METABOLIZABLE ENERGY VALUES OF SOME PLANT SEEDS CONSUMED BY BOBWHITE QUAIL IN KANSAS

by 632

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INTRODUCTION

This study was part of a larger, more comprehensive investigation at Kansas State University of the bioenergetic relationships of bobwhite quail (*Colinus virginianus*). One of the objectives of the overall project was to evaluate the effectiveness of a habitat improvement program for bobwhite quail in Kansas (Robel 1969). In some instances, upland bird management methods require intensive cultivation (monocultures) of beneficial food plants such as wild rice, corn, wheat and other grains. These feeding programs are found in many widlife management areas and, at times, have been helpful in sustaining upland birds through critical winter periods and in dispersing and increasing game bird numbers by providing adequate food where it had not previously existed.

The mean energy content of some seeds consumed by bobwhite quail in Kansas has been determined by Robel and Harper (1965), Johnson and Robel (1968) and by Derksen (unpublished data). Although such data are of use to the wildlife manager, the metabolizable energy contained in each food item may be of greater importance to the survival of birds in the wild. Knowing which species of seed bobwhite quail utilize most efficiently could be a great aid to habitat improvement programs for this gamebird in Kansas.

The specific objective of my study was to determine the metabolizable energy content of six common foods of bobwhite quail in Kansas.

LITERATURE REVIEW

General

One of the early avian energetic studies was conducted by Kleiber and Dougherty (1934). Their objectives included the determination of environmental effects on growth rate, food consumption and the conversion of food to body material in chicks and homoiothems in general. They reported (1934: 702) the "... existence of a certain critical environmental temperature below which a cooling of the environment causes an increase in metabolism and above which the metabolism is practically independent of changes in the environmental temperature." A temperature range of 21° to 40°C was used for periods of 9 days when the chicks were 0 to 15 days old. Within this range of temperatures they found the total food intake was a linear function of the environmental temperature. Kleiber and Dougherty (1934:724) also demonstrated that the "... heat production of the animals tended to approach the intake of metabolizable energy at high, as well as low, environmental temperatures."

Brody (1945) reviews energy and nitrogen metabolism and includes some bioenergetic methods on the energetic efficiency of productive processes in growing animals. In analyzing nutritional aspects of growth, Brody (1945:744) describes palatability as an "... important characteristic because the greater the palatability of a food the greater its consumption, the more rapid the productive process, ..." In comparing paired feeding (equalizing food intake) with *ad libitum* feeding Brody found the *ad libitum* method to be more useful for practical comparisons of feed values. The *ad libitum* feeding method is advantageous in that it places a premium on the feed's palatability.

Fraps (1945) measured the amount of metabolizable energy stored by young chickens, and found that the amount of metabolizable energy stored depends on the fat content of the birds.

Kendeigh (1949) studied the rate of energy intake of house sparrows (*Passer* domesticus) over a wide range of temperatures and analyzed the energy resources of the birds throughout the year. He concluded that, (1) gross energy intake and metabolizable energy intake of house sparrows, with a 10 hour photoperiod, increased linearly between +34° and -31°C and, (2) the increase in rate of metabolizable energy intake with decreasing temperature does not keep pace with the increase in gross energy intake. It is generally accepted (Brody 1945) that for birds as well as other animals, the completeness of digestion and efficiency of utilization of food energy decreases at lower temperatures.

Davis (1955) found no significant difference in the metabolizable energy values between male and female house sparrows at either constant or fluctuating environmental temperatures within a range of 10° to 29°C. Food consumption of the birds remained nearly constant even with fluctuating environmental temperatures. "When the environmental temperature rises," Davis (1955:410) explained, "the bird continues to consume approximately the same amount of food as it did at lower temperatures because of the lag in its physiological response to higher temperatures. Under fluctuating, out-of-doors conditions, there is little or no chance for the bird to adjust it's feeding to a given temperature. Therefore, energy intake does not adjust fully to day-by-day variations in temperature, but only to the general trend from week to week or month to month."

West (1960), studying the energy balance of the tree sparrow (Spizella arborea) in relation to migration, found that (1) the amount of energy lost in excrement per day increased linearly with decreasing temperature with no significant difference among photoperiods, and this increase was a result of a greater volume of food being digested at low temperature, (2) metabolizable energy increased with decreasing temperature with differences among photoperiods being explained by differences in night-time activity, and (3) the efficiency of food utilization increased with temperature at all photoperiods. However, because digestion is more rapid during the short photoperiod, winter birds at 10 hours of light per day are less efficient than summer birds at 15 or 19 hours.

West and Meng (1966) found that willow ptarmigan (Lagopus lagopus) in Alaska derive their nutritional and energy requirements from a variety of diets. The primary dietary component is willow (Salix spp.) when it is available, but it is not a necessity for survival of the ptarmigan.

West (1968) maintained captive willow ptarmigan out-of-doors under natural conditions or temperature and photoperiod to study their bioenergetics. He determined metabolizable energy by subtracting the caloric value of the excreta from that of the food consumed. The metabolizable energy of captive willow ptarmigan remained fairly constant throughout the year, although slight changes were statistically significant. The effects of temperature changes were masked by molt, egg laying, weight change, and the gross activity of the birds.

Bobwhite quail studies

Errington (1936) emphasized that winter is often a period of crises for bobwhite quail and effective management of this species usually requires improving and maintaining an adequate winter food supply. Only a small portion of foods qualify as winter staple diets and these must have sufficient amounts of utilizable protein, carbohydrates and fat. Errington found that lesser ragweed (Ambrosia artemisiifolia) and acorn mast (Quercus spp.) were valuable as natural foods, but could not be considered staple diets when eaten alone. He considered no food wholly complete, but corn (Zea mays) was best followed by soybeans (Glycine max) sorghum (Sorghum vulgare) and most of the cultivated grains.

Nestler and Bailey (1944) conducted five feeding tests to find the value of dwarf sumac (Rhus copallina) and smooth sumac (Rhus glabra) fruits as the sole diet of quail, as well as a supplement to other feedstuffs. They concluded that (1944:696) "even though sumac fruit is eaten by quail, and as small percentage of the diet it may have a definite nutritional value, nevertheless, as the sole or primary article of diet, it cannot be expected to maintain quail through a critical period in the winter."

Nestler (1949) found that bobwhite must have a winter diet high in easily digestible carbohydrates as well as in carotene. Pen-reared quail cannot survive long without access to vitamin A or its precursor, carotene, however, there was little evidence that vitamin A deficiency is serious in the wild.

Wycoff (1964) ascertained the nutritive content of foods consumed by bobwhite quail in the longleaf pine vegetation types in Louisiana. His most significant finding was the yearly fluctuation in abundance of the major winter food items and that it appears availability of foods was an important factor in determining the amount of different foods consumed by bobwhites. The use of sumac seeds (Rhus spp.) increased as winter progressed and oak mast (Quercus spp.) was consumed heavily throughout the winter.

Robel (1963) studied bobwhite quail food habits and found that the consumption of western ragweed (Ambrosia psilostachya) and sunflower seeds (Helianthus spp.) by bobwhites decreased markedly in the winter. A subsequent study by Robel and Slade (1965) determined that the numbers (and thus availability) of the seeds of both species decreased in abundance as winter progressed. He concluded that the decrease of ragweed and sunflower seeds in the winter diet of bobwhites probably resulted from a decrease in availability.

Case (personal communication) found that, for bobwhite quail, existence energy requirements are negatively correlated ($r = -0.996$) with ambient temperature. At 10 hours photoperiod and 20°C he found 32.948 kcals to be the mean daily existence energy requirement of a male bobwhite. Existence energy is defined as the energy required to maintain basal metabolism, chemical heat regulation, securing food and drink and in the heat increment of digestion and assimilation (Kendeigh 1949).

METHODS

General

This study involved two separate experiments designed to determine the metabolizable energy values of seed species eaten by bobwhite. Six seed species were used, sorghum (*Sorghum vulgare*), smooth sumac, pin oak (*Quercus palustris*), common sunflower (*Helianthus annus*), partridgepea (*Cassia nictitans*) and giant ragweed (*Ambrosia trifida*).

Seeds of these six plants were collected in the fall within a 20 km radius of Manhattan, Kansas. All species were wild except sorghum, which is cultivated intensively in eastern Kansas. Approximately 1000 grams of each species were gathered providing a sufficient amount for the feeding trials. All seeds were strained and cleaned to remove debris; seeds were stored at -16°C, to stop respiration and deterioration of the seeds (Kendeigh and West 1965). Moisture content and percent dry weight of each seed species were determined (Table 6 appendix) by drying them at 60°C for 72 hours. Food consumed by birds during this study are expressed on a dry weight basis.

A control diet (P-18) was a finely ground mash, prepared by the Milling Department of Kansas State University. Grit was not provided since bobwhite quail survive and maintain their weight as successfully without grit as birds with access to insoluble, non-friable grit (Nestler 1949).

Thirty adult male bobwhite quail were obtained from the Kansas State Quail Farm at Pittsburg, Kansas prior to each experiment. Each bird was confined in consecutively numbered 48 X 25 X 13 cm plastic boxes equipped with removable wire tops and bottoms. Food and water were provided in separate vials. The caged birds were placed on a portable, shelved metal cart and were kept in an environmental chamber under uniform conditions.

Birds were not handled for one week after being placed in the chamber. Feeding and watering was done daily at the start of the photoperiod. During the adjustment period P-18 mash was fed the birds *ad libitum*. Birds were weighed every three days after the first week until body weights stabilized (less than a 1 percent change in weight over a 3-day period). Weight of birds and the dry weight of food consumed and excreta produced were measured to the nearest 0.1 gram. All weighings of birds were made immediately following the beginning of the photoperiod to minimize diurnal differences in weight (West 1960). Preceeding the weighings, all food and water vials were removed from the cages of birds to be weighed to insure no additional weight gain from eating or drinking.

Each seed species and the birds fed each species were randomly selected. Because of random selection for each feeding trial the same bird could have been fed the same seed on several occasions. Each feeding trial lasted for 2 consecutive 3-day periods.

Water and feed were provided *ad libitum*. Each feed was fed to a total of 9 birds for a 6-day period (i.e., a total of 18, 3-day periods). Fecal collections were made and birds weights and grams of food remaining were determined at the end of the third and sixth day of each 6-day trial. Fecal material was collected from each cage and all spilled seeds were separated from the fecal matter. Fecal collections were placed in glass vials, identified as to seed species, date of collection and bird number, then stored at -16°C until analyzed.

Preliminary to caloric analysis, the feces were dried at 60°C to obtain dry weight. Dried feces were then ground in a Wiley mill with a 20 mesh-to-the-inch screen.

Caloric determinations of all samples in this study were made using a Parr 1200 adiabatic calorimeter with a Parr 1101 oxygen bomb under 30 atmospheres of oxygen. Approximately 1-gram samples of feces or feed were used in each bombing and all analyses were made in duplicate. The caloric value of each fecal collection was subtracted from the gross energy of the food consumed during the 3-day period to give the metabolizable energy which is the equivalent of the available energy defined by Kleiber and Dougherty (1934). Some slight loss of energy likely resulted from fermentation of undigested food and energy utilized by bacteria in the large intestine (Keindeigh 1949), but no correction was made. The Parr equipment was used according to the Parr instruction manual (1960).

Some birds lost weight during the 6-day trials. Before these birds were used again experimentally, they had to regain their pre-trial weight and stabilize.

Analysis

Data were analyzed by a three-way analysis of variance and Duncan's New Multiple Range Test ($P<0.05$) according to Fryer (1966). Data were analyzed for the first and second 3-day period to determine which period would provide more valid data with the assumption that the birds probably needed from one to three days to adjust to the diet change.

Data were adjusted for weight loss for both 3-day periods. Data were placed on IBM cards and all analyses were performed by a 360/50 IBM computer.

Metabolizable energy was obtained by subtracting the energy excreted from the gross energy consumed and efficiency was determined by dividing the metabolizable energy by the gross energy consumed times 100.

Experiment I

Experiment I was conducted in 1968 at 30°C, 14.5 hours photoperiod and 50 percent relative humidity. A photoperiod of 14.5 hours was selected as this approximates the hours of light outdoors under a mean environmental temperature of 30°C.

All feeds were fed to the birds in pelletized form. All 30 birds stabilized in weight prior to the first feeding trial. Feeding trials were conducted in three phases between which all birds were allowed to stabilize in weight before the next trial. Twenty-one birds (three for each of the seven feeds) were used during each of the three phases.

Experiment II

Experiment II was conducted in 1969 at 20°C, 10 hours photoperiod and 50 percent relative humidity. A photoperiod of 10 hours was selected as this approximates the hours of light outdoors under a mean environmental temperature of 20°C.

All feeds were fed to the birds as collected in the field, except acorn, which was shelled and ground to a rough mash. P-18 was presented as a fine mash. Birds began feeding trials as they stabilized. Trials were staggered: there was no repetition as in Experiment I. A minimum of three birds per seed species was used per 6-day trial.

Starvation experiment

Nine additional birds were used to measure the mean caloric content of feces from birds not fed for 2 consecutive 3-day periods (a 6-day trial). From the energy excreted and weight loss during the starvation trial, a weight loss factor was calculated. This weight loss factor was used to correct energy excreted, metabolizable energy and efficiency values for those birds on feeds which lost weight during Experiment I and II. All conditions and procedures used were identical with Experiment II. It was assumed there would be no difference in this weight loss factor between Experiment I and II.

RESULTS

General

Bioenergetic data were obtained for six seed species and the P-18 diet during 126 3-day trial periods. Variables measured were weight loss, grams of food consumed, gross energy consumed, grams excreted, energy excreted, metabolizable energy (M.E.) and efficiency (Tables 1 and 2).

Mean squares (Table 3) show significant differences ($P<0.05$) between the 3-day periods for all variables, except efficiency. Means were significantly greater the second 3-day period for grams of food consumed, gross energy consumed, grams excreted, energy excreted and M.E. and significantly less for weight loss. From these results, I decided the first 3-day period was a time of adjustment to the diet change and the second 3-day period provided the most valid measurements. All further comparisons therefore are based on the second 3-day period data (Table 2).

Differences between Experiments I and II

Each experiment was conducted at a different temperature and photoperiod (Experiment I at 30°C, 14.5 hours and Experiment II at 20°C and 10 hours). Therefore, differences between Experiment I and Experiment II may not be a result of temperature or photoperiod alone. Because of the significant interaction between Experiment and seed species, the comparisons (Duncan's New Multiple Range Test) between seed species was made on a within Experiment basis.

Metabolizable energy at 20°C and 10 hours

Metabolizable energy values ranged from 15.537 kcals/bird/3-days for ragweed to 98.180 kcals/bird/3-days for P-18. Ragweed, sumac and oak had the lowest M.E. values with 15.537, 25.445 and 23.952 kcals/bird/3-days, respectively. Sunflower and partridgepea were intermediate with 69.282 and 62.122

kcals/bird/3-days, respectively, and sorghum and P-18 had the highest M.E. with 92.277 and 98.180 kcals/bird/30 days, respectively. These groupings (lowest, intermediate and highest) were significantly (P<0.05) different from each other (Table 4).

Metabolizable energy at 30°C and 14.5 hours

At 30°, M.E. values ranged from 9.093 kcals/bird/3-days to 78.332 kcals/bird/3-days for P-18. Values at 30° were grouped differently from those at 20°. There was no significant difference between the mean M.E. for sumac, ragweed, oak and partridgepea (9.093, 13.741, 13.061 and 20.122 kcals/bird/3-days, respectively). Sunflower and sorghum were intermediate with 43.702 and 43.890 kcals/bird/3-days, respectively, and P-18 had the highest M.E. with 78.332 kcals/bird/3-days. These three groupings were significantly different (Table 5).

Efficiency at 20°C and 10 hours

Efficiencies ranged from 30.4 percent for sumac to 82.8 percent for sorghum. Sumac had the lowest efficiency, ragweed, partridgepea, oak and sunflower were intermediate with 40.2, 45.2, 55.3 and 48.3 percent, respectively, and P-18 and sorghum were highest with 75.1 and 82.8 percent, respectively. There were no significant differences between efficiencies.

Efficiency at 30°C and 14.5 hours

Efficiencies ranged from 26.3 percent for sumac to 81.5 percent for sorghum. Sumac was lowest with 26.3 percent, partridgepea, sunflower and oak were intermediate with 32.5, 50.0 and 53.9 percent, respectively, and P-18 ragweed and sorghum were highest with 73.8, 75.3 and 80.4 percent, respectively. There were no significant differences.

Weight loss at 20°C and 10 hours

Birds fed sumac lost the most weight, 21.1 g, birds on ragweed and oak were intermediate with 14.2 and 11.8 g lost, respectively, and birds on partridgepea, sunflower, sorghum and P-18 lost the least weight, 3.5, 0, -1.4 and -1.5 g, respectively. These groupings were significantly different (Table 4).

Weight loss at 30°C and 14.5 hours

Birds fed sumac and ragweed showed the greatest mean weight loss during the second 3-day period with 13.8 and 13.5 g, respectively. Oak and partridge-pea were intermediate in weight loss and sunflower, sorghum and P-18 showed the least weight loss. Significant differences are shown in Table 4.

Starvation experiment at 20°C and 10 hours

During the second 3-day period of the starvation experiment birds lost an average of 70.9 g, excreted an average of 9.3 g with a mean caloric value of 721 kcals/g. The mean energy excreted with 25.305 kcals/bird (0.3 x 2.721). A weight loss factor was determined to be 0.356 kcals/g weight lost/bird (25.305 70.9). This factor was used to correct the energy excreted, metabolizable energy and efficiency of birds in both Experiment 1 and 2.

Table 1. Means of variables analyzed for each seed species during Experiment 1 and Experiment 2 for the first 3-day period.

		VARIABLE	RAGWEED	SUMAC	OAK	SUNFLOWER	PARTRIDGEPEA	SORGHUM	P-18	STANDARD ERROR
Experiment II	20°C 10 hrs	WEIGHT LOSS (grams)	16.3	16.0	19.0	3.1	4.8	0.1	-3.1	1.1
		GRAMS CONSUMED	4.7	11.9	6.0	18.6	22.1	29.7	33.2	1.7
		GROSS ENERGY CONSUMED (kcals)	24.654	62.171	30.382	103.472	100.286	118.888	139.924	7.928
		GRAMS EXCRETED	4.2	11.4	5.0	11.3	13.9	5.9	10.5	1.3
		ENERGY EXCRETED (kcals)	9,166	45,267	12,007	48,146	55,290	22.184	34.586	6.076
		METABOLIZABLE ENERGY (kcals)	15.488	16.904	18.375	55.326	44.996	96.704	105.338	3.847
		EFFICIENCY (percent)	62.8	27.2	60.5	53.5	44.9	81.3	75.2	16.8
Experiment I	30°C 14.5 hrs	WEIGHT LOSS (grams)	15.3	19.9	14.6	11.3	14.1	3.2	0.0	1.4
		GRAMS CONSUMED	1.1	5.6	3.9	7.9	7.4	15.3	22.6	1.7
		GROSS ENERGY CONSUMED (kcals)	6.046	29.032	19.559	43.840	33.849	61.331	95.234	7.928
		GRAMS EXCRETED	1.8	5.6	3.0	7.6	7.1	2.8	7.8	1.3
		ENERGY EXCRETED (kcals)	0.553	16.681	7.575	28.037	23.659	9.559	25.813	6.076
		METABOLIZABLE ENERGY (kcals)	5.493	12.351	11.984	15.803	10.190	51.772	69.421	3.847
		EFFICIENCY (percent)	90.9	42.5	61.3	36.0	30.1	84.4	72.9	16.8

Table 2. Means of variables analyzed for each seed species during Experiment 1 and Experiment 2 for the second 3-day period.

		VARIABLE	RAGWEED	SUMAC	OAK	SUNFLOWER	PARTRIDGEPEA	SORGHUM	P-18	STANDARD ERROR
Experiment II	20°C 10 hrs	WEIGHT LOSS (grams)	14.2	21.1	11.8	0.0	3.5	-1.5	-1.4	2.0
		GRAMS CONSUMED	7.3	16.1	8.5	25.8	30.2	27.9	31.0	1.6
		GROSS ENERGY CONSUMED (kcals)	38.625	83.800	43.346	143.536	137.420	111.472	130.743	7.655
		GRAMS EXCRETED	7.2	14.6	6.1	16.7	18.5	5.1	10.1	1.1
		ENERGY EXCRETED (kcals)	23.088	58.355	19.394	74.254	75.298	19.195	32.563	4.958
		METABOLIZABLE ENERGY (kcals)	15.537	25.445	23.952	69.282	62.122	92.277	98.180	5.318
		EFFICIENCY (percent)	40.2	30.4	55.3	48.3	45.2	82.8	75.1	29.6
Experiment I	30°C 14.5 hrs	WEIGHT LOSS (grams)	13.5	13.8	7.4	2.1	6.1	1.6	-0.1	2.0
		GRAMS CONSUMED	3.5	6.6	4.8	15.7	13.6	13.5	25.1	1.6
		GROSS ENERGY CONSUMED (kcals)	18.256	34.527	24.238	87.372	61.839	53.871	106.008	7.655
		GRAMS EXCRETED	2.7	6.6	3.1	9.5	11.0	2.6	8.4	1.1
		ENERGY EXCRETED (kcals)	4.515	25.434	11.177	43.670	41.717	9.982	27.676	4.958
		METABOLIZABLE ENERGY (kcals)	13.741	9.093	13.061	43.702	20.122	43.890	78.332	5.318
		EFFICIENCY (percent)	75.3	26.3	53.9	50.0	32.5	81.5	73.9	29.6

Table 3. Mean squares of variables analyzed from three-way analysis of variance.

Source	DF	Weight Loss	Grams Consumed	Gross Energy Consumed	Grams Excreted	Energy Excreted	Metabol. Energy	Efficiency
Experiment	1	112[2]	5139[3]	113398[3]	1189[3]	19950[3]	38220[3]	6.481[2]
Seed	6	1905[3]	2726[3]	45752[3]	487[3]	9704[3]	36300[3]	3.477[3]
Period	1	685[3]	496[3]	13970[3]	242[3]	5303[3]	2059[3]	0.445
Exp. X Seed	6	130[3]	213[3]	3952[3]	40[3]	1007[3]	2642[3]	0.394
Exp. X Per	1	271[3]	7	98	17	304	749[1]	0.016
Seed X Per	6	99[3]	140[3]	3524[3]	44[3]	915[3]	983	1.357
Exp. X Seed X Per	6	39	24	497	5	94	277	0.998
Error	224	26	24	516	12	247	206	0.991

[1]Significantly different ($P<0.10$)

[2]Significantly different ($P<0.05$)

[3]Significantly different ($P<0.01$)

Table 4. Means of metabolizable energy and weight loss at 20°, 10 hours and 30°C, 14.5 hours. Values underlined are not significantly different ($P<0.05$) using Duncan's New Multiple Range Test.

Metabolizable Energy (kcals)		Ragweed	Oak	Sumac	P. pea	Sunfl.	Sorg.	P-18
	20° 10 hours	15.537	23.952	25.445	62.122	69.282	92.277	98.180
		Sumac	Oak	Ragweed	P. pea	Sunfl.	Sorg.	P-18
	30° 14.5 hours	9.093	13.061	13.741	20.122	43.702	43.890	78.332
Weight Loss (grams)		Sumac	Ragweed	Oak	P. pea	Sunfl.	Sorg.	P-18
	20° 10 hours	21.1	14.2	11.8	3.5	0	-1.4	-1.5
		Sumac	Ragweed	Oak	P. pea	Sunfl.	Sorg.	P-18
	30° 14.5 hours	13.8	13.5	7.4	6.1	2.1	1.6	-0.1

DISCUSSION

Since there were significant differences between the 3-day periods for all variables, except efficiency, the following discussion includes only the second 3-day period data. Significant Experiment x seed interaction prevented statistical comparisons of Experiment I and Experiment II means overaged over seed species. However, valid comparisons were made between experiments by using Experiment x seed species means.

Experiment I and II

Weight loss, grams of food consumed, grams excreted, gross energy consumed, energy excreted, metabolizable energy (M.E.) and efficiency were all significantly greater in Experiment II than in Experiment I. Whether or not these differences were a result of temperature or photoperiod or temperature x photoperiod interaction could not be determined. Case (personal communication) found a significant ($P<0.001$) temperature and photoperiod effect and a significant temperature x photoperiod interaction on M.E. and gross energy consumed for male bobwhite at 20°, 10 hours and 30°C, 15 hours. Gross energy consumed and M.E. increased from 30° to 20°C and decreased from 15 to 10 hours. His data suggest these effects may be offsetting. My results show a significant increase in M.E. and gross energy consumed from Experiment I (30°, 14.5 hours) to Experiment II (20°, 10 hours). Therefore, it is possible my experimental differences may be a result of temperature more than photoperiod.

For the sake of discussing the possible temperature effects, the possible photoperiod effects and temperature x photoperiod interactions will be overlooked. There was a significant experiment x seed interaction which revealed some effect of changing experiments (20°, 10 hours vs 30°C, 14.5 hours) which was not the same for each seed in my study. For comparing the possible temperature effects of my study with other works, this interactions will also be temporarily overlooked.

Kendeigh (1949) found gross energy intake and M.E. intake increasing as a straight line between +34° and -31°C in the house sparrow at 10 hours photoperiod. West (1968) studied captive willow ptarmigan (Lagopus lagopus) over a period of a year in outdoor cages and his results showed a significant decline in M.E. during the warmer, summer months. These data on M.E. support the results of my experiment. However, West (1968) also found that the efficiency of birds at lower temperatures was significantly less than that at higher temperatures, a conclusion opposite to the results of my experiment. This difference could be a result of the wide range of temperatures of West's study (-20.4° winter to 12.8°C summer) as opposed to my 20° to 30°C range. Also, since West's study was conducted over a period of a year there were many other factors influencing the energetics of the ptarmigan such as molt, egg laying, weight change and gross activity of the birds. These factors were minimized in my work by the use of male birds only, stabilizing weights and confining birds to very small areas.

West's studies (1960) on the tree sparrow in Illinois found that gross energy intake and M.E. increased with decreasing temperature. Such conclusions agree with the data collected in my study. Conversely, West (1960) found that the efficiency of birds increased with increasing temperature. Likewise, both Kendeigh (1949) and Seibert (1949) showed positive correlation between temperature and efficiency of winter acclimated house sparrows. However, Davis (1955) studied summer-acclimated birds and found an increase in efficiency up to 18°C, then a decrease in efficiency between 18° and 26°C. My bobwhite study was conducted in the 20° to 30°C range and thus my data may be more comparable to that of Davis than to West (1960), Kendeigh (1949) and Siebert (1949) since their studies extended over much greater temperature ranges (-31°C to +34°C).

The gross energy intake and M.E. data of my study conforms with most previous studies. The apparently anomalous result is the increase in efficiency of my birds at lower temperatures (20°C vs 30°C). West (1960, 1968) Kendeigh (1949) and Seibert (1949) all found efficiency increasing with increasing temperature. Davis (1955) found efficiency increased with temperature until 18°C then decreased sharply up to 26°C and Zimmerman (1965) found evidence of two peaks of efficiency in the dickcissel (Spiza americana). A fully adequate explanation for either set of results is not forthcoming from any of the above literature including Brody (1945) and Kleiber (1961). It is generally known that with decreasing temperatures, animals increase food consumption and as the mass of food ingested increases, the efficiency of digestion and absorption decreases. This partially explains the results of West (1960, 1968), Kendeigh (1949) and Seibert (1949) but sheds little light on the results herein and of those of Davis (1955) and Zimmerman (1965). A fairly good explanation is hypothesized by Zimmerman (1965). He reported that Dickcissels at 10 hours photoperiod showed an increase in excretory energy with decreasing temperature until 14°C. The excretory energy leveled off until 4°C when it rose again. At the same time the rate of feeding increasing with the decreasing temperature. If the excretory energy level remained constant from 14°C to 4°C with an increase in gross energy consumed the birds must have increased their efficiency. Zimmerman hypothesized that the (1965:377) " ... reduction of feces output, even while gross energy is increasing, must result from longer retention of food in the gut."

It seems that the most logical explanation of the increase in efficiency from 20° to 30°C may be the longer retention time of food in the gut of bobwhites at the lower temperature. At 20°C, birds consumed 9.2 more g/bird the second 3-day period than at 30°C while they only excreted 4.9 g/bird more at 20° than at 30°. This is a difference of 4.3 g. It could have been that the birds metabolized this difference as a result of longer retention of food in the gut, therefore more opportunity for increased digestion and absorption. Since the birds metabolized a greater percentage of the food consumed at 20°C, they were therefore more efficient.

Photoperiod effects

It was not possible to separate temperature and photoperiod effects in this study as birds held at 20° and 30°C were under photoperiods of 10 hours and 14.5 hours, respectively. Any difference between Experiment I and II for any of the variables analyzed may have been a result of either temperature or photoperiod, or both.

Kendeigh (1970) summarizes the work of various investigators who have studied photoperiod effects on metabolizable energy for thirteen species of birds. Significant ($P<0.05$) photoperiod differences were found in seven of the thirteen species including three phasionids (pheasants).

Data more comparable to my study have been analyzed by Case (personal communication). Case determined the M.E. (equals existence energy when birds weights are constant) of male bobwhites at 10 hours and 15 hours photoperiod over a range of 30°C (5° to 35°C). At both 20° and 30°C M.E. was significantly greater in the 15 hour birds than in the 10 hour birds. Gross energy intake was also significantly greater in 15 hour birds than in 10 hour birds at both 20° and 30°C.

Management aspects

Although sorghum is an excellent food for bobwhite quail, they do not consume sorghum exclusively. As Errington (1936) found, no food is sufficient for survival by itself, and a supplementary diet is necessary. Robel (1963) studied the fall and winter food habits of bobwhite in Kansas and found sorghum the preferred seed both in frequency and percent of total volume of crop contents. Crops also contained significant amounts of sumac, sunflower, partridgepea, ragweed and corn. Korschgen (1948) found that bobwhites in Missouri preferred corn and consumed lesser amounts of ragweed, sorghum and oak. Errington (1936) stated that corn provides the most complete diet for bobwhite in the northcentral states, but that the most balanced diet during critical winter periods provides a variety of seeds in addition to the primary staple food.

Sumac, ragweed, oak, partridgepea and sunflower cannot be considered staple diets for bobwhite quail because of either their low M.E. content and efficiency or significant bird weight loss. Birds fed these seeds lost excessive (more than one percent of beginning weight) amounts of weight while on these diets for 3-days (except sunflower at 20°C). Weight losses show a slight leveling off the second 3-day period in birds fed sunflower and partridgepea. Longer feeding trials are necessary to determine whether or not bobwhite can survive for extended periods of time on any of these species.

Based on Duncan's New Multiple Range Test for significant mean differences, I was able to classify the six seed species as "good," "fair," or "poor" according to their statistical rank in an ordered array of means. Metabolizable energy and weight loss were the variables used as criteria for determining each seed's classification. Sumac, oak and ragweed were "poor," partridgepea and sunflower were "fair" and sorghum was rated "good." The "poor" seed species, sumac and ragweed, have been found by various investigators to be supplementary foods (Robel 1969, Baumgartner et al. 1952, Korschgen 1952) to diets that contain more staple seeds such as corn and sorghum.

Nestler and Bailey (1944) conducted feeding tests to determine the value of sumac fruits as the sole diet of quail as well as supplemental to other feed stuffs. Bobwhites were force-fed sumac either alone or with millet or were fed sumac seed *ad libitum*. Many sumac seeds passed through the birds undigested (similar results were noted in my study when feces were collected from the cages). The quail lost weight nearly as rapidly on sumac alone as when fed nothing. Quail maintained their weight for 14 weeks during the fall and winter, outdoors, when fed a diet of 50 percent sumac with other foodstuffs of high feeding value, although a severe neck molt occurred in the birds during the ninth week. On a 75 percent sumac diet heavy mortality occurred during the third and fourth weeks and in spite of being kept from adverse weather the quail lost weight nearly as fast as those on a 100 percent sumac diet. The neck molt which occurred in the ninth week of the 50 percent sumac trial occurred in the first week of the 75 percent sumac trial. Nestler and Bailey (1944:696) concluded that, "even though sumac fruit is eaten by bobwhites, and as a small percentage of the diet it may have definite nutritional value, nevertheless as the sole or primary article of diet, it cannot be expected to maintain quail through a critical period in the winter." No concise definition of a critical period is given, but Errington (1936) implies these crises periods occur when staple food supplies are depleted or covered with snow and temperatures are abnormally low.

The conclusions of Nestler and Bailey are substantiated by the data of my study. Bobwhites lose weight most rapidly on sumac, do not efficiently utilize the available energy in sumac (if, in fact, it is available) and they eat less of it than seeds with higher metabolizabl energy values. Sumac is not a staple diet, but this is not to imply that it is not important as part of the total diet of bobwhites throughout the year.

Errington (1936) states that lesser ragweed and acorn mast may be of outstanding value as a diet for pheasants and quail. Data from my study do not substantiate this. Giant ragweed and oak were found to be "poor" diets for quail when they were the exclusive food.

It is only under very exceptional conditions that bobwhite are forced to feed exclusively on a single seed species. However, these conditions do occur. Heavy snowfall which would cover most food sources and restrict bird movement, combined with low temperatures which would increase heat loss of birds and necessitate an increase in gross energy consumption may, in some areas, coerce the birds to a single species diet. Under these extreme conditions, the question is then, on which seed species could bobwhites survive best? From data obtained in this study, it appears that quail can survive well on sorghum and may survive extended critical periods on partridgepea or sunflower. However, bobwhites probably will not survive when the only diet choice is ragweed, sumac or oak.

In the course of the feeding trials it became obvious some species of seeds were preferred over others. No attempt was made to determine palatability in my study.

There was no evidence to support the hypothesis (Kendeigh and West 1965) that birds consume more of those seed species with the higher energy content ratios. In fact, sorghum and partridgepea had the lowest per gram caloric value, but bobwhites consumed more grams of these two species than of any other species during both experiments (except sunflower in Experiment I).

Chemical analysis

Chemical analysis of all the seed species used in this experiment (except partridgepea) are available from several sources (Korschgen 1964, King and McClure 1944) and are presented in Table 6. Although no statistical analysis was done, there appears to be no obvious correlation between metabolizable energy, grams consumed, efficiency or weight loss and the percentage of protein, fat or nitrogen free extract present in each seed species. Dr. Deyoe (personal communication) of Kansas State University Milling and Grain Science Department commented that each parameter analyzed (protein, fat, and nitrogen free extract) is interrelated when considering palatability, digestibility and metabolizable energy of the different seeds. These relationships make it very difficult (if possible at all) to correlate any of the seed components with metabolizable energy, weight loss and efficiency. For example, the caloric value of each of the chemical components of a seed species are related to the percentage of all the other components both singly and in any combination. To correlate metabolizable energy, efficiency weight loss or grams consumed with the chemical composition of any of these seeds would be very difficult.

Starvation experiment

The starvation experiment demonstrated that even without feeding, bobwhite quail will excrete fecal material with a measurable caloric-value (2.721 kcals/g) at 29°C. Starving birds lost significantly more weight in the 6-day trial than did birds fed sumac, oak, ragweed or partridgepea at 20°C. Birds fed only these seeds do have a better chance of surviving than starving birds, but it was not determined how long bobwhites could survive on these seeds.

If it is assumed that the caloric value of the feces from starving birds is a reflection of weight loss from tissue breakdown within the bird, then a truer estimate of the metabolizable energy of feeds could be obtained for birds losing weight during the experiment. In effect, this is correlating the metabolizable energy of the diet for the percentage of energy in the feces, resulting from tissue breakdown (weight loss). This assumption and the following data suggest that the metabolizable energy of several of the seed species is greater than previously determined.

The energy lost per gram of weight lost was determined by dividing the mean energy excreted by the mean weight lost. The mean weight lost for the 6-day starvation trial was 70.9 g/bird and the mean energy excreted for the same period was 25.305 kcals/bird. Therefore, this weight loss factor was 0.356 kcals/g/bird (25.305 ÷ 70.9).

I am assuming this factor (0.356 kcals/g/bird) to be a constant for all birds exhibiting weight loss. Thus, 0.356 times the mean weight lost (g) per 6-day period provides an estimate of the excretory energy resulting from weight loss. These estimates of the excretory energy resulting from weight loss were then subtracted from the original excretory energy to obtain a new estimate of excretory energy resulting from seed consumption.

This new excretory energy was then subtracted from gross energy consumed to obtain a new estimate of the metabolizable energy per bird.

The increase in metabolizable energy also increased the efficiency of utilization of the seed energy of the birds. The new efficiency values were obtained by dividing the corrected metabolizable energy by the gross energy consumed times 100.

NOTES ON PROCEDURE

There are other possible sources of variation, not analyzed for, that should be pointed out.

It was assumed that photoperiod had little effect on the results. However, each of these experiments (I and II) were conducted, 1) at different times of the year, 2) with different personnel, and 3) with seeds that were collected in successive years.

The time of the year didn't appear to be significant and neither would the fact different persons ran the two experiments. However, the varying seed sources may possibly have affected the results, particularly since in Experiment I the seeds were ground and present in pelletized form, while in Experiment II the seeds were fed the birds as collected, except for oak. This could have caused differences in the grams consumed between seed species at 20° and 30° and consequently differences in gross energy consumed, M.E. and efficiency. The amount of this possible error was not estimated.

My method of separating feces and spilled seeds was possibly an uncorrectable source of slight error in the grams consumed, grams excreted and caloric values of the excrement. Several seed species, in particular sumac and partridgepea, readily passed through the birds intact making some decisions about sorting or leaving seeds in the feces very difficult.

The 9.5 and 14.5 hours of darkness appeared to be adequate time for all food ingested to pass through the birds as McFarland and Freedland (1965) found that ingesta passed completely through an alimentary tract of Japanese quail (*Coturnix coturnix*) in 1-2 hours. If this assumption is made for bobwhite quail all body weights should be free of bias from full of partly filled alimentary tracts.

CONCLUSIONS

1. Sorghum had a significantly higher metabolizable energy and efficiency value than any of the other species at 20°C and 10 hours.
2. Birds fed sorghum gained weight while birds fed the other seed species lost weight (except for sunflower in Experiment II).
3. Weight loss, grams consumed, gross energy consumed, grams excreted, energy excreted, metabolizable energy and efficiency were significantly greater in Experiment II than in Experiment I. Whether these differences were a result of temperature or photoperiod could not be determined.
4. There were significant differences between the first and second 3-day period for all variables except efficiency. Therefore, the first 3-day period was considered an adjustment period and the second 3-day period data were used for comparison and discussion.
5. Sumac, oak and ragweed were rated "poor" seed species, partridgepea and sunflower were "fair" and sorghum was rated a "good" seed species, based on statistical comparisons of the weight loss and metabolizable energy values of each seed species.
6. The caloric value of the feces of birds fed nothing was 2.721 kcals/g/bird for the 6-day trial and was assumed to reflect tissue breakdown as the starving birds lost weight. These starvation data allowed energy excreted, M.E. and efficiency to be corrected for weight loss.

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LITERATURE CITED

Baumgartner, F. M., M. J. Morris, J. L. Steele, and J. E. Williams. 1952. Oklahoma bobwhite food relations. Trans. N. A. Wildl. Conf. 17:338-359.

Brody, S. 1945. Bioenergetics and growth. Reinhold Publ. Corp. New Yor. xii + 1023 pp.

Davis, E. A. 1955. Seasonal changes in the energy balance of the English Sparrow. Auk 72(4):385-411.

Errington, P. L. 1936. Differences in nutritive values of winter game foods. Trans. N. A. Wildl. Conf. p 356-360.

Fraps, G. S. 1945. Utilization of metabolizable energy by growing chicks. Tex. Agr. Exp. Sta. Bull. 665.

Fryer, H. C. 1966. Concepts and methods of experimental statistics. Allyn and Bacon, Inc. Boston, Mass. 602 pp.

Johnson, S. R. and R. J. Robel. 1968. Caloric values of plant seeds from four range sites in northeastern Kansas. Ecology 49(5):956-961.

Kendeigh, S. C. 1949. Effect of temperature and season on the energy resources of the English Sparrow. Auk 66(2):113-127.

Kendeigh, S. C. 1970. Energy requirements for existence in relation to size of bird. Condor 72(1):60-65.

Kendeigh, S. C. and G. C. West. 1965. Caloric values of plant seeds eaten by birds. Ecology 46(4):553-555.

King, T. R. and H. E. McClure. 1944. Chemical composition of some American wild feedstuffs. Jour. Agr. Res. 69(1):33-46.

Kleiber, M. 1961. The fire of life - an introduction to animal energetics. John Wiley and Sons Inc., New York, 454 pp.

Kleiber, M. and J. E. Dougherty. 1934. The influence of environmental temperature on the utilization of food energy in baby chicks. J. Gen. Physiol., 17:701-726.

Korschgen, L. J. 1948. Late-fall and early-winter food habits of bobwhite quail in Missouri, J. Wildl. Mgmt 12(1):45-57.

______________. 1952. Analysis of the food habits of bobwhite quail in Missouri. Mo. Conservation Comm. Rept. March 1952. 59 pp.

______________. 1964. Foods and nutrition of Missouri and midwestern pheasants. Trans. N.A. Wildl. Conf. 29:159-181.

McFarland, L. Z. and R. A. Freedland. 1965. Time required for ingesta to pass through the alimentary tract of Coturnix. Am. Zool. 5(2):242.

Nestler, R. B. 1949. Nutrition of bobwhite quail. J. Wildl. Mgmt. 13(4): 342-358.

Nestler, R. B. and W. W. Bailey. 1944. Sumac fruit as a food for bobwhite quail. Am. Midland Nat. 31(3):689-696.

Parr Instrument Company. 1960. Oxygen-bomb calorimetry and combustion methods. Tech. Man. 130, Moline, Ill. 56 pp.

Robel, R. J. 1963. Fall and winter food habits of 150 bobwhite quail in Riley County, Kansas. Trans. Kans. Acad. Sci. 66(4):778-789.

__________. 1969. Food habits, weight dynamics and fat content of bobwhite in relation to food plantings in Kansas. J. Wildl. Mgmt. 33(2):237-249.

Robel, R. J. and W. R. Harper. 1965. Energy content and retention by ragweed and sunflower seeds during fall and winter. Trans. Kans. Acad. Sci. 68(3):401-405.

Robel, R. J. and N. A. Slade. 1965. The availability of sunflower and ragweed seeds during fall and winter. J. Wildl. Mgmt. 29(1):202-206.

Seibert, H. C. 1949. Differences between migrant and non-migrant birds in food and water intake at various temperatures and photoperiods. Auk 66(2):128-153.

West, G. C. 1960. Seasonal variation in the energy balance of the Tree Sparrow in relation to migration. Auk 77:306-329.

__________. 1968. Bioenergetics of captive willow ptarmigan under natural conditions. Ecology 49(6):1035-1045.

West, G. C. and M. S. Meng. 1966. Nutrition of willow ptarmingan in northern Alaska. Auk 83:603-615.

Wycoff, R. G. 1964. Nutritive content of foods utilized by bobwhite quail in the longleaf pine type of Rapides and Evangeline parishes, La. M.S. Thesis, Louisiana State Univ. 76 pp.

Zimmerman, J. L. 1965. Bioenergetics of the Dickcissel, _Spiza americana_. Physiol. Zool. 38(4):370-389.

APPENDIX

Table 5. Nutritional Analysis of Experimental Seeds Expressed as Percentages[1]

Seed[2]	Moisture	Protein	Fat	N.F.E.	Fiber	Ash	Ca	P
Giant Ragweed	3.20	18.80	23.60	20.73	29.70	3.97	.30	.07
Smooth Sumac	5.33	4.94	16.29	43.39	27.25	2.88	.48	.24
Pin Oak	11.60	4.99	17.60	51.91	12.20	1.70	.16	.13
Sunflower, annual	4.68	19.50	26.10	16.08	30.20	3.44	.24	.62
Sorghum	9.88	12.20	3.65	64.68	5.93	3.66	.06	.42

[1]From Korschgen (1964)

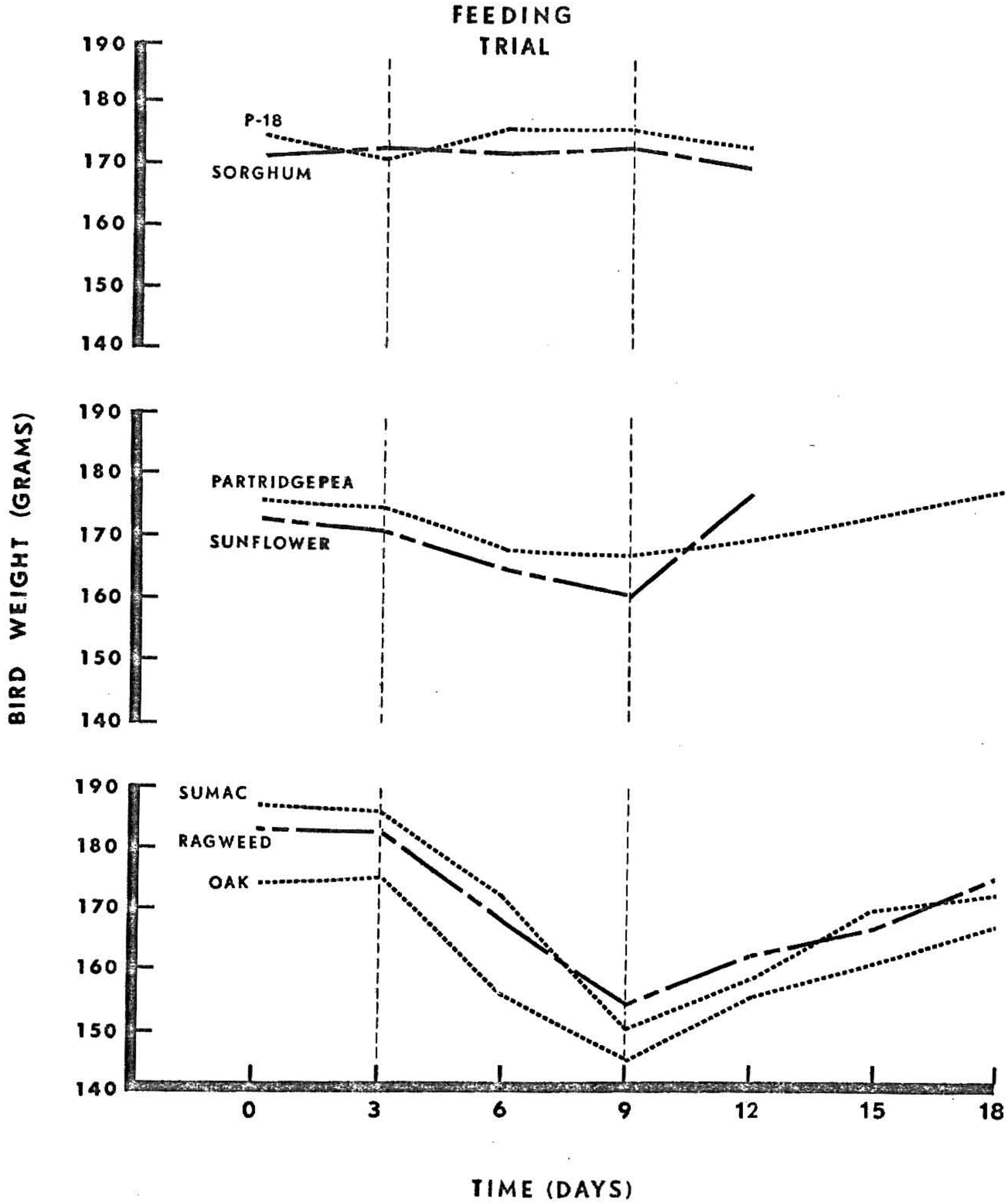
[2]No data for partridgepea (*Cassia nictitans*)

Table 6. Caloric values, moisture content and percent dry weight of experimental seeds and control diet dried at 60°C for 72 hours.

Species	Caloric[1/] Value (Kcals/gm)	Percent Moisture	Percent Dry Weight
Ambrosia trifida Giant Ragweed	5.283	15.8	84.2
Rhus glabra Smooth Sumac	5.205	9.7	90.3
Quercus palustris Pin Oak	5.073	26.9	73.1
Helianthus annus Sunflower	5.573	9.5	90.5
Cassia nictitans Partridgepea	4.547	10.0	90.0
Sorghum vulgare Sorghum grain	3.997	14.8	85.2
P-18 mash Control Diet	4.216	6.0	94.0

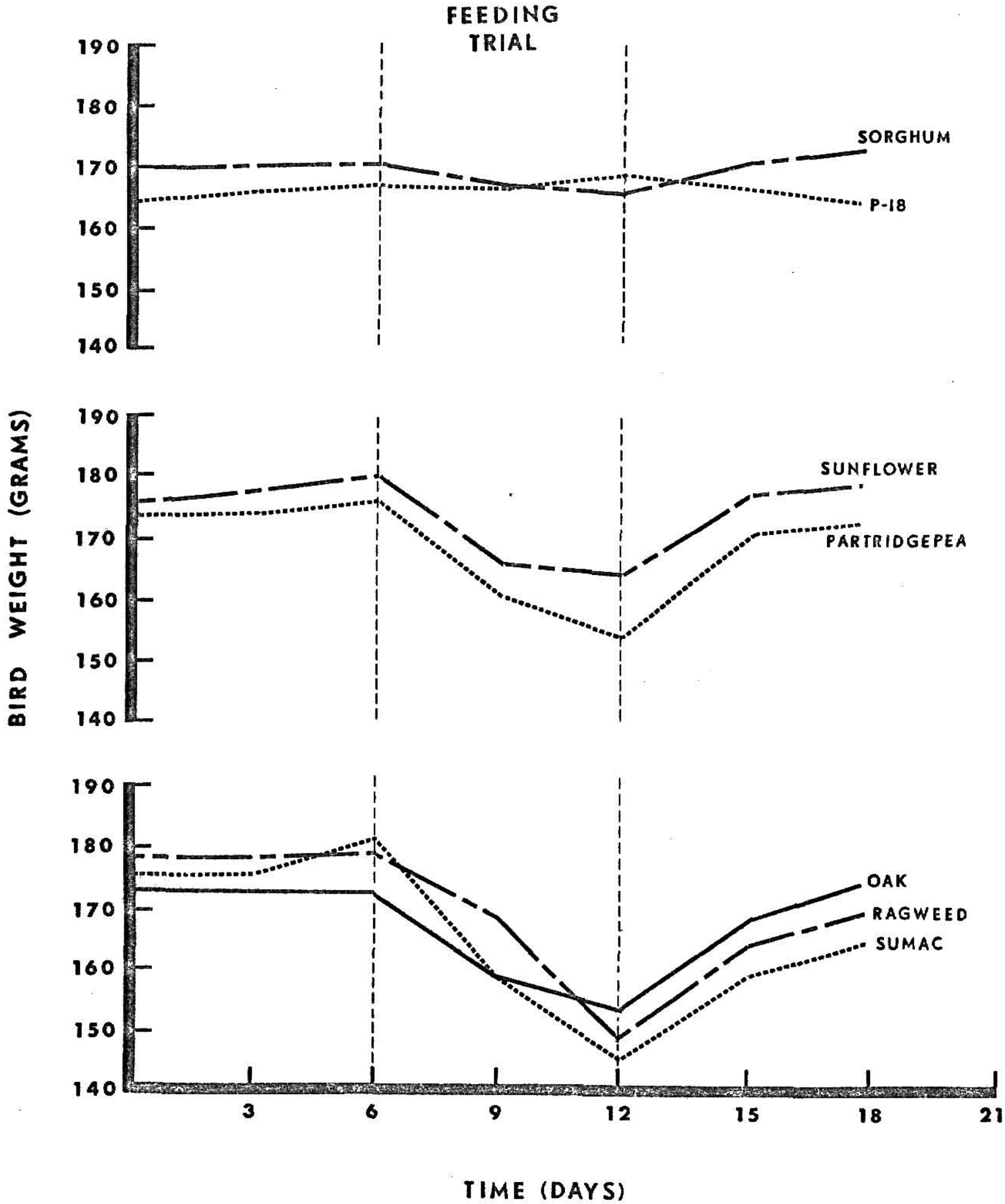
[1/] Caloric value sources: Ambrosia, Helianthus and Rhus from Johnson and Robel (1968).
Cassia and Sorghum from D. V. Derksen (unpublished data).
Quercus from T. M. Clement
P-18 mash from Ron Case (personal communication).

Fig. 1. Mean weight changes for nine birds on each diet preceeding, during and after 6-day feeding trials at 20°C and 10 hours photoperiod.



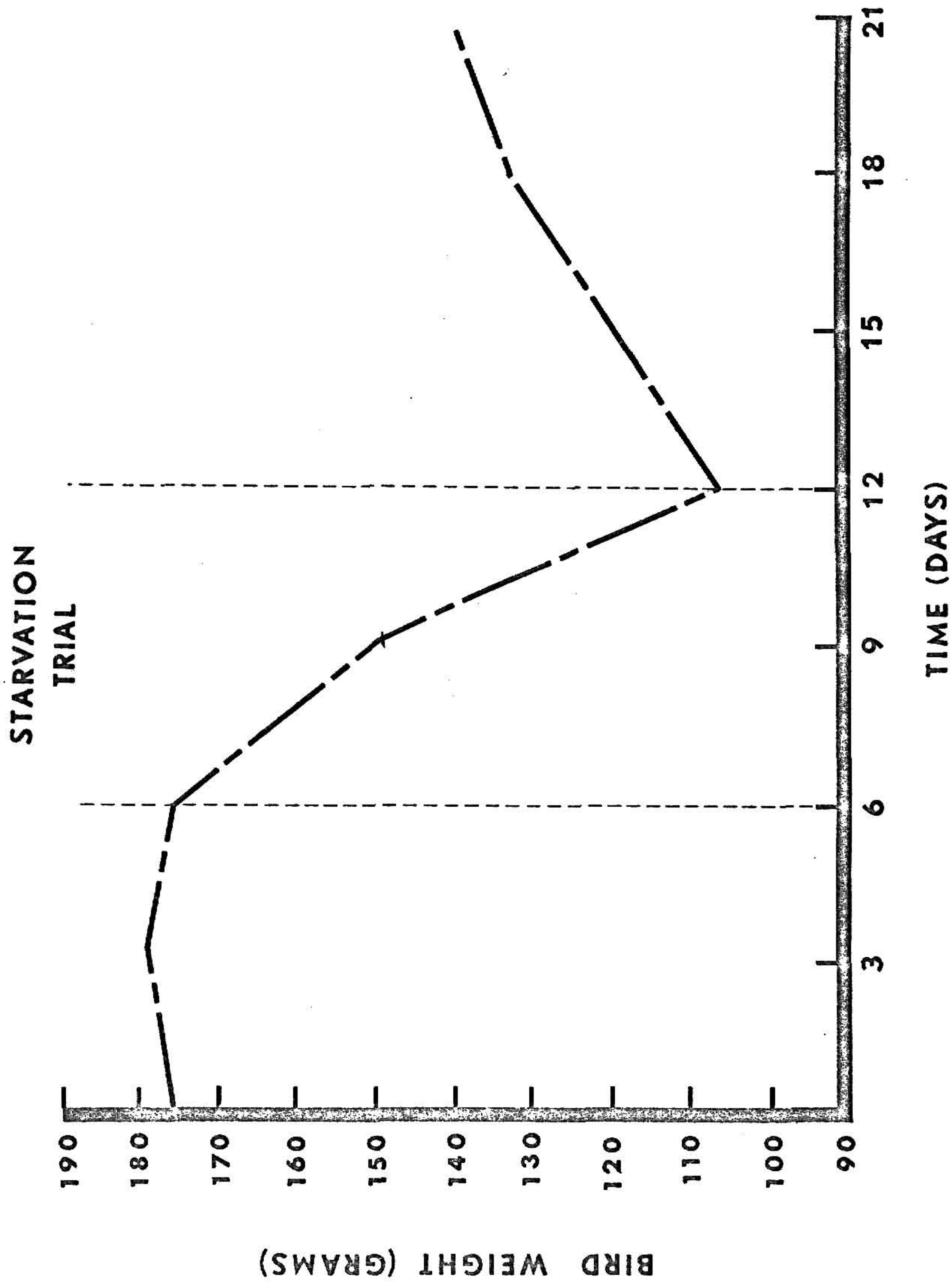
FEEDING TRIAL
BIRD WEIGHT (GRAMS)
190
180
170
160
150
140
P-18
SORGHUM
PARTRIDGEPEA
SUNFLOWER
SUMAC
RAGWEED
OAK
0
3
6
9
12
15
18
TIME (DAYS)

Fig. 2. Mean weight changes for nine birds on each diet preceeding, during and after 6-day feeding trials at 30°C and 14.5 hours photoperiod.



FEEDING TRIAL
190
180
170
160
150
140
SORGHUM
P-18
BIRD WEIGHT (GRAMS)
SUNFLOWER
PARTRIDGEPEA
OAK
RAGWEED
SUMAC
3
6
9
12
15
18
21
TIME (DAYS)

Fig. 3. Mean weight loss of nine birds preceeding, during and after 6-day starvation experiment at 20°C and 10 hours photoperiod.


STARVATION TRIAL
BIRD WEIGHT (GRAMS)
190
180
170
160
150
140
130
120
110
100
90
TIME (DAYS)
3
6
9
12
15
18
21

METABOLIZABLE ENERGY VALUES OF SOME

PLANT SEEDS CONSUMED BY BOBWHITE

QUAIL IN KANSAS

by

THOMAS MALCOLM CLEMENT Jr.

B.S., Washington State University, 1968

A MASTER'S THESIS

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requirements for the degree

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1970

Approved by:

____
Major Professor

Previous studies in Kansas have determined the energy content of some bobwhite quail (Colinus virginianus) foods (Johnson and Robel 1965; Robel and Harper 1965). The next step was to determine the metabolizable energy (M.E.) content of some selected quail foods. This study was part of a larger, continuing study of the bioenergetics of bobwhite quail at Kansas State University under the direction of Dr. R. J. Robel.

Two separate experiments were conducted in 1968 and 1969 under different environmental conditions. The 1968 test (Experiment I) was conducted at 30°C., 50% humidity and 14.5 hours of light and the 1969 (Experiment II) trial was conducted at 20°C., 50% humidity and 10 hours photoperiod. Birds were caged in separate 48 x 25 x 13 cm plastic boxes with wire covers and bottoms. All birds were contained within an environmental chamber during each experiment. Birds were stabilized on a high protein, chick mash diet before fed experimental seeds. Each feeding trial lasted six days and fecal collections, bird's weights, and food consumption data were taken after the first three days and after the six day trial. All seeds and water were fed the birds ad libitum. A three-way analysis of variance and Duncan's New Multiple Range Test ($P<0.05$) were performed on the data according to Fryer (1966).

Results for the 6-day trials showed that sorghum (Sorghum vulgare) had a significantly higher M.E. value than any other seed in both experiments. Significant differences existed between the means of all variables (except efficiency) measured during the two 3-day periods. From these results, I decided the first 3-day period was a time of adjustment to the diet change and the second 3-day period provided the most valid measurements. All discussion and conclusions were based on data from the second 3-day period.

Sumac and ragweed were rated "poor" seed species, oak, partridgepea and sunflower were "fair" and sorghum was rated a "good" seed species, based on statistical comparisons of the weight loss, metabolizable energy and efficiency values of each seed species.

The caloric value of the feces of birds fed nothing was 2.721 kcals/g/bird for the 6-day trial at 20°C and 10 hours and was assumed to reflect tissue breakdown as the starving birds lost weight. These starvation data allowed energy excreted, M.E. and efficiency to be corrected for weight loss in those birds exhibiting weight loss. These variables were found to be greater after being corrected for weight loss.