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The comparative energetics of some game birds, such as bobwhite quail, phessants, and some grouse fed wild and domestic seeds, have been determined, but little is known about the bioenergetics of the Scaled Quail of southwestern Kansas. The purpose of this investigation was to determine which of twelve different seeds, sorghum, Kester's milo, Kester's switchgrass, Blackwell switchgrass, amaranth, bulk amaranth, canary grass, Korean lespedeza, Western wheat grass, sanddrop seed, pearl millet, and sunflower chips, were best metabolized by Scaled Quail (Callipepla squamata) under the stress of simulated winter conditions. Based on utilization efficiencies, metabolized energies, and body weight changes of the quail, individual seeds were placed into categories of poor, good or excellent. Korean lespedeza and both switchgrasses were placed into the poor category, whereas sanddrop seed, Kester's milo and canary grass were considered to be good. Amaranth, bulk amaranth, sorghum, pearl millet, and sunflower chips were placed into the excellent category, since quail fed those seeds exhibited the best maintenance of body weights and highest metabolic utilization efficiencies. Western wheat grass, in contrast, was not eaten by any of the birds and was

considered an extremely poor food source for Scaled Quail. Poorly metabolized seeds, such as the switchgrasses, still may be of use to Scaled Quail, when accompanied by a well metabolized seed such as amaranth since birds given a choice of both amaranth and switchgrass did equally as well as birds given amaranth alone.

Metabolic similarities and differences were found when the results from Scaled Quail were compared to previous investigations with Northern Bobwhites fed similar diets. Overall, the bioenergetics of the Scaled Quail and bobwhite quail appear to be similar.

Bioenergetics of Wintering Scaled Quail

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INTRODUCTION

One component of the effective management of game birds involves assessing the importance of various food sources. The most valuable method is through the use of bioenergetics. Bioenergetics is the science, or the means, of determining the amount of energy available in a food source and the amount of energy that can be obtained from that food source by an animal. Early research on avian bioenergetics included that of Kendeigh, (1949) who worked on the effects of temperature and seasonal variation on the energy resources of House (English) Sparrows (*Passer domesticus*), and that of Seibert (1949), who examined similar relationships in both migratory and nonmigratory birds. Subsequent work included that of West, (1960) who worked on the seasonal variations in the energy balance of the American Tree Sparrow (*Spizella arborea*) in relation to its migration, and that of Kontogiannis, (1968) who worked on the temperature and exercise effects on energy metabolism of the White-throated Sparrow (*Zonotrichia albicolis*). The importance of the study of bioenergetics of game birds was realized from those earlier works done on passerines. In 1963, Breitenbach and colleagues looked at the effects of limited food intake on cyclic annual changes in Ring-necked Pheasant hens (*Phasianus colchicus*). The bioenergetics of pheasants has been examined in greater detail recently (Solomon 1986). West (1968) worked on the bioenergetics of the Willow Ptarmigan (*Lagopus lagopus*). A more recent study involved the investigation of the energetics of the Canada

Goose (_Branta canadensis_) (Williams and Kendeigh 1982). The Northern Bobwhite (_Colinus virginianus_) has been extensively investigated in the Great Plains by R. J. Robel and his colleagues. They have shown that severe winters may provoke weight losses, reduce fat reserves, and increase mortality in bobwhites (Robel 1965, 1969, 1972; Robel et al. 1974; Robel and Fretwell 1970, Case 1982). Those studies suggested that it would be desirable to increase winter food supplies, preferably those which are best metabolized by the birds, in order to increase the survival of the quail during the stress of winter.

Although bioenergetic studies have been performed on a number of different game birds in an attempt to determine which foods were best metabolized, such data are lacking for the Scaled Quail (_Callipepla squamata_), a game bird of the southwestern United States. The purpose of the present laboratory study was to measure the ability of Scaled Quail to metabolize twelve different seeds, some of which are known to be eaten by wintering quail in their natural habitat (Martin et al. 1961, Schemnitz 1961, Ault and Stormer 1983).

MATERIALS AND METHODS

Thirteen Scaled Quail (eight males and five females) were trapped in southwestern Kansas, during the first week of January 1986, and placed in individual 31 cm x 23.5 cm x 23.5 cm cages constructed of 1.25 cm by 2.54 cm hardware cloth (Appendix 1). The top and sides of each cage were lined on the inside with standard fiberglass window-screen to prevent injury to the quail. Birds were maintained on a diet of Purina Chick Start and Grow (approximately 17 per cent protein) during all pretesting periods.

Seed testing trials consisted of two consecutive, 2-day trials for each seed. The seeds were fed individually except one trial in which the quail were supplied with a combination of amaranth and Blackwell switchgrass. All trials were carried out under a constant temperature of 5 C $\pm$ 0.5 C except during the first feeding trial when equipment problems allowed temperatures to rise to about 7 C; thereafter temperatures were maintained constant. A constant photoperiod of 10L:14D was used throughout the duration of the experiment. Two days prior to the start of each trial, the seed to be tested and the standard maintenance diet were mixed approximately half and half to assure that each bird was familiar with the subsequent test seed.

Previously weighed heavy duty aluminum foil was placed below the wire floor of each cage at the start of each 2-day trial to collect excreta and spilled seed. Birds were weighed to the nearest 0.1 gram at the beginning and end of each 2-day trial. Food was removed prior to the onset of the photoperiod to assure that none was consumed before weighing took place. The birds were weighed at the same time each day in order to obtain consistent data (Kontogiannis 1967). The quail were randomly divided into two groups of six or seven birds for all feeding. All trials ended with the same number of birds except for those quail fed Korean lespedeza or the switchgrasses. In all three of those trials one bird failed to eat sufficient quantities of seed to maintain its weight and was removed from the feeding trial. The data from those birds were not included in the energetic calculations. Thus, in each of those trials, the data are based on only five birds.

The twelve different seeds tested, which included some eaten by wintering quail in their natural habitat (Martin et al. 1961, Schemnitz 1961, Ault and Stormer 1983) were Kester's Wild Game Food Sorghum (Sorghum vulgare), Kester's switchgrass (Panicum virgatum) and canary grass (Phalaris canariensis) obtained from Kester's Wild Game Food Nurseries, Inc., Omro, Wisconsin; Blackwell switchgrass (Panicum virgatum), sanddrop seed (Sporobolus cryptandris), Western wheat grass (Agropyron smithii) and Korean lespedeza (Lespedeza stipulacea), obtained from Sharp Brothers Seed Company, Healy, Kansas; pigweed (Amaranthus hypochondriacus), bulk amaranth (Amaranthus spp.), which consisted of a mixture of high yield varieties of A. hypochondriacus and A. cruentus hybrids, and pearl millet (Pennisetum glaucum), which were supplied by the Kansas

State University Experiment Station at Hays, Kansas; and sorghum (<u>Sorghum vulgare</u>) and oil-type sunflower chips (<u>Helianthus</u> spp.), obtained from a local elevator. All seeds, along with water, and grit, composed of crushed granite, were provided <u>ad libitum</u> during each trial.

Excreta and spilled seed were collected, separated and weighed to the nearest 0.1 gram, at the end of each 2-day trial. Both the seed and excreta collections were then placed into a 65 C drying oven for five days. They were then reweighed to the nearest 0.1 gram, and the moisture content of each determined. Prior to caloric analysis, feed and excreta samples were ground separately using a mortar and pestle, then brushed through a 0.023 inch mesh screen. Samples were weighed to the nearest 0.1 mg before caloric analysis in a Parr (Model 1351) oxygen bomb calorimeter. A BASIC program was used to facilitate the caloric computations (Appendix 2). Duplicate analyses were performed on all excreta samples, while five separate analyses were performed on all test seeds. In a few instances where the duplicate excreta samples varied by more than five per cent in caloric content, a third sample was analyzed. All collected data were kept on a record form for each bird (Appendix 3). Gross energy intake (GE = caloric content of the seed x grams consumed), excretory energy output (EE = caloric content of the excreta x grams excreted), metabolized energy (ME = GE - EE), and utilization efficiency (UE = ME/GE x 100) were calculated from the data obtained from the caloric analyses. Because there were not significant differences in body weight changes or any of the energetic components between the first and second 2-day service periods, data were analyzed for the entire four days of feeding.

Statistical analyses were performed on a Zenith Z-150 microcomputer using the BIOM statistical package written by F. James Rohlf (1981). The Scheffe-box test for homogeneity of variance was run on the raw data using the program, HOMOV; comparison among the means was tested with a one-level nested analysis of variance using the program, NESTAN; and the range among all of the subsets of means was tested using the sum of squares program, SSSTP. The utilization values, which were expressed as percentages, were transformed using the arcsin transformation (Sokal and Rohlf, 1981). Differences among means were considered statistically significant if the calculated statistical value was equal to or greater than the table value at the 0.05 level (two-way tables).

RESULTS

Body Weights of the Quail

Mean pre-trial body weights ranged from 186.6 grams per bird to 200.8 grams per bird (Table 1). Mean weight changes of the birds during the studies ranged from -16.3 grams over a period of four days for birds fed Kester's switchgrass to an 8.9 grams gain for birds on a diet of sunflower chips (Table 1). Birds on diets of Kester's switchgrass, Blackwell switchgrass and canary grass had significantly greater weight losses, while birds fed diets of sunflower chips and bulk amaranth showed significant weight gains (Table 1). Only those birds fed Korean lespedeza, one of the switchgrasses or canary grass lost significantly more weight than any of the quail fed the Purina maintenance diet (Table 1).

Combustible Energy Content of Seeds and Seed Consumption

The caloric content of the maintenance diet and all of the seeds used in the experiment was near about 4.5 kcal/g, except sunflower which had a calorie content of about 6 kcal/g (Table 2). The amount of seed consumed varied from 9.2 grams per day for birds on a diet of Korean lespedeza (Table 3A) to 15.1 grams per day for birds fed sanddrop seed (Table 3B). Korean lespedeza, Kester's switchgrass (Table 3A), canary grass (Table 3B) and sunflower chips (Table 3C) were consumed in significantly lower quantities, while sanddrop seed (Table 3B) and the Purina maintenance diet (Table 3D) were cousumed in siguificantly greater amounts among the birds.

Table 1. Average pre-trial weights and changes in weight of Scaled Quail fed various seeds.

Seed	Pre-trial weight (g)	Body weight change (g)
Purina chick starter/grower	186.5 ± 3.8	- 1.7 ± 0.7
Sanddrop seed	191.7 ± 3.9	- 3.4 ± 0.7
Sunflower chips	192.8 ± 4.5	8.9 ± 0.9 [a]
Bulk switchgrass	193.0 ± 4.4	-16.3 ± 1.6 [b]
Blackwell switchgrass	193.4 ± 6.2	-11.3 ± 1.7 [b]
Sorghum	195.0 ± 4.2	- 1.2 ± 0.8
Amaranth (pigweed)	196.0 ± 5.8	- 0.1 ± 1.4
Pearl millet	196.2 ± 4.7	- 1.2 ± 0.9
Canary grass	198.5 ± 5.5	- 8.7 ± 1.9 [b]
Bulk amaranth	199.3 ± 3.6	3.1 ± 0.5 [a]
Korean lespedeza	199.5 ± 4.4	- 6.2 ± 0.7 [b]
Kester's milo	200.8 ± 4.4	- 4.9 ± 1.1

[a] Birds fed seeds with same letter gained significantly more weight than birds without letters or a different letter.

[b] Birds fed seeds with same letter lost significantly more weight than those without letters or a different letter.

Table 2. Average combustible energy content (kcal/g dry weight) of seeds tested (± SEM).

Seed	Caloric content[a]
Purina chick starter/grower	4.3 ± 0.03
Sanddrop seed	4.3 ± 0.04
Sorghum (milo)	4.3 ± 0.02
Kester's milo	4.4 ± 0.06
Pearl millet	4.5 ± 0.01
Amaranth (pigweed)	4.5 ± 0.03
Bulk amaranth	4.6 ± 0.02
Canary grass	4.6 ± 0.01
Korean lespedeza	4.6 ± 0.02
Blackwell switchgrass	4.7 ± 0.03
Bulk switchgrass	4.7 ± 0.02
Sunflower chips (oil-type)	6.1 ± 0.11

[a] Average of 5 trials.

Table 3A. Mean energetic values and standard errors for birds fed Korean lespedeza, Kester's switchgrass and Blackwell switchgrass.

Energy component	Korean lespedeza	Keater's switchgraas	Blackwell switchgrass
Number of birds	5	5	5
Grams consumed/day	9.8[a] ± 2.0	10.1[a] ± 2.9	11.1 ± 1.9
GE (kcal/bird/day)	49.1[a] ±10.2	47.7[a] ± 10.1	52.7 ± 9.2
GE (kcal/gram body weight/day)	0.248[a] ±.052	0.257[a] ± .057	0.278 ± .048
Grams excreted/day	5.4 ± 0.6	6.6[b] ± 1.1	4.9 ± 0.8
Kcal/gram excrement	3.6 ± 0.03	2.6[a] ± 0.2	3.7 ± 0.02
EE (kcal/bird/day)	19.2[b] ± 2.1	16.7 ± 1.9	18.2 ± 3.0
EE (kcal/gram body weight/day)	0.096 ±.034	0.090 ± .014	0.096 ± .015
ME (kcal/bird/day)	29.9[a] ± 2.4	31.0[a] ± 2.7	34.5[a] ± 6.3
ME (kcal/gram body weight/day)	0.152[a] ±.048	0.167[a] ± .012	0.182 ± .067
UE (%)	60.8[a]	61.7[a]	65.3[a]

Values significantly lower than those values from Tables 3A, 3B, 3C, and 3D.

[b] Values significantly higher than those values from Tables 3A, 3B, 3C, and 3D.

Table 3B. Mean energetic values and atandard errors for birds fed Kester's milo, canary grass, and sanddrop aeed.

Energy component	Kester's milo	Canary grass	Sanddrop seed
Number of birda	6	6	7
Grams consumed/day	12.2 ± 1.9	10.5[a] ±1.7	15.1[b] ± 1.4
GE (kcal/bird/day)	53.3 ± 8.4	48.6[a] ±8.0	65.4 ± 6.2
GE (kcal/gram body weight/day)	0.268 ±.040	0.256[a] ±.043	0.343[b] ±.068
Grams excreted/day	3.1 ± 0.4	4.7 ± 1.0	5.9 ± 0.6
Kcal/gram excreted	4.4[b] ± 0.08	2.7[a] ± 0.12	3.5 ± 0.08
EE (kcal/bird/day)	13.4 ± 2.0	12.8 ± 0.36	20.7[b] ± 2.8
EE (kcal/gram body weight/day)	0.067 ±.010	0.068 ±.011	0.109[b] ±.024
ME (kcal/bird/day)	40.0 ± 6.6	35.7[a] ± 6.9	44.7 ± 5.1
ME (kcal/gram body weight/day)	0.201 ±.031	0.188 ±.038	0.234 ±.048
UE (%)	74.5	74.1	68.3[a]

[a] Values significantly lower than those values from Tables 3A, 3B, 3C, and 3D.

[b] Values significantly higher than those values from Tables 3A, 3B, 3C, and 3D.

Table 3C. Mean energetic values and standard errors for birds fed amaranth, bulk amaranth, pearl millet, sorghum and sunflower chips.

Energy component	Amaranth	Bulk amaranth	Pearl millet	Sorghum	Sun flower
Number of birds	6	6	6	6	6
Grams consumed/ day	12.7 ± 1.1	13.9 ± 1.0	12.6 ± 1.0	13.1 ± 1.8	10.6[a] ± 1.8
GE (kcal/bird/ day)	57.5 ± 4.9	63.5 ± 4.8	56.2 ± 4.6	56.4 ± 7.7	64.5 ± 10.4
GE (kcal/gram body weight/day)	0.294 ±0.023	0.317 ±0.024	0.288 ±0.025	0.290 ±0.025	0.327 ±0.052
Grams excreted/ day	2.9 ± 0.21	3.3 ± 0.40	3.5 ± 0.80	5.1 ± 1.90	3.0 ± 0.40
Kcal/gram excreted	3.6 ± 0.03	3.0 ± 0.12	2.6 ± 0.23	1.9[a] ± 0.31	2.9[a] ± 0.09
EE (kcal/bird/ day)	10.4[a] ± 1.9	9.9[a] ± 1.1	9.2[a] ± 1.9	7.3[a] ± 1.8	8.8[a] ± 1.2
EE (kcal/gram body weight/day)	0.053 ±0.005	0.049[a] ± 0.11	0.048[a] ±0.005	0.038[a] ±0.005	0.045[a] ±0.006
ME (kcal/bird/ day)	47.1 ± 4.2	53.6[b] ± 4.5	47.0 ± 4.1	49.0 ± 7.8	55.8[b] ± 9.8
ME (kcal/gram body weight/day)	0.241 ±0.020	0.268[b] ±0.027	0.241 ±0.023	0.252 ±0.023	0.283[b] ±0.048
UE (%)	81.8	84.4	83.5	86.5	86.4

[a] Values significantly lower than those values from Tables 3A, 3B, 3C, and 3D.

[b] Values significantly higher than those values from Tables 3A, 3B, 3C, and 3D.

Table 3D. Mean energetic values and standard errors for the birds on the maintenance diet of Purina Chick Start and Grow for the two test trials on Group 1 and the one test trial for Group 2.

Energy component	Chick Grower (Group 1A)	Chick Grower (Group 1B)	Chick Grower (Group 2)
Number of birds	6	6	6
Grams consumed/day	13.8 ± 0.8	16.4[b] ±3.9	16.5[b] ± 1.7
GE (kcal/bird/day)	58.8 ± 3.5	70.3[b] ±16.7	70.4[b] ± 7.3
GE (kcal/gram body weight/day)	0.293 ±.013	0.384[b] ±.037	0.375[b] ±.044
Grams excreted/day	4.2 ± 0.3	5.0 ± 0.4	5.8 ± 0.6
Kcal/gram excreted	3.2 ± 0.05	3.2 ± 0.01	3.3 ± 0.04
EE (kcal/bird/day)	13.4 ± 0.7	16.1 ± 1.2	19.0[b] ± 2.3
EE (kcal/gram body weight/day)	0.068 ±.004	0.088 ±.013	0.102[b] ±.011
ME (kcal/bird/day)	45.4 ± 3.0	54.1[b] ± 5.8	51.3 ± 5.6
ME (kcal/gram body weight/day)	0.226 ±.011	0.296[b] ±.027	0.274[b] ±.038
UE (%)	77.1	77.0	72.9
Weight changes	- 1.7 ± 2.4	2.5 ± 0.7	4.2 ± 1.6

[b] Values significantly greater than those values from tables 3A, 3B, 3C, and 3D.

Energy Intake

Gross energy intake ranged from 43.9 kcal/bird/day for birds fed Kester's switchgrass (Table 3A) to 65.4 kcal/bird/day for birds on a diet of sanddrop seed (Table 3B). Gross energy intake per bird per day and per gram body weight of bird per day, were significantly lower for birds on diets of Korean lespedeza and Kester's switchgrass (Table 3A). Those birds on diets of sanddrop seed (Table 3B), sunflower chips and bulk amaranth (Table 3C) had significantly higher gross energies per gram body weight per day.

Energy Output

The amount of excrement ranged from 2.9 grams/bird/day for birds on a diet of amaranth (Table 3C) to 6.7 grams/bird/day for birds fed Kester's switchgrass (Table 3A). Birds on a diet of Kester's switchgrass (Table 3A) produced significantly greater amounts of excrement than birds on all of the other diets (Tables 3A, 3B and 3D).

The caloric value of the excrement ranged from 1.4 kcal/gram excreted for birds fed canary grass (Table 3A) to 4.4 kcal/gram for birds on a diet of Kester's milo (Table 3B). Birds on diets of canary grass (Table 3B), sorghum, pearl millet, sunflower chips (Table 3C) and Kester's switchgrass (Table 3A) had excreta with significantly lower caloric content, while the caloric levels in the excrement of the birds on the diet of Kester's milo (Table 3B) was significantly higher than the birds on all the other diets.

Excretory energy per bird per day ranged from 7.3

kcal/bird/day for the birds fed sorghum (Table 3C) to 20.7 kcal/bird/day for birds on a diet of sanddrop seed (Table 2B). Excretory energy was significantly lower for birds on diets of bulk amaranth, pearl millet, sorghum and sunflower chips both per bird per day and per gram body weight per day (Table 3C). Excretory energies per gram body weight per day ranged from 0.04 kcal/g body weight/day for birds on diets of sorghum and sunflower (Table 3C) to greater than 0.1 kcal/g body weight/day for the birds fed sanddrop seed (Table 3B).

Energy Metabolism and Utilization Efficiency

Metabolized energy (ME) ranged from a low for birds fed Korean lespedeza (Table 3A) to a high for birds on a diet of sunflower chips (Table 3C), when ME was based either on a per bird per day basis or a per gram body weight per day basis. On a per bird per day basis the ME averaged about 50 kcal/bird/day for the birds fed the best utilized seeds (Tables 3B and 3C). Birds on diets of Korean lespedeza and Kester's switchgrass had significantly lower metabolized energies per bird per day (Table 3A). The birds fed the same two diets, and in addition, those also fed Blackwell switchgrass or canary grass (Table 3A) all had significantly lower metabolized energies per gram body weight per day.

The utilization efficiency of energy ranged from 60.8 per cent for birds on a diet of Korean lespedeza (Table 3A) to 86.5 per cent for birds fed sorghum (Table 3C). Quail fed Kester's switchgrass, Blackwell switchgrass, Korean lespedeza (Table 3A) and Sanddrop seed (Table 3B) had significantly lower utilization efficiencies.

Joint-Feeding Study

In a separate joint-feeding study, birds were given a choice of amaranth or Blackwell switchgrass. Amaranth was found to comprise 79 per cent of the total seeds consumed by the quail in that trial. The significantly greater food consumption in the amaranth/switchgrass-fed birds caused those birds to have a significantly higher gross energy intake/bird/day. The significantly greater excreta production in the amaranth/ switchgrass-fed quail resulted in a greater, though not statistically significant, increase in excretory energy in those birds (Table 4). The net result was a nonsignificant difference in the metabolized energies, utilization efficiencies and body weights changes between the two groups of birds.

Table 4. Mean energetic values and standard errors for the joint feeding trial of amaranth/Blackwell switchgrass and for amaranth alone.

Energy component	Amaranth	Amaranth/switchgrass[a]
Number of birds	6	6
Grams consumed/day	12.7 ± 1.1	14.5[b] ± 2.3
GE (kcal/bird/day)	57.5 ± 4.9	66.4[b] ± 3.5
GE (kcal/gram body weight/day)	0.294 ±.023	0.342 ± .050
Grams excreted/day	2.9 ± 0.2	6.9[b] ± 1.2
Kcal/gram excreted	3.6 ±0.03	3.7 ± 0.40
EE (kcal/bird/day)	10.4 ± 1.9	13.1 ± 2.3
EE (kcal/gram body weight/day)	0.053 ±.005	0.070 ± .010
ME (kcal/bird/day)	47.1 ± 4.2	53.3 ± 8.5
ME (kcal/gram body weight/day)	0.241 ±.020	0.275 ± .040
UE (%)	81.8	80.8
Weight changes (g)	- 0.1 ± 1.4	- 1.9 ± 1.2

[a] The quail were given a choice of both Amaranth or Blackwell switchgrass. Amaranth comprised 79 per cent of the total amount of the grams consumed with Blackwell switchgrass comprising the remaining 21 per cent.

[b] Values are significantly higher than those of amaranth alone.

DISCUSSION

The Efficacy of Chick Start and Grow as a Maintenance Diet

In order to be reasonably assured that all of the energetic values obtained through the duration of the experiments came from consistently healthy birds, the maintenance diet of Purina Chick Start and Grow was tested twice on the same group of birds (Group 1), once at the start of the experiment (Group 1A), and again at the end of the experiment (Group 1B). Data collections for the second trial, however, were taken only for two days since the birds had been on that same diet for the previous two weeks. The energetic values obtained for the latter trial were all higher than those from the first trial. The grams of feed consumed per bird per day, gross energy intake per bird per day, excretory energy output per bird per day, metabolized energy per bird per day, and weight changes were all significantly greater for the birds during the second trial (Table 3D). Utilization efficiency, in contrast, remained nearly equal for both trials (Table 3D). The combined results imply that all of the quail were just as healthy at the end of the studies as they were at the start.

The maintenance diet also was tested on the second group of birds (Group 2) at the end of the experiment. None of the energetic values obtained from the birds in Group 2 varied significantly from those in Group 1B at the end of the experiment (Table 3D). Those data demonstrate that all thirteen of the Scaled Quail used in these studies had similar digestive capabilities, and that the data obtained on each of the single seed types likely would be similar for other Scaled Quail placed under similar experimental conditions.

Energetic Components of Quail Feed Seed Diets

The amount of an individual seed consumed by each bird likely reflects the palatability or acceptability of that seed since all seeds were provided *ad libitum* to the quail. The consumption of sorghum, amaranth, bulk amaranth, pearl millet (Table 3C), Kester's milo (Table 3B) and Blackwell switchgrass (Table 3A) was not significantly different, which suggested that each seed was equally palatable. The consumption of Kester's switchgrass, Korean lespedeza (Table 3A) and canary grass (Table 3B), however, was significantly less than all the other seeds, implying that those seeds were less palatable to the quail. Sunflower chips also were eaten in significantly lower quantities. This was likely due to the birds' abilities to obtain their caloric and protein requirements on lesser amounts of that seed since sunflowers contain the highest energy content (Table 2) and also possess relatively large amounts of protein. Sanddrop seed, in contrast, was consumed in significantly larger amounts than all of the other seeds (Table 3B). Whether this was due to its extremely small size or its greater palatability is not known. Western wheat grass was not eaten by any of the Scaled Quail which indicates that it was highly unpalatable.

The significantly lesser quantities of Korean lespedeza, Kester's switchgrass and canary grass consumed resulted in the significantly lower gross energies per bird per day for birds on those diets (Tables 3A and 3B). The significantly lower gross energies of the quail on those seeds, when combined with the quail's high excretory energies resulted in the significantly lower metabolized energies per bird per day for the birds fed those seeds. Quail fed sanddrop seed had a significantly higher gross energy intake per gram body weight per day as well as the highest excretory energy output per gram body weight per day of the birds on all of the other seeds (Table 3B). This resulted in an average metabolized energy per gram body weight per day for those quail that was not significantly different from those birds on diets of pearl millet, sorghum, sunflower chips, amaranth, bulk amaranth (Table 3C), canary grass or Kester's milo (Table 3B).

When metabolized energy was based on kilocalories per gram body weight per day, the metabolized energy of quail fed Blackwell switchgrass, in addition to those fed Korean lespedeza, Kester's switchgrass, and canary grass, were all significantly lower (Table 3A) than those quail fed the other seeds.

Based on the utilization efficiencies and body weight changes of the birds on each of the seed types, the diets were placed into categories of poor, good or excellent. Korean lespedeza, Kester's switchgrass, and Blackwell switchgrass were placed into the poor category (Table 3A). Kester's milo, sanddrop seed and canary grass were placed into the good category (Table 3B), while amaranth, bulk amaranth, pearl millet, sorghum, sunflower chips and the maintenance diet were considered excellent feeds for Scaled Quail (Tables 3C and 3D). Since Western wheat grass was not consumed by any of the six quail tested, it was considered to be exceptionally poor. Robel et al., (1979a) found that weight loss was inversely proportional to utilizable energy. This was evidenced in the present study where the birds fed Korean lespedeza and the two varieties of switchgrass, which had the lowest metabolized energies, also had a weight loss that was greater than that of the quail fed the other eight types of seeds.

Value of the Tested Seeds to Scaled Quail

Robel et al., (1979a) used the metabolized energy per bird per day as an index value for the seeds fed to bobwhites because that value took into account both food quality and digestibility. A similar index value based, instead on the metabolized energy per gram body weight of the Scaled Quail in this study was calculated for each of the seeds fed to the birds (Table 5). This value results in a similar placement of the seeds into poor, good, or excellent categories, approximating the rankings of the seeds as based on the quail's utilization efficiencies, metabolized energies, and weight changes on each of the different seeds. This value also is thought to be a more realistic representation of the actual value of a seed to Scaled Quail than the often times used metabolizable energy value of seeds (CE x UE) (Table 5). For example, from Table 5 it can be seen that the metabolizable energy value of

Table 5. Metabolized energies of quail and metabolizable energies for the seeds tested.

Seed	Metabolized Energy (per gram body per day) (GE - EE)	Metabolizable energy (CE x UE)
Chick Start & Grow (Group 1B)	0.296	3.31
Sunflower chips	0.283	5.27
Chick Start & Grow (Group 2)	0.274	3.13
Bulk amaranth	0.268	3.88
Sorghum	0.252	3.72
Pearl millet	0.241	3.76
Amaranth	0.241	3.68
Sanddrop seed	0.234	2.94
Chick Start & Grow (Group 1A)	0.225	3.31
Kester's milo	0.201	3.28
Canary grass	0.188	3.41
Blackwell switchgrass	0.182	3.07
Kester's switchgrass	0.167	2.90
Korean lespedeza	0.152	2.86

sanddrop seed (2.94) is nearly equal to that of Kester's switchgrass (2.90), while the metabolized energy per gram body weight per day for sanddrop seed is about 50 per cent more than the metabolized energy per gram body weight per day for Kester's switchgrass, as well as Korean lespedeza. This suggests that the metabolizable energy values tend to under estimate the value of relatively poorly metabolized and utilized seeds.

Those seeds which were metabolized well, and utilized efficiently by the Scaled Quail in the present study, also previously have been reported in the crops of wild Scaled Quail. Schemnitz (1961), in a study on the ecology of Scaled Quail in the Oklahoma Panhandle, found that sorghum comprised almost 50 per cent of the total crop volume, whereas amaranth, sunflower, and sanddrop seed comprised about 12 per cent, five per cent and one per cent, respectively, in the 181 winter birds taken from the short-grass prairie. Furthermore, amaranth was found in about 85 per cent of the total crops examined, sorghum in about 83 per cent, sunflower in almost 43 per cent and sanddrop seed in over 27 per cent of the crops. While sanddrop seed was utilized only moderately well by the quail in this study (Table 3B), they did consume it in significantly greater amounts than all other individual seeds (Table 3B). Thus, sanddrop seed produced metabolized energies for those quail that were similar to those of the quail fed seeds which were rated as excellent. Since sanddrop seed is readily available in the quails habitat and is moderately consumed by Scaled Quail, it is possibly as important to Scaled Quail as lespedezas are to Northern Bobwhites, even though both seeds are only metabolized moderately well by each of the birds. Pearl millet, which also was well -metabolized and - utilized by the birds in our study, is commonly eaten from food plots planted in western Kansas (Schwilling pers comm). Other seeds found in large quantities and frequencies in the cropa of Scaled Quail by Schemnitz (1961) were gumweed (Grindelia aquarrosa) and Russian-thistle (Salsola pestifer). Since those seeds are consumed by Scaled Quail in moderately large amounts it is probable that those seeds, like those of sorghum, sunflower, bulk amaranth, amaranth and pearl millet, may be utilized and metabolized well by Scaled Quail. Further research would be necessary to confirm that contention.

Schemnitz (1961) also found that panic grasses (Panicum spp.) were eaten in lesser quantities and frequency than the aforementioned seeds, although they were more important than some of the other grass seeds. The low use of panic grasses may be due to the Scaled Quail's inability to efficiently utilize and metabolize those seeds belonging to the genus Panicum as indicated by the low metabolic values obtained from Kester's switchgrass and Blackwell switchgrass (Table 3A). Korean lespedeza and canary grass, like the switchgrasses, also were poorly metabolized, but unlike switchgrass, the former seeds have not been reported to be found in the crops of Scaled Quail (Schemnitz 1961). Korean lespedeza, which had the poorest utilization efficiency (Table 3A) and lowest metabolized energy per gram body weight per day (Table 5) may be hard to digest due to its dense, hard seed coat (Eddy pers comm). Canary grass had a moderate utilization efficiency (Table 3B), but the birds on that diet exhibited a significant loss of body weight (Table 1). This suggests that the seeds of canary grass may have had a high internal cost of digestion for the Scaled Quail. Birds fed the dwarf variety of Kester's milo, a commercial bird seed, also showed a moderate utilization efficiency of that seed (Table 3B), but those birds did not show a significant loss of body weight compared to quail fed canary grass (Table 1). Thus, Kester's milo appears to be nearly as valuable to the Scaled Quail as sorghum, sunflower, pearl millet, amaranth and bulk amaranth seeds.

Factors Involved in Seed Selection by Scaled Quail

The availability, palatability or acceptability, and utilization efficiencies of seeds are of major importance in seed selection by Scaled Quail and other birds. In addition, such factors as protein content of the seeds, amino acid content, calorie to protein ratios, as well as mineral and vitamin contents of the seeds are equally important to the overall nutrition of birds. Doerr and coworkers (1979) suggested that Ruffed Grouse have a higher protein requirement during the winter. Beckerton and Middleton (1983) working with the same species found that metabolized energies decreased as the protein level decreased, even in those birds fed diets of nearly equal caloric content. The importance of the amino acid contents of diets to wild birds in captivity has been demonstrated by Parrish and Martin (1977) who found that dietary protein usage may depend on the protein's amino acid content. Although essential amino acid requirements are not available for Scaled Quail they are available for another galliform, the domestic chicken (Gallus gallus). The 13 essential amino acids include arginine, glycine plus serine, histidine, isoleucine, leucine, lysine, methionine plus cystine, phenylalanine, threonine, tryptophan and valine (Jurgens 1982). When the amino acid content of a seed which was poorly metabolized by the quail in this study was compared with a seed of similar protein content, such as sorghum, but which was well-metabolized by the quail, dramatic differences in amino acid composition were found. In the case of Little (proso) millet (Panicum miliare), which may be used as a representative of the genus Panicum, the content of tryptophan, lysine and leucine are about 20-50 per cent lower than that of sorghum (Orr and Watt 1957). The switchgrasses also were poorly metabolized by the quail in the present studies (Table 3A) in spite of the fact that those seeds had the highest combustible energy content than any of the other grain seeds tested (Table 2). It is likely that the absence of sufficient quantities of the amino acids tryptophan, lysine and leucine contributed to the switchgrass' low utilization efficiency. In marked contrast, those seeds which were well-utilized and -metabolized by the quail (Tables 3B and 3C) likely had sufficient quantities of all the essential amino acids even though some of the potentially essential amino acids occurred in smaller quantities in those seeds than in the poorly metabolized representative Panicum species (Orr and Watt 1957).

Calorie to protein ratios represent the number of kilocalories per gram of seed divided by the percentage of protein in that seed. High calorie to protein ratios, in general, reflect moderate to high caloric contents of seeds and low protein levels, whereas low calorie to protein ratios indicate low to moderately high caloric content of the seed and high protein levels. Intermediate calorie to protein ratios, therefore, seem likely to be most beneficial, since birds would have to consume lesser quantities of those seeds with intermediate calorie to protein ratios in order to fulfill both their caloric and protein requirements. The seeds in this study which had intermediate calorie to protein ratios were pearl millet (39.5), sorghum (39.1), amaranth (30.8) and sunflower chips (26.5). Those quail on those seeds also had high utilization efficiencies and birds on those diets either lost less than one per cent of their original weight, maintained their weight, or gained weight at the end of the feeding trials (Tables 1 and 3C).

Joint-Feeding Study

Even though Blackwell switchgrass was shown to be a poor seed when provided as an individual dietary source the present investigations suggest that it may have some value when fed in combination with a seed, or seeds, of higher metsbolized energies and utilization efficiencies. Evidence for this occurred in the study in which Blackwell switchgrass and amaranth were jointly fed to the the quail. Those findings revealed that the total grams of feed consumed per bird per day, gross energy intake per bird per day, and the grams excreted per bird per day were significantly higher than for birds fed amaranth alone (Table 4). In contrast, utilization efficiencies between the two groups were nearly equal (Table 4), which indicates that switchgrass, or other poorly metabolized seeds, may be useful to Scaled Quail when fed in combination with seeds of greater utilization efficiencies.

Energetics Comparisons Between Scaled Quail and Bobwhites

Some of those seeds used in this study also have been used in bioenergetic studies performed on Northern Bobwhites (Colinus virginianus) (Clement 1970, Robel et al. 1974, 1979a,b). Comparisons of the present results with those studies show that the utilization efficiencies of sorghum (approximately 86 per cent) and lespedeza (approximately 60 per cent) were nearly identical for both types of quail. On the contrary, the almost 25 per cent lower utilization efficiencies of bobwhites than Scaled Quail fed individual diets of sunflower and switchgrass may be due to the differences in palatability, ease of handling, digestibility, or other factors between the two species of birds. The differences in the utilization efficiency of the birds on diets of sunflowers also were perhaps due to the difference in the sunflower species fed. In this study commercially bought oil-type sunflower chips were fed, while in those studies performed on bobwhites Maximilian sunflower seeds, which occur naturally in the bobwhites habitat, were used (Robel et al. 1979a,b), The metabolized energies for the Scaled Quail were within about the same range (35 to 56 kcal/bird/day) as those of bobwhites (37 to 58 kcal/bird/day) also fed seeds which were ranked good to excellent (Robel et al. 1979a). This suggests that metabolic requirements may be similar between the two types of quail. The dissimilarities in the utilization efficiencies between the quails on several of the same types of seeds, however, indicate their uniqueness. Further evidence of differences between the two types of quail is seen from comparisons of our data with some early feeding experiments on bobwhites by Williamson (1955, 1956). He showed that 50 per cent of bobwhites fed pigweed (*Amaranthus* spp.) died after about three weeks, whereas the present results showed pigweed to be an excellent seed for Scaled Quail (Table 3C). Interestingly, while there are no indications that sanddrop seeds are eaten by bobwhites, those quail lost less body weight after having eaten sanddrop seeds for 12 days longer than other bobwhites fed milo seeds (Williamson 1956).

Significance for Managers

Cold temperatures place a physiological stress on birds as shown by the increased gross energy intake and metabolized energy values experienced by birds subjected to decreasing ambient temperatures (Kendeigh 1949, 1969, West

1960, Zimmerman 1965, Kontogiannis 1968, Case and Robel 1974). Severe winters have been shown to provoke weight losses, reduce fat reserves, and lead to increased mortality in the bobwhite (Robel 1965, 1969, 1972, Robel and Fretwell 1970; Robel et al. 1974). It has been demonstrated that increased food availability increases the survivability of birds during severe winters (Robel 1972, Robel et al. 1974). While the gross energy content of many of those seeds commonly eaten by Scaled Quail has been documented (Kendeigh and West 1965, Robel 1972, Shuman 1984), little is known about the energy available for metabolism from those seeds. Techniques similar to those used by Robel and coworkers on bobwhites (1974, 1979a,b) have been used in the present study in order to determine which of the twelve seeds tested would be of the most benefit to wintering Scaled Quail. By comparing the energetic data obtained in the current study with the palatability or acceptability of the seeds, protein contents, amino acid contents, and calorie to protein ratios of the seeds, it was determined that sorghum, pearl millet, amaranth, bulk amaranth and sunflower would be excellent seeds to provide wintering Scaled Quail. Sanddrop seed and Kester's milo would be rated as good seeds for wintering quail.

Seeds which are poorly metabolized and are poorly utilized alone, such as the switchgrasses, may still be of benefit if those seeds which are well-metabolized and -utilized by wintering Scaled Quail are also readily available as shown by the joint-feeding study. It certainly would be more beneficial to the quail to provide high quality seeds than to merely increase the availability of poor quality seeds.

SUMMARY

Twelve different seeds, Korean lespedeza (Lespedeza stipulacea), Blackwell switchgrass (Panicum virgatum), Kester's switchgrass (Panicum virgatum), sunflower chips (Helianthus spp.), sorghum (Sorghum vulgare), Kester's milo (Sorghum vulgare), pearl millet (Pennisetum glaucum), sanddrop seed (Sporobolus cryptandris), canary grass (Phalaris canariensis), pigweed (Amaranthus hypochondriacus), bulk amaranth (Amaranthus spp.) and Western wheat grsss (Agropyron smithii) were fed as individual diets, with the exception of one joint feeding trial, to Scaled Quail (Callipepla squamata) in order to determine which seeds were best metabolized under the stress of simulated winter conditions. All trials were carried out within an environmentally controlled walk-in chamber held at 5 C ± 0.5 C with a 10L:14D photoperiod. Excreta and spilled seed were separated, and the dry weights of each determined. The caloric content of the seeds and excreta was determined using a Parr oxygen bomb calorimeter. From the caloric analyses and other data, gross energy, excretory energy, metabolized energy, and utilization efficiency were calculated for birds fed each seed. The seeds were placed into categories of poor, good, or excellent with respect to their metabolized energy, utilization efficiency, and their ability to permit the quail to maintain their body weight. Kester's switchgrass, Blackwell switchgrass and Korean lespedeza were rated poor. Sanddrop seed, canary grass and Kester's milo were rated good, while pearl millet,

amaranth, bulk amaranth, sunflower chips and sorghum were rated as excellent foods for Scaled Quail. Western wheat grass, which was not eaten by any of the Scaled Quail in this study, was considered to be an extremely poor food source for Scaled Quail. It was suggested that seeds which were rated poorly, such as the switchgrasses, still may be of use to Scaled Quail when accompanied by a well -metabolized seed such as amaranth since birds given a choice of both amaranth and switchgrass did equally as well as birds given amaranth alone.

When the bioenergetics of Scaled Quail were compared with previous studies of Northern Bobwhites on similar diets, it was seen that sorghum and lespedeza are similarly metabolized, but that was not the case for sunflower and Blackwell switchgrass. The differences in the metabolism of sunflower and switchgrass were suggested to likely be due to the availability, palatability, and digestibility differences of the seeds by the two types of quail. Overall, the bioenergetics of wintering Scaled Quail and bobwhite quail appear to be similar.

The high protein content, high utilization efficiency, low calorie to protein ratio, and apparent excellent palatability of pearl millet, sorghum, amaranth and sunflower chips suggest that those seeds are of the most importance to Scaled Quail under low temperature thermal stress. Not surprisingly, those types of seeds have been shown to be the most abundant in the crops of wintering Scaled Quail.

LITERATURE CITED

LITERATURE CITED

Ault, S. C. and F. A. Stormer. 1983. Seasonal food aelection by Scaled Quail in northwest Texas. J. Wildl. Manage. 47(1): 222-228.

Beckerton, P. R. and A. L. Middleton. 1983. Effects of dietary protein levels on body weight, food consumption, and nitrogen balance in Ruffed Grouse. Condor 85:53-60.

Breitenbach, R. P., C. L. Nagra and R. K. Meyer. 1963. Effect of limited food intake on cyclic annual changes in Ring-necked Pheasant hens. J. Wildl. Manage. 27(1):24-36.

Case, R. M. 1982. Adaptations of female bobwhites to energy demands of the reproductive cycle. Pages 74-78 in F. Schitoskey, E. C. Schitoskey and L. G. Talent, eds. Proc. 2nd Natl. Bobwhite Quail Symp., Okla. State Univ., Stillwater.

_____, and R. J. Robel. 1974. Bioenergetics of the bobwhite. J. Wildl. Manage. 38(4):638-652.

Clement, T. M., Jr. 1970. Metabolizable energy values of some plant seeds consumed by bobwhite quail in Kansas. M. S. Thesis, Kansas State Univ., Manhattan.

Doerr, P. D., L. B. Keith, D. H. Rusch and C. A. Fischer. 1974. Characteristics of winter feeding aggregations of Ruffed Grouse in Alberta. J. Wildl. Manage. 38:601-615.

Jurgens, M. H. 1982. Animal Feeding and Nutrition. 5th Ed., Pages 375-392. Kendall/Hunt Publishing Co., Dubuque, Iowa. 549 pp.

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

_____. 1969. Energy responses of birds to their thermal environments. Wilson Bull. 81:441-449.

_____, and G. C. West. 1965. Caloric vslue of plant seeds eaten by birds. Ecology 46:553-555.

Kontogiannis, J. E. 1967. Day and night changes in body weight of the White-throated Sparrow Zonotrichia albicolis. Auk 84(3):390-395.

_____. 1968. Effects of temperature and exercise on energy intake and body weight of the White-throated Sparrow Zonotrichia albicolis. Physiol. Zool. 41(1):54-64.

Martin, A. C., H. S. Zim and A. L. Nelson. 1961. American Wildlife and Plants. Pages 100-103. Dover Publications, New York. 500pp.

Orr, M. L. and B. K. Watt. 1957. Amino acid content of foods. U.S. Dept. Agric., Home Economics Res. Rep. 4:1-82.

Parrish J. W. Jr. and E. W. Martin. 1977. The effects of dietary lysine level on the energy and nitrogen balance of the Dark-eyed Junco. Condor 79(1):24-30.

Robel, R. J. 1965. Differential winter mortality of bobwhites in Kansas. J. Wildl. Manage. 29:261-266.

______. 1969. Food habits, weight dynamics, and fat content of bobwhites in relation to food plantings in Kansas. J. Wildl. Manage. 33:237-249.

______. 1972. Body fat conteut of bobwhites in relation to food plantings in Kansas. Pages 139-149 in J. A. Morrison and J. C. Lewis, eds. Proc. 1st Natl. Bobwhite Quail Symp., Okla. State Univ., Stillwater.

______, A. R. Bisset, T. M. Clement, Jr. and A. D. Dayton. 1979a. Metabolizable energy of important foods of bobwhites in Kanaas. J. Wildl. Manage. 43(4):982-986.

______, A. R. Bisset, T. M. Clement, Jr., A. D. Dayton and K. E. Kemp. 1979b. Comparative energetics of bobwhites on six different foods. J. Wildl. Manage. 43(4):987-992.

______, R. M. Case, A. R. Bisset and T. M. Clement, Jr. 1974. Energetics of food plots in bobwhite management. J. Wildl. Manage. 38:653-664.

______, and S. D. Fretwell. 1970. Winter mortality of bobwhite quail estimated from age ratio data. Trans. Kans. Acad. Sci. 73:361-367.

Rohlf, F. J. 1981. BIOM-PC. SUNY, Stony Brook, N.Y.

Schemnitz, S. D. 1961. Ecology of the Scaled Quail in the Oklahoma Panhandle. Wildl. Monogr. 8. 47pp.

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

Shuman, T. W. 1984. Energetic responses of avian granivores to winter in northeast Kansas. M. S. Thesis, Kansas State Univ., Manhattan.

Sokal, R. R. and F. J. Rohlf. 1981. Biometry. 2nd Ed., W. H. Freeman Company, San Francisco.

Solomon, K. 1986. Pheasant Bioenergetics. Quail Unlimited 5(3):7-9, 26-29.

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 Ptarmigans under natural conditions. Ecology 49(6):1035-1045.

Williams J. E. and S. C. Kendeigh. 1982. Energetics of the Canada Goose. J. Wildl. Manage. 46(3):588-600.

Williamson H.G. 1955. Feeding experiments on bobwhite quail. Okla. Game and Fish Dept. Job Completion Report W-44-R-4. 8 pp. Mimeograghed.

______. 1956. Feeding experiments on bobwhite quail. Okla. Game and Fish Dept. Job Completion Report W-44-R-5. 6 pp. Mimeographed.

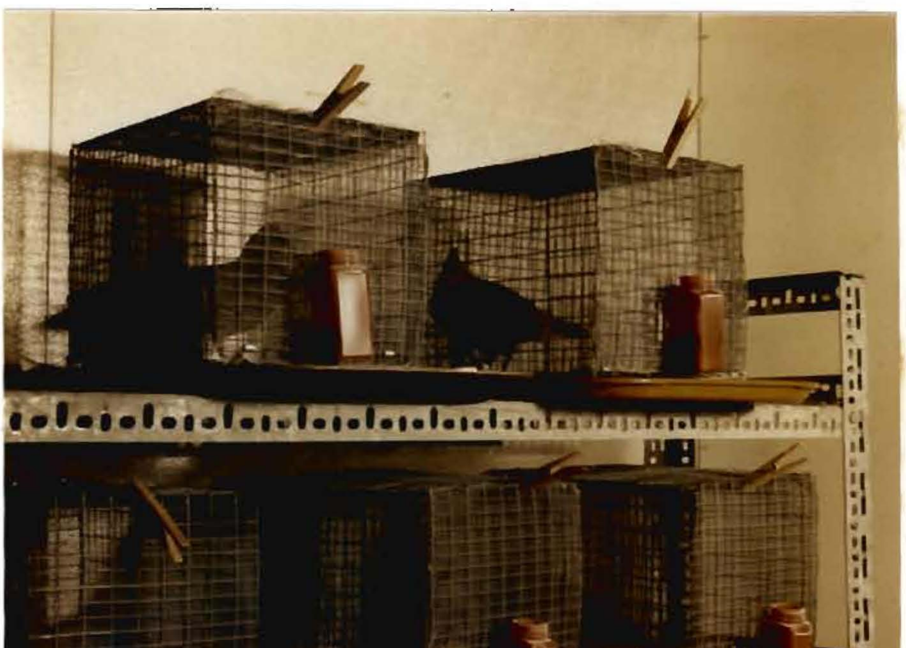
Zimmerman, J. L. 1965. Bioenergetics of the Dickcissel, *Spiza americana*. Physiol. Zool. 38:370-389.

APPENDIX 1

Front view of bird cage

Side view of bird cage

Experimental set up



APPENDIX 2

BASIC bomb calorimetry program

```
10 PRINT "**********************************************"
20 PRINT "     BOMB1        VER. 2.0a       REL. 15 MAY 1986"
30 PRINT "                                                  "
40 PRINT "      PROGRAM TO CALCULATE CALORIES PER GRAM      "
50 PRINT "           FROM BOMB CALORIMETRY DATA             "
60 PRINT "                        by                        "
70 PRINT "      DWIGHT MOORE, EMPORIA STATE UNIVERISTY      "
75 PRINT "          Modified by John Parrish (7/86)"
80 PRINT "**********************************************"
90 PRINT:PRINT:PRINT
120 INPUT "DO YOU WISH TO SAVE DATA IN A FILE, BOMB.DTA? (Y/N)";Y$
130 IF Y$="y" OR Y$="Y" THEN OPEN "A",#1, "BOMB.DTA"
140 INPUT "ARE YOU GOING TO ENTER DATA FROM THE KEYBOARD? (Y/N)";X$
150 IF (Y$="y" OR Y$="Y") AND (X$="n" OR X$="N") THEN 540
160 IF X$="N" OR X$="n" GOTO 460
170 INPUT "SAMPLE LABEL";B$
180 PRINT "ENTER THE TIMES AS HOURS, MINUTES, SECONDS;USE
    MILITARY TIME":PRINT
200 INPUT "TIME OF BOMBING (H,M,S)";A1,A2,A3
210 INPUT "TIME OF 60% RISE (H,M,S)";B1,B2,B3
220 INPUT "TIME AT EQUILIBRIUM H,M,S)";CT1,CT2,CT3:PRINT
240 PRINT "ENTER THE TEMPERATURE AT THE BEGINNING AND END OF
    BOMBING"
250 INPUT "TA,TC";TA,TC 260 TAC=TA+.004 270 TCC=TC+8.000001E-03
290 PRINT:INPUT "ENTER RATE CONSTANTS, R1, R2";R1,R2
300 INPUT "ML OF ACID";C1
310 INPUT "CM OF FUSE WIRE";C3
320 INPUT "MASS OF SAMPLE";M:PRINT
340 REM *** ROUTINE TO CONVERT RAW TIMES TO ELASPED MINUTES
    FROM 0:00 h ***
350 A=A1*60+A2+A3/60
360 B=B1*60+B2+B3/60
370 C=CT1*60+CT2+CT3/60
380 REM ****************************************************
390 T=TCC-TAC-R1*(B-A)-R2*(C-B)
400 HG=((T*2426)-C1-C3)/M
410 PRINT HG;"CALORIES PER GRAM FOR SAMPLE ";B$
420 IF Y$="Y" OR Y$="y" THEN PRINT#1,B$;",";B-A;C-B;TA;TC;R1;R2;
    C1;C3;M
426 PRINT:PRINT "---"
430 INPUT "DO YOU WISH TO DO ANOTHER CALCULATION? (Y/N)";A$
440 IF A$="Y" OR A$="y" THEN PRINT:GOTO 170
450 CLOSE:STOP
460 OPEN "I",#2,"BOMB.DTA"
470 IF EOF(2) THEN END
480 INPUT#2,B$,B,C,TA,TC,R1,R2,C1,C3,M
490 TAC=TA+.004:TCC=TC+8.000001E-03
500 T=TCC-TAC-R1*B-R2*C
510 HG=((T*2426)-C1-C3)/M
520 LPRINT HG;"CALORIES PER GRAM IN SAMPLE  ";B$
530 GOTO 470
540 PRINT "YOU CAN NOT READ FROM AND WRITE TO THE SAME DATA FILE"
550 CLOSE:STOP
560 END
```

APPENDIX 3

Data collection card

Species___________________ No.__________ Card No.________

Date begin trial _________________ Begin wt.__________.____g

Date ending trial_________________ End wt. __________.____g

Length trial _____________________ Wt. change_________.____g

Temperature: Max. __________C; Min. __________C

Photoperiod: ________L:________D (hrs); Fat class: ______

Molt record:

Notes:

Wet weight of feed__________.____g Dry wt. feed_________._____g

%moisture feed _______________% Protein content feed _________%

Caloric value dry feed _____________._____kcal/g

Oven dry wt old feed____________._____g; feces_____________._____g

Wt. of tare of feed_____________._____g; feces_____________._____g

Net dry wt. old feed____________._____g; feces_____________._____g

Weight of tare (foil) next period feces_____________._____g

EXCRETA ANALYSIS:

Calories _________________._____kcal/g; Nitrogen________._____mg/g

Protein________%; Ether extract__________mg/g; Ash________mg/g