rumen fill, VFA measurements are subject to variability since feeding time and forage consumption cannot be controlled in range deer.

The metabolic requirements of young, actively growing deer differ from those of mature animals. Fawns tend to lay down less depot fat on normal range diets. Therefore, it was important to measure fat reserves at an initial site of fat deposition. Bone marrow fat appears to yield an accurate assessment of physical condition in fawns as young as 5 months. The marrow fat measurement appears more sensitive than that of dry matter judging from significance levels (Table 2). Riney (1955) found that bone marrow was the first fat depot to respond to favorable metabolic change in ruminants. Bone marrow appears to be a good indicator of condition during suboptimal forage conditions. It is possible that muscle tissue fat levels indicate relative condition. However, further work is needed to determine the precise relationship of muscle tissue fat and physical condition. Kidney fat was not measured in this study as fawns in our area rarely have detectable amounts of it.

One objective of this study was to test the feasibility of a modified Babcock acid digestion procedure for determining femur marrow fat. Our results indicate acceptable accuracy and consistency with this method. The Babcock procedure is faster than a solvent extraction method and more accurate than visual or compression methods of marrow fat analysis. Samples can be digested and fat determined in approximately 30 minutes. To the best of our knowledge, no one has previously reported analysis of bone marrow fat with this procedure. It is thought that further refinement will allow this technique to be used for rapid, one-step analysis of marrow samples for ruminant species of all ages.

Throughout this study, the physical condition of fawns in the oak woodland appeared to be superior to that of fawns in the chaparral. This conclusion agrees with that reported by Longhurst and Connolly (1970). The ability of oak woodland fawns to shift their diet seasonally appears to be responsible. The high browse diet of chaparral fawns tends to limit nutritional quality in this area.

LITERATURE CITED

Allo, A. A., J. H. Oh, W. M. Longhurst and G. E. Connolly. 1973. VFA production in the digestive systems of deer and sheep. J. Wildl. Manage. 37(2):202-211.

Anderson, F. M., G. E. Connolly, A. N. Halter and W. M. Longhurst. 1974. A computer simulation study of deer in Mendocino County, California. Oregon Expt. Sta. Tech. Bull. 130. 72 p.

Book, S. A., G. E. Connolly and W. M. Longhurst. 1972. Fallout Cs^{137} accumulation in two adjacent populations of northern California deer. Health Physics 22:379-385.

Church, D. C. 1969. Digestive physiology and nutrition of ruminants. Vol. 1. Oregon State University. 316 pp.

Cowan, I. McT. and A. J. Wood. 1955. The growth rate of black-tailed deer. J. Wildl. Manage. 19(3):331-336.

Hammarstrand, K. 1966. Gas chromatographic analysis of fatty acids. Varian Aerograph publication. p. 2.

Klein, D. R. 1964. Range-related differences in growth of deer reflected in skeletal ratios. J. Mammol. 45:226-235.

Longhurst, W. M. 1964. Evaluation of the eye lens technique for aging Columbian black-tailed deer. J. Wildl. Manage. 28(4):773-784.

Longhurst, W. M. and G. E. Connolly. 1970. The effects of brush burning on deer. Trans. Ann. Mtg. Calif.-Nev. Section, Wildl. Soc. pp. 139-155.

Mansfield, T. M. 1974. A comparison of black-tailed deer fawns from oak woodland and chaparral vegetation types. M.S. thesis, Univer. Calif., Davis, Calif.

Riney, T. 1955. Evaluating condition of free-ranging red deer (Cervus elaphus), with special reference to New Zealand. New Zealand J. Sci. Tech. Sec. B. 36(4):429-464.

Salwin, H., I. K. Block and J. H. Mitchell Jr. 1955. Rapid determination of fat in meat products. J. Agr. Food Chem. 3(7):588-593.

Schalm, O. W. 1961. Veterinary hematology. Lea and Febiger, Philadelphia, Penn. pp. 54-61.

Short, H. L., E. E. Remmenga and C. E. Boyd. 1969(a). Variations in ruminoreticular contents of white-tailed deer. J. Wildl. Manage. 33(1):187-191.

Short, H. L., C. A. Segelquist, P. D. Goodrum and C. E. Boyd. 1969(b). Rumino-reticular characteristics of deer on food of two types. J. Wildl. Manage. 33(2):380-383.

Torell, D. T. 1971. Strategic management of sheep. Calif. Livestock news 47(6):8-10.

Weast, R. C., ed. 1968. Pages D184-189 in Handbook of chemistry and physics. 49th ed. Chemical Rubber Co., Cleveland, Ohio.