THE NUTRITIONAL QUALITY OF SELECTED ROWCROP AND MOIST-SOIL SEEDS FOR CANADA GEESE

A Thesis

Presented to

the Faculty of the Graduate School

University of Missouri-Columbia

In Partial Fulfillment

of the Requirements for the Degree

Master of Science

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by

CHAD E. BUCKLEY

Dr. Leigh H. Fredrickson Thesis Supervisor

December, 1989

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CHAPTER I

INTRODUCTION

The nutritional quality of foods produced for waterfowl is an important consideration in wetland management programs. Understanding how nutrition affects waterfowl is essential in providing for their needs throughout the annual cycle. Because habitat and food use by Canada geese (Branta canadensis) in fall and winter appear to be related to availability of these resources (Austin 1988, Eggeman et al. In preparation), it is important that foods produced and made available for geese meet the energy and nutrient demands of the birds (Kendeigh et al. 1977, Williams and Kendeigh 1982, Joyner et al. 1987). If the only foods available for use by geese have poor nutritional quality, the immediate physiological condition and later reproductive performance of the birds could be adversely affected (Ankney and MacInnes 1978, Raveling 1979, Joyner et al. 1984). Likewise, rates of fat and protein deposition for migrating, egg-laying, incubation and molting are determined in part by the content and availability of energy and protein in foods (King 1972, Raveling 1979). Thus, effective management should attempt to provide the optimal combination of food types that meet the seasonal energy and nutrient requirements of target species.

Management practices for migrating and wintering Canada geese focus on producing a mixture of agricultural and native foods (Vaught and Kirsch 1966, Arthur 1968, Fredrickson and Taylor 1982, Eggeman et al. In preparation).

Geese feed on a combination of seeds, tubers and green vegetation that contribute the necessary nutrients and energy for maintenance and survival (Korschgen 1955, Kear 1966, Reed 1976, Bellrose 1980, Craven 1984**a**,**b**, Sedinger 1984, Sedinger and Raveling 1984, McKenzie 1987). Unfortunately, little is known about the nutrient and energy content of foods commonly consumed by Canada geese or how efficiently geese utilize the nutrients and energy in these foods (Burton et al. 1979, Thomas and Prevett 1980, Sedinger 1984, Sedinger and Raveling 1984, Buchsbaum et al. 1986, Joyner et al. 1987).

Environmental conditions also influence the quality and availability of waterfowl foods. Because foods are often shallowly flooded to enhance attractiveness and availability for waterfowl, an understanding of how different foods are affected by these conditions will facilitate more timely manipulations to attract and hold waterfowl (Neely 1956, McGinn and Glasgow 1963, Shearer et al. 1969).

Objectives:

The objectives of this study were:

1) To determine energy and nutrient content of selected rowcrop and moist-soil seeds regularly consumed by wintering Canada geese in Missouri and to assess the variability in energy and nutrient content of seeds from four locations in northcentral, northeast and southeast Missouri.

2) To evaluate how efficiently Canada geese utilize the energy contained in selected seeds by means of true metabolizable energy determinations.
3) To assess the effects of flooding on energy content of seeds and the rate of seed deterioration.

Acknowledgments

I would like to sincerely thank my advisor, Dr. Leigh H. Fredrickson for his guidance, patience and encouragement thoughout this project.

Dave Graber of the Missouri Department of Conservation provided invaluable assistance and friendship. His door was always open to me.

I thank my committee members Drs. Ron Drobney and J. E. Savage for their guidance and help. Dr. Savage graciously allowed me use of the bomb calorimeter in his lab as well as space for housing geese and conducting feeding trials. Dr. Savage's staff and graduate students assisted me in many ways.

Dr. G. Krause helped with statistical analyses.

I owe many thanks to P. Rexroad and R. Sweeney at the University of Missouri Agricultural Experiment Station Chemical Laboratories for the nutritional analyses performed on the seeds and for allowing me use of a Wiley mill.

M. Jackson and B. Burton at the MDC Swan Lake Hunting Headquarters caught and cared for the geese prior to transport to Columbia by J. Austin.

Managers J. Frye and P. Thompsen (Swan Lake), R. Leonard (Fountain Grove), P. Covington (Ted Shanks), and L. Heggeman (Duck Creek) assisted in planning seed collections at their areas. P. Magee and K. Simmons helped with seed collections.

P. Magee, M. Mitchell, T. Pesch, L. Henze, and T. Yates provided help with metabolizable energy feeding trials. T. Yates also helped with seed cleaning and bomb calorimetry. K. Simmons and C. Wenger cared for the geese on several occasions in my absence.

Secretaries C. Cox, S. Clark and D. Combs helped keep things going smoothly.

Thanks to all the F & W grad students for their friendship and input: P. Magee, F. Reid, J. Kelley, D. McKenzie, N. Gruenhagen, A. Strong, J. Austin, N. Kemble, K. Reeves, H. Hands and K. Kritz.

My dear friends Tricia Hilliard, Renda Saffouri, Kevin Simmons, Henry Hudson, Gina Hudnut, and Cherise Wenger encouraged me very much. This research would not have been completed without them.

My parents, Charles and Shirley, have always supported me in all I've done. I thank them for their love.

Many thanks are due to the twenty-five geese which endured months of captivity and feeding trials.

Finally I would like to thank God for always being with me in season and out. His love and support sustained me when I did not want to go on.

Funding and support for this research project were provided by the Missouri Department of Conservation, Missouri Cooperative Fish and Wildlife Research Unit, University of Missouri Agricultural Experiment Station, Gaylord Memorial Laboratory, Gregory Fellowship and Edward K. Love Fellowship.

CHAPTER II

NUTRIENT CONTENT OF SEEDS

Wintering Canada geese in Missouri consume a variety of food items (Korschgen 1955, Eggeman Unpubl. data). Some foods appear to be more important in the diet at certain periods than others (Austin 1988, Eggeman et al. In preparation). Such shifts in food consumption are most likely due to changes in the availabilities of the foods resulting from management practices such as mowing and flooding or from weather conditions including freezing temperatures and precipitation. Food use shifts could also result from changes in the energy and nutrient requirements of geese at certain periods in the annual cycle (Drobney and Fredrickson 1979, McLandress and Raveling 1981).

Assessment of the nutritional quality of foods is an essential step in devising a sound Canada goose management program. Proximate analysis is widely used as a basic measure of an item's nutrient content (Scott et al. 1982). It yields values for moisture, crude fat, crude protein, crude fiber, ash and nitrogen-free extract (NFE). Crude fat, or ether extract, is a measure of the lipid content in a sample. The protein content in a food is estimated by crude protein, which is calculated by multiplying the determined nitrogen content of a sample by 6.25, because proteins have an average nitrogen content of 16% (100/16 = 6.25). Ash measures a sample's mineral content. Crude fiber is an estimate of the indigestible carbohydrate in a sample. Nitrogen-free extract, an estimate of readily digestible carbohydrate, is calculated by subtracting crude fat, crude protein, crude fiber and ash from 100.

Proximate analysis has a number of limitations, however, in predicting a food's nutritional value for an animal. Crude fiber and NFE are poor approximations of indigestible and digestible carbohydrate for many types of foods (Goering and Van Soest 1970, Scott et al. 1982). Ether extraction does not take into account phospholipids or fats that are bound to proteins. The calculation of crude protein as percent nitrogen multiplied by 6.25 may not be very accurate in some instances. Not all of the nitrogen in a foodstuff is in the form of protein. Non-protein nitrogen compounds include nucleic acids and secondary plant compounds. Crude protein overestimated the true protein content (sum of all amino acids) of tundra vegetation by 22 to 52 percent (Sedinger 1984). He concluded that crude protein was a better approximation of total protein for seeds than for green plants.

Crude protein by itself is also inadequate as a measure of a food's nutritive value, because an animal actually requires specific amino acids in its diet rather than just a general protein source (Scott et al. 1982, Sedinger 1984). Certain amino acids are termed essential because an animal cannot synthesize them in its body, and they must therefore be supplied by the diet. Non-essential amino acids can be synthesized by the animal as long as an adequate amount of nitrogen is consumed and absorbed. Additionally, specific measurements of essential fatty acids and individual minerals and vitamins in a food must be made to fully understand that food's potential for meeting the nutritional requirements of an animal (Scott et al. 1982, Robbins 1983).

The energy content of a food must also be considered. Energy is an important dietary need of wintering waterfowl (Prince 1979). It is required for general body maintenance, thermoregulation at low temperatures, and activities such as standing, walking, flying, swimming, feeding and avoiding predators (Kendeigh et al. 1977, Robbins 1983). Energy is also needed to deposit fat reserves which may be used for migration (King 1972) and reproduction the following breeding season (Ankney and MacInnes 1978, Raveling 1979, Krapu 1981, McLandress and Raveling 1981, Joyner et al. 1984). Energy-supplying constituents in foods are carbohydrates, proteins and lipids (fats), with one gram of each respectively providing about 4.0, 5.65 or 9.45 kilocalories of energy when metabolized (Scott et al. 1982, Robbins 1983).

A number of past studies have focused specifically on the energy or nutrient content of wildlife foods (Spinner and Bishop 1950, Junca et al. 1962, Thomas and Prevett 1980). Additionally, many studies of waterfowl ecology have included some nutritional analysis of foods (Hobaugh 1985, Miller 1987, Alisauskas et al. 1988). However, information on the nutritional quality of many waterfowl foods is lacking in part or totally.

Little attention has been given to the variability of these nutritional measures for a certain food item from various locations or at different seasons. Considerable variation existed in the protein content of milo from different locations in Kansas, among years, and for different hybrids (Miller et al. 1964). The protein content and amino acid composition of many agricultural grains has been shown to depend on such factors as genetics, variety, nitrogen, phosphorus and potassium fertilization, soil type and moisture (Frey 1949, Sauberlich et al. 1953, Eppendorfer 1978). The nutritional quality of waste corn did not change significantly as the season progressed (Baldassare et al. 1983). Similarly, the proximate composition of seeds did not change according to any pattern when exposed to flooded or non-flooded conditions for up to 120 days (McGinn and Glasgow 1963). Conditions during the growing season thus appear to have a greater effect on the nutritional quality of foods than conditions between the time of food production and consumption by waterfowl. Managers must take these factors into account and attempt to produce foods of high nutritional quality for Canada geese.

MATERIALS AND METHODS

The following moist-soil and rowcrop seeds regularly consumed by wintering Canada geese in Missouri (Korschgen 1955, Eggeman Unpubl. data) were collected for nutrient analysis:

Moist-soil

Bidens sp.	Beggarticks
Echinochloa crusgalli	Wild millet
Echinochloa muricata	Wild millet
Leersia oryzoides	Rice cutgrass
Polygonum lapathifolium	Nodding smartweed
Polygonum pensylvanicum	Largeseed smartweed
Setaria faberii	Nodding foxtail

Rowcrop

Glycine max	Common soybean
Sorghum vulgare	Milo
Zea mays	Corn

Mature seeds were collected by hand from standing plants at Fountain Grove Wildlife Management Area (WMA), Ted Shanks Wildlife Area (WA), Duck Creek WA, Swan Lake National Wildlife Refuge (NWR) and Mingo NWR. For most seeds five plots were randomly selected in up to six randomly selected fields or patches per wildlife area as availability permitted. The proposed sampling scheme was not possible to follow because of waterfowl use, mowing of rowcrops, and limited availability, rapid maturation and drop of moist-soil seeds. Several seed species were represented by only single samples. For the 1986 growing season, only corn and milo were collected during the following winter and spring (Jan-Mar 1987). All seed types were collected in the fall (Sep-Oct 1987) of the 1987 growing season. Samples of high lysine and CFS waxy grain corn were obtained from Custom Farm Seed in Momence, Illinois, and a sample of open-pollinated corn was obtained from Swan Lake NWR.

Seeds were separated from chaff, oven-dried, cleaned by hand and stored in sealed plastic bags in a walk-in cooler. A portion of each sample was then ground in a Wiley mill finely enough to pass through a 1-mm mesh screen. Percent moisture was determined by oven-drying at 80C until constant weight was reached. Dry matter (DM) was determined by subtracting percent moisture from 100.

Gross energy (GE) (kcal/g DM) was determined on duplicate subsamples from each plot with a Parr adiabatic oxygen bomb calorimeter using 30 atm O_2. Proximate analysis and amino acid assay of samples were conducted by the University of Missouri Agricultural Experiment Station Chemical Laboratories. A proximate analysis was conducted on a subsample from each plot. Crude protein was determined with a LECO FP-228 Nitrogen Determinator (Sweeney and Rexroad 1987) with 10 percent reruns by manual Kjeldahl with copper catalyst (AOAC 1984). Percent moisture was determined by drying in a vacuum oven at 95-100C, crude fat by the indirect method, crude fiber by the asbestos free method and ash by heating in a cold furnace until 625C was reached after 15 hours (AOAC 1984).

An amino acid profile was determined for a composite sample made up of equal amounts of subsamples from each of the five plots from a rowcrop field or moist-soil patch. Tryptophan content was determined by enzymatic hydrolysis and colorimetric detection (Spies and Chambers 1949). Performic acid oxidation was conducted for cystine and methionine (Schram et al. 1954, Moore 1963). Chromatography was done with automated cation exchange (Benson and Patterson 1971, Raymond and Dunmire 1981). Quantification of other amino acids was determined by hydrolysis with 6N HCl for four hours at 145C (Roach and Gehrke 1970, Kaiser et al. 1974, Gehrke et al. 1985).

Statistical analyses included analysis of variance (ANOVA) and least significant difference (LSD) tests between means.

RESULTS

Proximate analysis and gross energy assay revealed differences between seed species as well as variability in the values within species. Percent moisture ranged from 6.60 for soybeans to 13.61 for winter corn (Table 1). The corn and milo samples collected in late winter 1987 had the highest average moisture contents. Because the moisture content of the seeds covered such a wide range, all other nutritional measures are reported on a dry matter basis to facilitate comparisons.

Most seeds had crude fat values between 2 and 5 percent with the exception of beggarticks and soybeans with about 20 percent ether extract (Table 1). Crude fiber of rowcrop seeds averaged about 5 percent or less. Moist-soil seeds had higher fiber contents ranging from about 11 percent for rice cut-grass to 22 percent for beggarticks. Crude protein was quite variable. Smartweeds, wild millets, corn and milo averaged less than 10 percent crude protein. Rice cut-grass had a protein content of 14 percent and nodding foxtail averaged about 18 percent. Beggarticks and soybeans had the highest crude protein contents at 23 and 44.5 percent respectively. The high lysine and waxy corn samples had

Table 1. Average proximate composition of seeds

			% Dry matter				
Species	N	Moisture (%)	Crude fat	Crude fiber	Crude protein	Ash	NFE
Corn^W	80	13.61	3.99	2.09	8.78	1.51	83.63
Corn^F	1	10.20	3.90	2.23	9.46	1.56	82.85
Milo^W	13	13.22	3.24	2.11	8.12	1.64	84.89
Milo^F	1	10.60	3.58	1.57	7.61	2.01	85.23
Soybean	1	6.60	19.49	5.46	44.54	5.99	24.52
Wild millet[1]	20	8.26	3.25	20.07	9.30	6.09	61.29
Wild millet[2]	5	8.44	4.70	15.90	9.09	6.05	64.26
Nodding smartweed	5	9.24	4.05	19.90	9.58	2.23	64.24
Largeseed smartweed	10	8.82	3.63	12.54	8.08	1.79	73.96
Rice cutgrass	1	9.40	2.21	10.93	14.35	4.74	67.77
Nodding foxtail	10	7.19	2.28	20.48	17.78	10.78	48.68
Beggarticks	1	7.70	20.26	22.21	23.08	5.96	28.49

^{W,F} - Denotes samples collected in winter (Jan/Feb) and fall (Sep/Oct) 1987 respectively

[1,2] - Denotes *E. crusgalli* and *E. muricata* respectively

protein contents a little higher than the average for corn (Table 2), but not outside the range of crude protein values for corn. Ash content of all seeds was low. Nodding foxtail had the highest ash content at 11 percent followed by the wild millets, beggarticks and soybeans at about 6 percent. Nitrogen-free extract values were quite variable. They were lowest for beggarticks and soybeans at 28 and 24.5 percent respectively. Corn and milo had the highest average NFE contents at 84 and 85 percent respectively. The NFE contents of the rest of the seeds were intermediate ranging from 49 percent for nodding foxtail to 74 percent for largeseed smartweed.

Beggarticks and soybeans had the highest gross energy contents at about 5.6 kcal/g followed by the smartweeds at about 4.8 kcal/g (Table 3). The remainder of the seeds had GE contents of about 4.4 kcal/g.

Soybeans, beggarticks, nodding foxtail and rice cutgrass seeds contained the highest levels of both essential (Table 4) and non-essential (Table 5) amino acids expressed as percentages of the total DM. Amino acid levels as percentages of total protein (Tables 6 and 7) were relatively similar for all seeds.

Crude protein content and total amino acids were similar for most seed species (Table 8). Crude protein overestimated total amino acids most for largeseed and nodding smartweed, beggarticks and rice cutgrass.

Analysis of variance for corn indicated significant variation ($P < 0.05$) for some of the nutritional variables

Table 2. Proximate composition of corn (*Zea mays*) varieties

Variety	N	Moisture (%)	% Dry matter: Crude fat	Crude fiber	Crude protein	Ash	NFE
High lysine	1	10.00	4.78	2.22	10.44	1.67	80.89
CFS waxy grain	1	9.60	4.42	2.32	11.06	1.55	80.65
Open-pollinated	1	12.90	4.59	2.18	9.99	1.61	81.63
F_1 hybrid	80	13.61	3.99	2.09	8.78	1.51	83.63

Table 3. Gross energy content of seeds

Species/Variety	N	GE(kcal/g DM)	SE	Range
Nodding foxtail	10	4.33	0.02	4.25-4.39
Wild millet[2]	5	4.36	0.01	4.33-4.41
Wild millet[1]	20	4.46	0.01	4.35-4.62
Corn[W]	80	4.37	0.01	4.21-4.46
Corn[F]	1	4.42	-	-
High lysine corn	1	4.41	-	-
CFS waxy grain corn	1	4.38	-	-
Open-pollinated corn	1	4.43	-	-
Milo[W]	13	4.40	0.01	4.36-4.45
Milo[F]	1	4.50	-	-
Rice cutgrass	1	4.41	-	-
Largeseed smartweed	8	4.74	0.01	4.70-4.83
Nodding smartweed	5	4.78	0.03	4.73-4.86
Soybean	1	5.60	-	-
Beggarticks	1	5.65	-	-

W,F - Denotes samples collected in winter (Jan/Feb) and fall (Sep/Oct) 1987 respectively

1,2 - Denotes _E_. _crusgalli_ and _E_. _muricata_ respectively

Table 4. Average essential amino acid composition of seeds expressed as percent of dry matter

		% Dry matter									
Species	N	Thr	Val	Ile	Leu	Phe	His	Lys	Arg	Met	Trp
Corn[W]	16	0.31	0.41	0.30	0.99	0.44	0.26	0.30	0.45	0.23	0.07
Corn[F]	1	0.33	0.48	0.36	1.14	0.49	0.30	0.32	0.50	0.20	0.08
Milo[W]	3	0.28	0.40	0.33	1.01	0.46	0.20	0.22	0.34	0.15	0.07
Milo[F]	1	0.27	0.40	0.30	0.87	0.38	0.20	0.25	0.37	0.16	0.07
Largeseed smartweed	2	0.26	0.41	0.33	0.52	0.38	0.20	0.32	0.73	0.16	0.05
Nodding smartweed	1	0.29	0.44	0.36	0.55	0.42	0.22	0.37	0.83	0.19	0.06
Wild millet[2]	1	0.34	0.52	0.42	0.91	0.63	0.22	0.23	0.40	0.22	0.07
Wild millet[1]	4	0.36	0.55	0.44	0.95	0.63	0.23	0.27	0.45	0.25	0.05
Rice cutgrass	1	0.53	0.75	0.55	0.99	0.72	0.32	0.65	1.04	0.32	0.04
Nodding foxtail	2	0.54	0.88	0.76	2.46	0.96	0.34	0.24	0.51	0.50	0.33
Beggarticks	1	0.76	1.15	0.83	1.35	1.32	0.57	1.20	1.52	0.41	0.25
Soybean	1	1.68	2.09	1.98	3.28	2.23	1.17	2.73	3.14	0.58	0.56
Requirement[A]		0.50	0.56	0.38	0.50	0.66	0.72	0.56	0.56	0.25	0.13

W,F - Denotes samples collected in winter (Jan/Feb) and fall (Sep/Oct) 1987 respectively

1,2 - Denotes _E_. _crusgalli_ and _E_. _muricata_ respectively

A - For domestic geese under holding conditions (Summers and Leeson 1985)

Table 5. Average non-essential amino acid composition of seeds expressed as percent of dry matter

Species	N	Pro	Asp	Ser	Glu	Gly	Ala	Tyr	Cys	Hpr
		% Dry matter								
Corn[W]	16	0.75	0.57	0.39	1.54	0.36	0.64	0.35	0.22	0.06
Corn[F]	1	0.85	0.63	0.38	1.79	0.40	0.71	0.31	0.23	0.06
Milo[W]	3	0.63	0.55	0.37	1.55	0.29	0.72	0.32	0.16	0.05
Milo[F]	1	0.57	0.56	0.31	1.43	0.31	0.63	0.25	0.16	0.04
Largeseed smartweed	2	0.28	0.60	0.31	1.06	0.38	0.37	0.25	0.10	0.09
Nodding smartweed	1	0.31	0.65	0.35	1.16	0.42	0.39	0.26	0.11	0.10
Wild millet[2]	1	0.62	0.60	0.44	1.96	0.31	0.83	0.35	0.15	0.13
Wild millet[1]	4	0.68	0.65	0.45	1.99	0.38	0.86	0.35	0.18	0.12
Rice cutgrass	1	0.62	1.24	0.60	2.34	0.64	0.73	0.54	0.30	0.07
Nodding foxtail	2	1.37	1.14	0.75	3.71	0.39	1.63	0.52	0.25	0.08
Beggarticks	1	1.13	2.04	0.91	4.31	1.26	0.85	0.53	0.44	0.24
Soybean	1	2.17	4.96	2.14	8.19	1.88	1.83	1.45	0.60	0.20

[W,F] - Denotes samples collected in winter (Jan/Feb) and fall (Sep/Oct) 1987 respectively

[1,2] - Denotes *E. crusgalli* and *E. muricata* respectively

Table 6. Average essential amino acid composition of seeds expressed as percent of total protein

Species	N	% Total protein									
		Thr	Val	Ile	Leu	Phe	His	Lys	Arg	Met	Trp
Corn[W]	16	3.6	4.7	3.5	11.5	5.1	3.1	3.5	5.2	2.7	0.8
Corn[F]	1	3.5	5.0	3.7	11.9	5.1	3.1	3.4	5.2	2.1	0.8
Milo[W]	3	3.5	4.9	4.0	12.5	5.6	2.5	2.8	4.2	1.8	0.9
Milo[F]	1	3.6	5.3	4.0	11.6	5.0	2.7	3.3	4.9	2.1	0.9
Largeseed smartweed	2	3.8	6.0	4.8	7.6	5.6	2.9	4.8	10.7	2.4	0.8
Nodding smartweed	1	3.8	5.9	4.9	7.4	5.6	3.0	5.0	11.1	2.5	0.7
Wild millet[2]	1	3.6	5.6	4.5	9.7	6.8	2.3	2.5	4.3	2.3	0.7
Wild millet[1]	4	3.6	5.5	4.5	9.7	6.4	2.4	2.7	4.6	2.5	0.5
Rice cutgrass	1	4.1	5.8	4.2	7.7	5.5	2.5	5.0	8.0	2.5	0.3
Nodding foxtail	2	3.1	5.1	4.4	14.1	5.5	2.0	1.4	2.9	2.9	1.9
Beggarticks	1	3.6	5.4	4.0	6.4	6.3	2.7	5.7	7.2	2.0	1.2
Soybean	1	3.9	4.9	4.6	7.6	5.2	2.7	6.4	7.3	1.3	1.3
Gosling Carcass[A]		4.5	5.1	3.8	7.5	4.3	2.2	5.3	7.1	1.4	-

W,F - Denotes samples collected in winter (Jan/Feb) and fall (Sep/Oct) 1987 respectively

1,2 - Denotes *E. crusgalli* and *E. muricata* respectively

A - *Branta canadensis*

Table 7. Average non-essential amino acid composition of seeds expressed as percent of total protein

Species	N	Pro	Asp	Ser	Glu	Gly	Ala	Tyr	Cys	Hpr
		% Total protein								
Corn[W]	16	8.7	6.6	4.5	17.7	4.1	7.4	4.0	2.6	0.7
Corn[F]	1	8.9	6.6	4.0	18.7	4.2	7.5	3.3	2.4	0.6
Milo[W]	3	7.8	6.8	4.6	19.1	3.6	8.9	3.9	2.0	0.6
Milo[F]	1	7.6	7.4	4.2	19.0	4.1	8.3	3.3	2.1	0.6
Largeseed smartweed	2	4.1	8.8	4.5	15.6	5.6	5.5	3.7	1.5	1.3
Nodding smartweed	1	4.1	8.7	4.7	15.5	5.6	5.2	3.5	1.5	1.3
Wild millet[2]	1	6.7	6.4	4.7	20.9	3.3	8.9	3.8	1.6	1.4
Wild millet[1]	4	6.9	6.6	4.6	20.2	3.8	8.8	3.6	1.9	1.2
Rice cutgrass	1	4.8	9.5	4.6	18.0	4.9	5.6	4.2	2.3	0.5
Nodding foxtail	2	7.9	6.5	4.3	21.3	2.3	9.4	3.0	1.5	0.5
Beggarticks	1	5.3	9.7	4.3	20.5	6.0	4.0	2.5	2.1	1.1
Soybean	1	5.1	11.6	5.0	19.1	4.4	4.3	3.4	1.4	0.5
Gosling Carcass[A]		7.9	8.8	6.6	12.6	8.6	6.1	4.1	3.3	-

W,F - Denotes samples collected in winter (Jan/Feb) and fall (Sep/Oct) 1987 respectively

1,2 - Denotes _E. crusgalli_ and _E. muricata_ respectively

A - _Branta canadensis_

Table 8. Comparison of crude protein content and total amino acid content of seeds

Seed species	Crude protein (%)	Total amino acids (%)	$\frac{\text{Crude protein}}{\text{Total amino acids}} \times 100$
Corn	8.82	8.67	101.73
Milo	8.13	7.90	102.91
Soybean	44.54	42.64	104.46
Wild millet[1]	9.30	9.75	95.38
Wild millet[2]	9.09	9.21	98.70
Nodding foxtail	17.78	17.29	102.83
Beggarticks	23.08	20.83	110.08
Rice cutgrass	14.34	12.91	111.08
Largeseed smartweed	8.08	6.72	120.24
Nodding smartweed	9.58	7.37	129.99

[1,2] - Denotes *E. crusgalli* and *E. muricata* respectively

within and among wildife areas (Table 9). Within-field variation did not appear to be as great as between-field or among-area variation, but it could not be measured statistically.

Other seed species showed some within- and among-area variation, but sample sizes were insufficient for analysis of variance. Differences between area and field averages were significant ($P < 0.05$) for several seed species (Tables 10, 11, 12 and 13). Variation in a nutrient within a seed species generally did not appear to be as great as between-species differences.

DISCUSSION

Few seeds appeared to be nutritionally complete by themselves. Most seeds were high in GE, but contained inadequate levels of crude protein and essential amino acid necessary to satisfy the requirements of Canada geese (Tables 1, 3 and 4).

Beggarticks and soybeans were high in GE, crude protein and essential amino acids, but are of limited usefulness in goose management. Beggarticks are rarely utilized by Canada geese (Korschgen 1955, Eggeman Unpubl. data), perhaps because they are unavailable or unpalatable. Consumption of soybeans by geese may result in crop impaction followed by death (Durant 1956). The quality of soybeans is also diminished by the antinutritional factors they contain (Scott et al. 1982, Spurlock 1987). A trypsin inhibitor in soybeans interferes with their digestion by domestic poultry.

Table 9. Average proximate and gross energy content of corn (*Zea mays*) by area and field

Location	N	Moisture (%)	Crude fat	Crude fiber	Crude protein	Ash	NFE	GE(kcal/g DM)
			----------------% Dry matter------------					
Fountain Grove								
Field 1	5	14.50 [AB]	2.63 [C]	1.96 [A]	8.83 [A]	1.59 [A]	84.98 [A]	4.32 [AB]
Field 2	5	14.96 [A]	3.64 [B]	1.98 [A]	8.23 [AB]	1.58 [A]	84.57 [A]	4.30 [B]
Field 3	5	13.74 [C]	4.03 [AB]	1.97 [A]	7.35 [B]	1.41 [B]	85.23 [A]	4.33 [AB]
Field 4	5	14.02 [BC]	4.28 [A]	2.02 [A]	8.07 [AB]	1.47 [B]	84.16 [A]	4.37 [A]
Area avg.	20	14.31 [R]	3.65 [S]	1.98 [T]	8.12 [T]	1.51 [S]	84.74 [R]	4.33 [T]
Swan Lake								
Field 1	5	13.72 [A]	4.27 [A]	2.20 [B]	9.67 [A]	1.60 [A]	82.27 [A]	4.40 [B]
Field 2	5	13.80 [A]	4.15 [A]	2.09 [B]	9.56 [A]	1.58 [A]	82.62 [A]	4.45 [A]
Field 3	5	13.24 [B]	4.29 [A]	2.35 [A]	9.54 [A]	1.52 [A]	82.30 [A]	4.42 [AB]
Area avg.	15	13.59 [T]	4.24 [R]	2.21 [S]	9.59 [R]	1.57 [R]	82.39 [T]	4.42 [R]
Ted Shanks								
Field 1	5	13.94 [A]	4.25 [A]	1.95 [A]	9.50 [A]	1.65 [A]	82.64 [B]	4.38 [A]
Field 2	5	13.84 [A]	4.46 [A]	1.88 [A]	9.35 [AB]	1.44 [B]	82.87 [AB]	4.37 [A]
Field 3	5	13.96 [A]	4.60 [A]	1.67 [B]	8.27 [B]	1.42 [B]	84.03 [A]	4.38 [A]
Field 4	5	13.68 [A]	4.17 [A]	1.99 [A]	8.39 [AB]	1.37 [B]	84.08 [A]	4.36 [A]
Area avg.	20	13.86 [S]	4.37 [R]	1.87 [U]	8.88 [S]	1.47 [S]	83.41 [S]	4.37 [S]
Duck Creek								
Field 1	5	12.96 [AB]	3.93 [B]	2.21 [B]	6.46 [D]	1.40 [C]	86.01 [A]	4.36 [BC]
Field 2	5	13.14 [A]	2.90 [C]	2.21 [B]	10.38 [A]	1.77 [A]	82.73 [B]	4.33 [C]
Field 3	5	13.02 [AB]	3.86 [B]	2.32 [AB]	8.94 [BC]	1.40 [C]	83.47 [B]	4.39 [AB]
Field 4	5	12.66 [B]	3.78 [B]	2.27 [B]	9.55 [AB]	1.49 [BC]	82.92 [B]	4.38 [AB]
Field 5	5	12.64 [B]	4.56 [A]	2.43 [A]	8.31 [C]	1.53 [B]	83.17 [B]	4.41 [A]
Area avg.	25	12.88 [U]	3.81 [S]	2.29 [R]	8.73 [S]	1.52 [RS]	83.66 [S]	4.37 [S]

ABCD - Different superscripts in the same column indicate significant within-area differences ($P < 0.05$)

RSTU - Different superscripts in the same column indicate significant between-area differences ($P < 0.05$)

Table 10. Average proximate and gross energy content of milo (*Sorghum vulgare*) by area

Location	N	Moisture (%)	% Dry matter: Crude fat	Crude fiber	Crude protein	Ash	NFE	GE(kcal/g DM)
Fountain Grove	5	13.66^{R}	3.31^{R}	2.20^{S}	7.09^{S}	1.74^{R}	85.66^{R}	4.38^{S}
Swan Lake	5	13.20^{R}	3.48^{R}	1.66^{T}	8.39^{R}	1.54^{S}	84.93^{R}	4.39^{S}
Duck Creek	3	12.50^{S}	2.70^{S}	2.70^{R}	9.41^{R}	1.64^{RS}	83.55^{S}	4.43^{R}

^{RST} - Different superscripts in the same column indicate significant between-area differences ($P < 0.05$)

Table 11. Average proximate and gross energy content of wild millet (*E. crusgalli*) by area and field

Location	N	Moisture (%)	% Dry matter: Crude fat	Crude fiber	Crude protein	Ash	NFE	GE(kcal/g DM)
Ted Shanks								
Field 1	5	8.86 A	3.53 A	19.13 A	8.12 B	5.24 A	63.97 A	4.46 A
Field 2	5	7.94 B	3.91 A	17.09 A	10.91 A	5.30 A	62.79 A	4.51 A
Area avg.	10	8.40 R	3.72 R	18.11 S	9.51 R	5.27 S	63.38 R	4.48 R
Mingo								
Field 1	5	7.80 B	2.84 A	20.91 A	9.50 A	7.11 A	59.63 A	4.46 A
Field 2	5	8.44 A	2.73 A	23.16 A	8.65 A	6.68 A	58.78 A	4.43 A
Area avg.	10	8.12 R	2.79 S	22.03 R	9.08 R	6.90 R	59.21 S	4.45 R

AB - Different superscripts in the same column indicate significant within-area differences ($P < 0.05$)

RS - Different superscripts in the same column indicate significant between-area differences ($P < 0.05$)

Table 12. Average proximate and gross energy content of nodding foxtail (*S. faberii*) by area

			% Dry matter					
Location	N	Moisture (%)	Crude fat	Crude fiber	Crude protein	Ash	NFE	GE(kcal/g DM)
Fountain Grove	5	7.40^{A}	2.25^{A}	21.17^{A}	17.91^{A}	10.02^{B}	48.65^{A}	4.37^{A}
Ted Shanks	5	6.98^{A}	2.32^{A}	19.78^{A}	17.65^{A}	11.55^{A}	48.70^{A}	4.30^{B}

^{AB} - Values in a column with different superscripts are significantly different ($P < 0.05$)

Table 13. Average proximate and gross energy content of largeseed smartweed (*P. pensylvanicum*) by field

Location	N	Moisture (%)	% Dry matter: Crude fat	% Dry matter: Crude fiber	% Dry matter: Crude protein	% Dry matter: Ash	% Dry matter: NFE	GE(kcal/g DM)
Fountain Grove								
Field 1	5	9.42 A	3.71 A	12.74 A	7.71 B	1.83 A	74.01 A	4.737 A
Field 2	5	8.22 A	3.55 A	12.35 A	8.45 A	1.74 A	73.90 A	4.747 A
Area avg.	10	8.82	3.63	12.54	8.08	1.79	73.96	4.740

AB - Values in a column with different superscripts are significantly different ($P < 0.05$)

Other seeds had lower energy, protein and amino acid contents than soybeans or beggarticks. Corn and milo were good energy sources because of their low fiber and high NFE contents, but were poor suppliers of protein and essential amino acids. The smartweeds and wild millets were similar to corn and milo in protein and amino acid content (Tables 1, 4 and 5). Smartweed seeds were intermediate in energy content between soybeans and beggarticks and the rest of the seeds (Table 3). Nodding foxtail and rice cutgrass were similar in gross energy content to corn and milo, but were second only to soybeans and beggarticks in crude protein and essential amino acids. Consumption of both of these seeds would apparently satisfy the essential amino acid requirements of geese, whereas just one would not. Nodding foxtail was deficient only in lysine, and rice cutgrass only in tryptophan (Table 4). Thus, these two seeds balance out each other's deficiencies. Similarly, a combination of rowcrop and moist-soil seeds would provide for both the energy and protein demands of geese. Availability of seeds should be timed to coincide with the nutritional demands of geese at specific periods in the annual cycle. Energy is a critical need in winter for thermoregulation and maintenance and deposition of fat reserves (King 1972, Prince 1979, Austin 1988). Protein is required at all times for body maintenance, but especially in preparation for breeding (Ankney and MacInnes 1978, Raveling 1979).

Some seeds that appear to be deficient in protein or certain essential amino acids may not be so under actual field conditions. The protein or amino acid requirement as a percentage of the total dry matter in the diet is based on the available energy in the food and the assumption that food intake is an average for holding or breeding conditions (Scott et al. 1982). Birds generally consume food to satisfy their daily energy demand. Thus a goose would need to consume much less high-energy food than low-energy food on a given day. If the two foods contained the same percentage of crude protein, a goose consuming the low-energy food would have a greater daily protein intake than a goose feeding on the high-energy food. A low-energy food can therefore have a lower protein or amino acid content and still satisfy the requirement of the goose. Similarly, at very low environmental temperatures food intake increases, resulting in a greater actual protein or amino acid intake. Thus a goose feeding on corn in winter might be able to satisfy its protein and essential amino acid demands to a greater extent than is apparent by simply comparing the protein or amino acid levels in corn with the published requirements for domestic geese in a holding situation.

Crude protein estimates and total amino acids (true protein) in seeds were similar. Some seeds contained more non-protein nitrogen than others (Table 8). Smartweed seeds were actually more deficient in true protein than they appeared on the basis of crude protein. This overestimation of true protein content by crude protein was generally not as great for seeds as for green vegetation (Sedinger 1984). The apparent underestimation of true protein by crude protein for wild millet was probably due to the method of sample pooling for amino acid analyses and averaging of crude protein values.

Energy, protein and amino acid values from this study were generally lower than published averages (National Research Council 1969, National Research Council 1984, Sibbald 1986). These differences could be due to random variation or to climatic and soil conditions on Missouri wildlife areas. However, results of regular soil tests from the study fields were not correlated ($p > 0.05$) with levels of nutrients or energy in corn. Such factors as genetics, fertilization, soil type and moisture affect the nutrient content of seeds (Frey 1949, Sauberlich et al. 1953, Miller et al. 1964, Eppendorfer 1978). Between- and within-wildlife area variation for the nutritional variables in corn was most likely a result of the influence of some of these factors. However, no consistent patterns in these differences between fields and areas were apparent. Some areas had higher averages for certain nutrients than other areas, but most of the variation appeared to result from differences between fields within areas (Table 9). Corn from two fields at Duck Creek WA had the highest and lowest average crude protein contents of all fields. Other variables and areas were similar. Some of this variation could possibly be controlled by managers and should be investigated further. Within species differences (Tables 9, 10, 11, 12 and 13) were not as great as between species differences (Table 1), however. Thus, even if protein content in hybrid corn were maximized, it would probably still be deficient relative to seeds such as rice cutgrass or nodding foxtail.

CHAPTER III

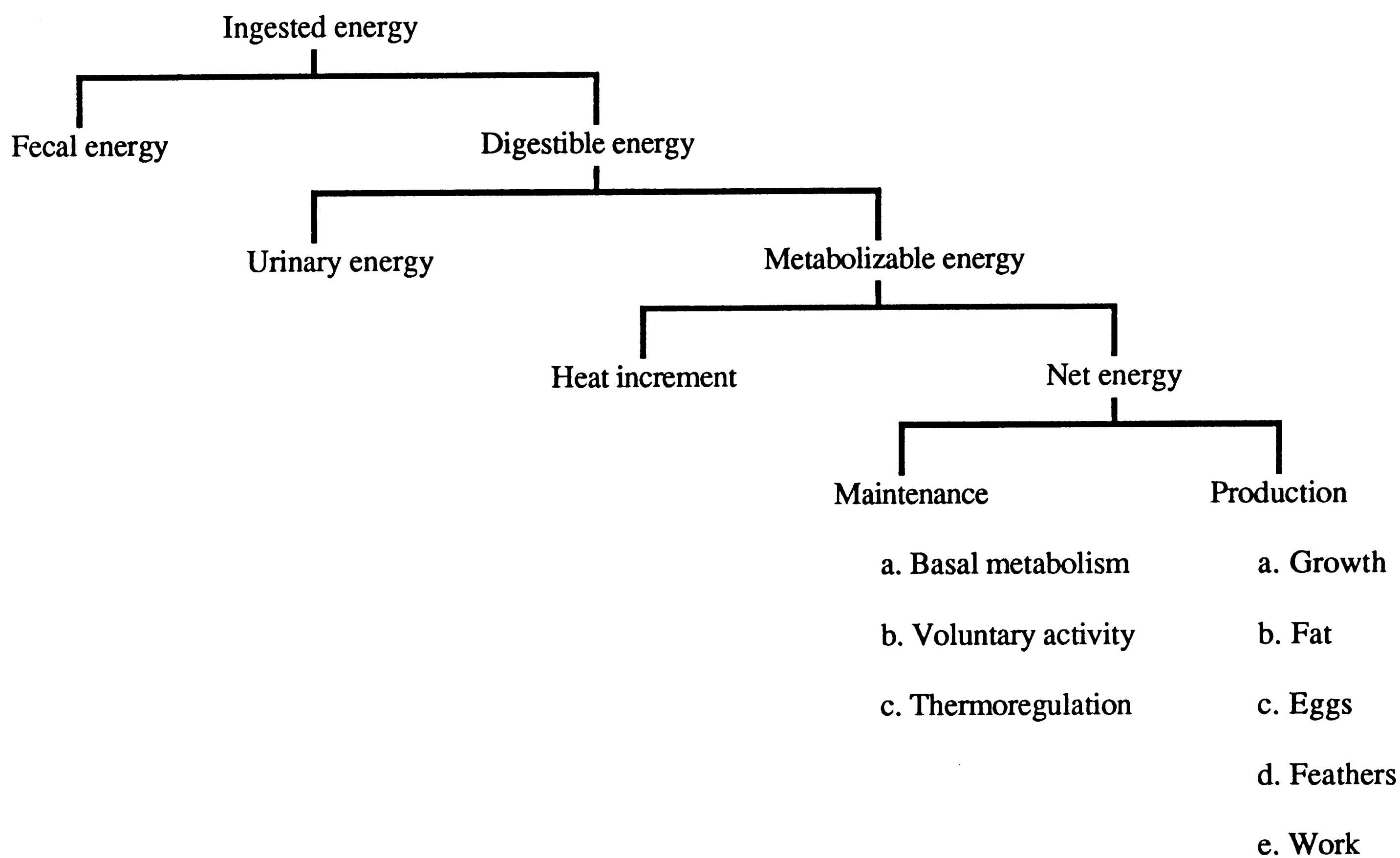
AVAILABILITY OF ENERGY IN SEEDS FOR CANADA GEESE

Wintering and migrating waterfowl require a dietary source of energy to satisfy needs including thermoregulation at cold winter temperatures (Kendeigh et al. 1977, Robbins 1983) and deposition of fat reserves used during migration and reproduction (King 1972, Ankney and MacInnes 1978, Raveling 1979, McLandress and Raveling 1981).

However, only a portion of the energy ingested by a bird is actually available for use (Scott et al. 1982, Robbins 1983, Sibbald 1986). A foodstuff is usually not completely digested or absorbed, so a quantity of energy is lost in the bird's feces (Figure 1). Energy losses as methane resulting from fermentation are negligible in non-ruminants (von Engelhardt et al. 1978, Robbins 1983). Of the compounds absorbed by the bird (digestible energy), some cannot be metabolized or oxidized. This energy is excreted in the urine and unavailable, leaving metabolizable energy (ME). The metabolism of nutrients also produces heat, some of which may be used by the bird for thermoregulation. Most of this heat increment, however, is lost. The remaining net energy is available to the bird for maintenance and production.

Metabolizable energy is generally used as an estimate of the energy in a food that is available for a bird's use because the heat increment is difficult to measure and because birds void feces and urine together from a common cloacal

Figure 1. Energy utilization by birds



opening. Metabolizable energy can be expressed as either apparent or true metabolizable energy (AME and TME, respectively) and may be corrected to zero nitrogen balance (Miller and Reinecke 1984, Sibbald 1986). Apparent ME is uncorrected for endogenous contributions to the excreta energy, whereas TME takes these endogenous energy losses in the feces and urine into account and is a more accurate estimate of the available energy in the diet (Sibbald 1986). The AME value for a food is always less than the TME value, and TME is less sensitive to variation in food intake by experimental birds.

Apparent ME has been widely used in avian energetics studies (Sugden 1971, Evans and Dietz 1974, Robel et al. 1979, Miller 1984, Miller and Reinecke 1984, Spurlock 1987, Shuman et al. 1988). However, studies of wildlife nutrition have rarely used TME as a measure of available energy (Hoffman and Bookhout 1985). TME is more commonly used in studies of domestic poultry (Storey and Allen 1982**a**,**b**, Sibbald 1986) but should see increasing usage in wildlife research because only small amounts of the test food are required (Miller and Reinecke 1984, Sibbald 1986).

MATERIALS AND METHODS

Twenty-five adult female Canada geese (*B. c. interior*) were captured at Swan Lake NWR in January 1987 for use in TME determinations. The geese were held at the Missouri Department of Conservation Swan Lake State Hunting Headquarters and fed whole corn until February when they were transported to the Porter Street Poultry Farm in Columbia, Missouri. Geese were placed five to a pen (approximately 1.5 by 2 m) and maintained on Purina Meat Builder (crude protein not less than 20.0%, crude fat not less than 3.0%, crude fiber not more than 5.0%) with access to fresh water at all times. Grit was not provided, as recommended by Sibbald (1986) for TME feeding trials. Geese were weighed to the nearest 0.1 kg weekly. Preliminary feeding trials were conducted from April through June 1987 to practice precision-feeding techniques and to investigate excreta collection methods. Metal trays beneath cages or plastic bags held directly over each goose's cloaca with a harness proved ineffective as excreta collection techniques because of spillage. Plastic sheeting suspended beneath each cage with safety pins such that excreta and water drained to the center was selected as the most effective method for quantitative collection of excreta.

In November 1987 geese were transferred to another building at the Porter Street Poultry Farm. Twelve or thirteen birds were held in each pen (about 4.5 by 6 m). Cages for feeding trials were also transferred and installed in the new building.

Feeding trials were conducted in 1988. The following seeds were tested: corn (February 2-5), milo (February 23-26), largeseed smartweed (April 12-15), nodding foxtail (April 26-29), and soybean (May 10-13). Two feeding trials were attempted with wild millet, but the geese regurgitated the seeds each time.

Procedure for TME feeding trials followed that of Sibbald (1976, 1986) and Hoffman and Bookhout (1985). Photoperiod was 14L:10D. Temperature ranged from about 10C to 27C while feeding trials were being conducted. For each feeding trial seven geese were randomly selected as experimental birds to be precision-fed the test seed. A goose of similar weight was paired with each experimental bird to serve as a control to estimate endogenous losses in the excreta. All birds were placed in alternate individual metabolism cages (61 x 46 x 61 cm) which had been cleaned prior to the trial. Geese had access to water at all times while in the metabolism cages. After a 24 hour fasting period, each experimental bird was precision-fed a known weight of the test seed by means of a 1.2 by 40 cm copper tube inserted down the esophagus via the mouth. Seeds were slowly poured into a funnel attached to the upper end of the tube and pushed down the tube with a steel rod. For the corn and milo trials, experimental birds were fed approximately 30 g each. Experimental birds received only about 10 g each of nodding foxtail, largeseed smartweed and soybeans to prevent crop impaction or regurgitation caused by feeding greater quantities. Control birds were not fed. After precision-feeding was completed, a 61 x 91 cm piece of plastic sheeting was suspended beneath each cage. Excreta samples were collected quantitatively after 48 hours by rinsing into labelled one quart plastic containers. Samples were frozen for later analysis. Feathers were later picked from excreta samples, and excreta was rinsed from the feathers. Samples were then oven-dried at 65C until dry, weighed and ground with a mortar and pestle. Percent moisture of excreta samples was determined by oven-drying to constant weight. Gross energy of samples was determined on duplicate subsamples with a Parr adiabatic oxygen bomb calorimeter (30 atm O_2).

True metabolizable energy was calculated after Sibbald (1976): $TME = ((GE_f \times W_f) - (EE_f - EE_c)) / W_f$ where GE_f is the gross energy of the foodstuff (kcal/g dry matter), W_f is the dry weight fed (g), EE_f is the energy voided as excreta by the experimental bird, and EE_c is the energy voided as excreta by the control bird.

RESULTS

Energy excreted and dry matter excreted by control birds were not correlated ($P > 0.90$) with weight of the control bird for the corn feeding trial (Table 14). Pooled values for energy and dry matter excreted by control birds in a feeding trial were therefore used to calculate TME and true digestibility rather than pairing birds of similar weight.

Largeseed smartweed had the lowest TME, metabolic efficiency and true digestibility of all the seeds tested (Tables 15, 16 and 17). These differences were significant ($P < 0.05$) for TME and metabolic efficiency. Values for corn and milo tended to be higher than for other seeds, although these differences were not always significant ($P < 0.05$). Nodding foxtail and soybeans were intermediate.

Table 14. Weight of control bird, energy and dry matter excreted for corn feeding trial

Weight (kg)	Energy excreted (kcal)	Dry matter excreted (g)
3.4	13.48	4.55
3.7	9.24	3.26
3.9	11.31	3.75
4.1	15.34	5.48
4.6	10.30	3.14
5.0	12.86	4.33

Table 15. True metabolizable energy of seeds

Species	N	TME (kcal/g)	SE
Soybean	7	4.104 [A]	0.17
Milo	6	4.016 [A]	0.03
Corn	6	3.856 [A]	0.09
Nodding foxtail	6	3.463 [A]	0.18
Largeseed smartweed	6	2.726 [B]	0.49

[AB] - Different superscripts indicate significant between-species differences ($P < 0.05$)

Table 16. Metabolic efficiencies for seeds

Species	N	Metabolic efficiency (%)	SE
Milo	6	89.30 ^{A}	0.74
Corn	6	87.26 ^{AB}	2.06
Nodding foxtail	6	78.39 ^{AB}	3.87
Soybean	7	73.32 ^{B}	2.97
Largeseed smartweed	6	56.86 ^{C}	10.25

^{ABC} - Different superscripts indicate significant between-species differences ($P < 0.05$)

Table 17. True digestibilities of seeds

Species	N	True Digestibility (%)	SE
Milo	6	89.29 ^{A}	0.89
Corn	6	84.58 ^{A}	2.60
Nodding foxtail	6	77.33 ^{AB}	5.34
Soybean	7	64.86 ^{BC}	2.97
Largeseed smartweed	6	58.87 ^{C}	11.13

^{ABC} - Different superscripts indicate significant between-species differences ($P < 0.05$)

Values for largeseed smartweed, nodding foxtail and soybeans were also more variable than for corn and milo.

DISCUSSION

Energy and dry matter excreted by control birds were averaged for each feeding trial because neither variable was correlated ($P > 0.90$) with the weight of the control bird (Table 14). Use of pooled values reduced standard errors associated with TME, metabolic efficiency and true digestibility values. Pairing control and experimental birds of similar weight apparently did little good in this case. The use of each experimental bird as its own control might have yielded less variable data (Sibbald and Price 1980).

The hard seedcoat of largeseed smartweed was most likely responsible for the low true ME and metabolic efficiency values of this seed for Canada geese. Many smartweed seeds passed through the geese in a few hours with no visible evidence of digestion. This lack of digestion was not noted for any of the other seed species. Smartweed and nodding foxtail seeds also had higher crude fiber contents than corn or milo. Geese appear to have little or no cecal fermentation and digest cellulose very poorly (Marriott and Forbes 1970, Mattocks 1971, Sedinger et al. 1989), making crude fiber largely unavailable as an energy source. This could have resulted in lower true digestibilities and metabolic efficiencies for the moist-soil seeds as compared to the rowcrops.

Soybeans, despite having a fiber content similar to milo or corn (Table 1), had lower metabolic efficiencies and true digestibilities than these seeds. Soybeans are known to contain appreciable levels of antinutritional factors which decrease the efficiency of feed utilization in poultry (Scott et al. 1982, Spurlock 1987). One of these factors is an inhibitor which interferes with the action of the proteolytic enzyme trypsin. The presence of these antinutritional factors in soybeans is probably responsible for the low metabolic efficiency and true digestibility of this seed for Canada geese. Although soybeans had a much higher GE than the other seeds (Table 3), their TME was about the same as that of corn or milo. Corn and milo were the best sources of available energy because of their low fiber content and high level of NFE (Table 1).

TME, metabolic efficiency and true digestibility values were more variable for largeseed smartweed, nodding foxtail and soybeans than for corn and milo (Tables 15, 16 and 17). Several factors presumably account for this variation. The most likely is the difference in the amounts of each seed species fed to the experimental geese. Each goose received about 30 g DM of corn and milo compared to only 10 to 12 g DM of smartweed, foxtail and soybeans. Lesser amounts of these seeds were fed to prevent regurgitation. This probably increased the margin for error in the excreta collections for these seeds. TME has been shown to increase as feed intake increases, up to a point where increased intake results in regurgitation (Sibbald 1976). Other factors which may have affected the variability of the results include retention of seeds with higher fiber contents within the experimental birds' digestive tracts beyond the 48 hour excreta collection period or the possibility of undetected regurgitation or loss of excreta which would tend to increase TME values for those birds (Sibbald 1986).

Temperatures varied among feeding trials, ranging from about 10C for corn and milo up to about 27C for the soybean trial. Temperature should have had little effect on ME values. Environmental temperature does influence feed intake (Scott et al. 1982, Perry et al. 1986), but variation in this variable was controlled by precision-feeding. Geese also had no access to grit, no period to acclimate to the new diet, and photoperiod was roughly equivalent to spring or summer, rather than winter. Photoperiod, like temperature would likely influence food intake and should not have affected ME values too much. Grit would be expected to enhance physical digestion of seeds, possibly resulting in increased ME values for those seeds such as smartweed which were incompletely digested. A period of acclimation to each food might have resulted in changes in digestive tract morphology which could have increased efficiency of digestion of foods (Miller 1975). These conditions raise some doubt about directly relating the results of this research to wintering geese in the wild.

The results of this study do, however, compare reasonably well with previously reported ME, metabolic efficiency and digestibility values for Canada geese, various duck species and domestic fowl (Tables 18 and 19). Values

Table 18. Comparison of ME values of seeds for several bird species

Seed species	Canada goose TME[a]	Mallard TME[b]	Chicken TME[c]	Embden goose TME[d]	Embden goose AME[d]	Canada goose AME[e]
Corn	3.856	-	4.111	4.265	4.016	3.970
Milo	4.016	-	3.991	4.034	3.845	3.960
Soybean	4.104	-	3.059	-	-	-
Largeseed smartweed	2.726	1.080	-	-	-	-

[a]This study
[b]Hoffman and Bookhout (1985)
[c]Calculated from Sibbald (1986)
[d]Storey and Allen (1982b)
[e]Joyner et al. (1987)

Table 19. Comparison of efficiency of energy utilization of corn and milo by Embden and Canada geese

	Efficiency of energy utilization (%)			
Seed species	Canada goose[a]	Canada goose[b]	Embden goose[c]	Embden goose[d]
Corn	87	91	92	87
Milo	89	89	92	88

[a] This study - based on TME
[b] Joyner et al. (1987) - based on AME
[c] Storey and Allen (1982b) - based on TME
[d] Storey and Allen (1982b) - based on AME

for corn and milo from other studies were within about 10 percent of the values determined for Canada geese in this study. TME values of soybeans and largeseed smartweed, however, were much less for chickens and mallards, respectively, than for Canada geese. This suggests that geese are more efficient at metabolizing the energy in these seeds than other species of fowl, but the validity of the values obtained from these seeds for Canada geese is subject to question. Perhaps the digestive tract of geese is adapted to physically process food more effectively than mallards or chickens because of the generally higher fiber content of the diet of geese. Geese may not be as affected by the antinutritional factors in soybeans, or more likely these factors were denatured to some extent when the soybeans were dried at 80C prior to the feeding trial. Thus soybean digestibility was apparently increased (Scott et al. 1984).

The results of the feeding trials lend support to the idea that geese cannot digest cellulose well and utilize fiber very inefficiently (Marriott and Forbes 1970, Mattocks 1971, Sedinger et al. 1989). They rely on high rates of food intake and rapid passage rates to meet their daily energy requirements rather than on efficiently digesting and metabolizing the energy in a food as many herbivores do (Robbins 1983), although Buchsbaum et al. (1986) estimated the metabolizability of cellulose by Canada geese and Atlantic brant to be about 30%. Waterfowl presumably alter their gut morphology in response to a high fiber diet to enhance digestion (Miller 1975).

The daily existence metabolism and food intake of a Canada goose can be used to determine which foods contain sufficient metabolizable energy to support a wintering goose. Daily food consumption is influenced by the energy content of the food and environmental temperature (Scott et al. 1982, Summers and Leeson 1985, Perry et al. 1986). Birds generally try to consume enough food each day to satisfy their energy demands (Scott et al. 1982). The daily energy requirement is in turn determined to a great extent by the temperature of the environment (Kendeigh et al. 1977, Williams and Kendeigh 1982). Austin (1988) calculated the daily existence metabolism of a female Canada goose at Swan Lake NWR during the coldest part of the year to be about 597 kcal/bird/day using the equations developed by Williams and Kendeigh (1982). Canada geese have been reported to consume varying amounts of food each day. Average maximum daily DM intake was 160 - 180 g (Joyner er al. 1984) and 148 g (Joyner et al. 1987) in studies of captive geese. Estimates of daily food consumption in winter by wild geese were 0.527 lb (239 g) of grain (Vaught and Kirsch 1966) and 0.4 lb (181 g) of corn or 0.36 lb (163 g) of small grains (Jordan 1953). Assuming a maximum daily DM intake of about 180 g and daily existence metabolism of about 600 kcal/day, a female goose would need to consume a food with a TME content of at least 3.3 kcal/g DM to satisfy its energy demands. All of the seeds tested except largeseed smartweed had TME levels more than adequate for this. Geese feeding on higher energy foods such as corn or milo would not have to consume as great a quantity of food and could therefore spend less time feeding. This suggests that rowcrops can be very important energy sources when lipid reserves must be acquired in a short period of time or during the cold winter months.

Information on the available energy in a food and the daily energy requirements of waterfowl can also be combined with the food production figures on a given area to determine the number of waterfowl-use days available (Hoffman and Bookhout 1985, Austin 1988). During a severe winter at Swan Lake NWR (mean temperature of -8C), the daily existence metabolisms of male and female geese were 550 and 524 kcal/day, respectively (Austin 1988). The average TME for corn was about 3.86 kcal/g DM (Table 15). About 3.5 million kg (3.0 million kg DM based on average moisture content for corn of 13.6% (this study)) of corn are available for geese during a typical year at Swan Lake NWR (Austin 1988). This translates to 11.7 billion kcal of available energy which provides about 21 million goose-use days. Thus the corn production on Swan Lake NWR in a typical year could support 100,000 geese for a little over 200 days. This assumes, however, that the corn produced on the refuge is completely available to geese and that no ducks or other birds are utilizing this grain, both of which are very unlikely.

CHAPTER IV

EFFECTS OF FLOODING ON SEED DETERIORATION AND ENERGY CONTENT

Waterfowl foods are exposed to a variety of environmental conditions prior to consumption by ducks or geese. Certain foods may remain unused by waterfowl for some time until supplies of more preferred foods become exhausted or unavailable (Paulus 1982). Natural or intentional fall flooding by managers may result in seeds being immersed in water for up to several months before they are used by waterfowl. Whether seeds are flooded, exposed on the ground, or remain attached to the plant, deterioration or changes in their nutrient and energy content are possible. Consumption of seeds by other animals such as rodents or nongame birds is also a possibility (Davison 1961, McGinn and Glasgow 1963). It is therefore important that managers understand how the availability and quality of waterfowl foods are affected by exposure to flooded and non-flooded conditions prior to use by waterfowl.

Several previous studies have examined the effects of flooding on deterioration rates of seeds, loss of seeds, or nutritional quality of seeds. Dry matter deterioration of flooded seeds varied greatly among species, ranging from 1% for bulrush (Scirpus robustus) to 86% for soybeans after 90 days immersion (Neely 1956). All species showed exponential rates of deterioration over time. Seeds from one stand of Panicum ramosum were less susceptible to flooding deterioration than those from other sites. Similar results were obtained by Shearer et al. (1969), although percentages of deterioration for the same or similar species were slightly less than those from the previous study. They also concluded that agricultural grains are readily accepted by mallards (Anas platyrhynchos) following exposure to flooding. McGinn and Glasgow (1963) examined seed loss, deterioration, viability and nutritional content after exposure on both the ground and in water for up to 120 days. Seed loss occurred more rapidly on the ground than under water. Loss may have resulted from consumption by rodents, birds or insects, or from removal of seeds by wind or runoff from precipitation.

MATERIALS AND METHODS

Six species of seeds were exposed to flooded and non-flooded conditions at Fountain Grove WA for 30 and 95 days beginning October 27, 1987. Three replications were made for each treatment and duration. For each replication, a measured weight of each seed along with a plastic identification tag was placed in a nylon mesh bag which was secured with staples. Gross energy of each seed sample was determined with a Parr adiabatic oxygen bomb calorimeter (30 atm O_2) prior to exposure. One bag of each seed species was placed in a 30 x 30 x 15 cm hardware-cloth cage. Twelve such cages were placed at Fountain Grove, six being submerged in about 60 cm of water (pH = 8.20) near the shore in Pool 2 close to the area headquarters, and six being staked out on a mowed area west of the headquarters building. After 30 days, three cages were randomly retrieved from the flooded group and three from the non-flooded group. The remaining cages were retrieved after 95 days. Thick ice covering the flooded cages prevented retrieval at 90 days as proposed. Samples were returned to the lab immediately following retrieval and washed while still in the nylon mesh bags. Each sample was oven-dried at 65C until constant weight was reached. Each sample was then weighed and gross energy determined.

RESULTS

Rowcrop and moist-soil seeds deteriorated to varying degrees when exposed to flooded and non-flooded conditions for 30 and 95 days (Table 20). Wild millet deteriorated the least and soybeans the most for all treatments. Soybeans were especially susceptible to dry matter loss when flooded. The other seed species deteriorated somewhat more than wild millet when flooded, but 80 to 90 percent of the original dry matter of these seeds remained after flooding for 95 days. Non-flooded soybeans still lost significantly more dry matter than other seeds ($P < 0.05$), but losses were less than when flooded. Wild millet, corn, milo, nodding foxtail and largeseed smartweed all lost no more than about 10 percent dry matter in the non-flooded situation regardless of the duration of exposure.

No significant differences ($P > 0.05$) in deterioration of wild millet exposed for 30 and 95 days existed between flooded and non-flooded conditions. Duration of exposure had little effect on deterioration for this

Table 20. Percent dry matter of seeds remaining after exposure to flooded and non-flooded conditions for 30 and 95 days

Seed	Flooded		Non-flooded	
	30 days	95 days	30 days	95 days
Wild millet[1]	$97.35^{A\ R}$	$103.69^{B\ R}$	$96.36^{A\ R}$	$98.92^{AB\ R}$
Nodding foxtail	$89.79^{A\ S}$	$89.53^{A\ S}$	$91.71^{A\ RS}$	$94.18^{A\ RS}$
Corn	$86.02^{A\ ST}$	$82.88^{A\ T}$	$92.18^{B\ RS}$	$93.33^{B\ S}$
Milo	$83.06^{A\ T}$	$78.92^{A\ T}$	$90.81^{B\ RS}$	$91.53^{B\ S}$
Largeseed smartweed	$82.57^{A\ T}$	$78.69^{A\ T}$	$89.54^{B\ S}$	$89.41^{B\ S}$
Soybean	$48.40^{A\ U}$	$23.08^{B\ U}$	$79.82^{C\ T}$	$75.44^{C\ T}$

[1] - Denotes _E_. _crusgalli_

ABC - Different superscripts in the same row indicate significant differences ($P < 0.05$) between treatments for a given seed species

RSTU - Different superscripts in the same column indicate significant differences ($P < 0.05$) between seed species for a given treatment species, although millet samples exposed to flooding for 95 days actually gained weight. Similarly, nodding foxtail deterioration was not significantly different ($P > 0.05$) between treatments. Corn, milo, largeseed smartweed and soybeans all lost more dry matter when flooded than non-flooded. Duration of exposure affected deterioration only of flooded soybeans, with significantly less ($P < 0.05$) dry matter remaining after 95 days than after 30 days.

Gross energy per gram dry matter of some seed species also changed after exposure to flooded and non-flooded conditions (Table 21). Soybeans increased significantly ($P < 0.05$) in energy content for all treatments. Other seed species lost small percentages of their original energy, except for corn which was essentially unaffected. The increase in soybean energy content was significantly greater ($P < 0.05$) for flooded samples. The gross energy of soybeans increased from 5.597 to 6.259 kcal/g dry matter when flooded for 30 days. Duration of exposure had no significant effect for soybeans ($P > 0.05$). For wild millet, energy loss was significantly greater ($P < 0.05$) when flooded than non-flooded. Both largeseed smartweed and nodding foxtail showed no difference in energy loss between flooded and non-flooded conditions at 30 days. After 95 days, however, energy loss was greater for flooded than for non-flooded samples of these species. For corn and milo, no differences in energy loss existed between flooded and non-flooded conditions or between the two durations for either treatment.

Table 21. Percent gross energy change of seeds after exposure to flooded and non-flooded conditions for 30 and 95 days

Seed	Flooded 30 days		Flooded 95 days		Non-flooded 30 days		Non-flooded 95 days	
Milo	$-2.05^{A\ TU}$		$-2.91^{A\ T}$		$-2.86^{A\ T}$		$-2.84^{A\ U}$	
Largeseed smartweed	$-1.33^{A\ TU}$		$-3.93^{B\ T}$		$-1.69^{A\ ST}$		$-1.53^{A\ TU}$	
Wild millet[1]	$-3.06^{B\ U}$		$-3.49^{B\ T}$		$-0.01^{A\ S}$		$-1.00^{A\ TU}$	
Nodding foxtail	$-0.98^{AB\ ST}$		$-2.52^{B\ T}$		$-0.75^{AB\ S}$		$-0.49^{A\ ST}$	
Corn	$+0.91^{A\ S}$		$+0.81^{A\ S}$		$+0.78^{A\ RS}$		$+1.31^{A\ S}$	
Soybean	$+11.83^{A\ R}$		$+9.30^{B\ R}$		$+2.51^{C\ R}$		$+4.23^{C\ R}$	

[1] - Denotes E. crusgalli

ABC - Different superscripts in the same row indicate significant differences ($P < 0.05$) between treatments for a given seed species

RSTU - Different superscripts in the same column indicate significant differences ($P < 0.05$) between seed species for a given treatment

DISCUSSION

As studies have shown for other locations (Neely 1955, McGinn and Glasgow 1963, Shearer et al. 1969), seeds deteriorated to varying degrees when subjected to flooded and non-flooded conditions in Missouri (Table 20). No differences were apparent between rowcrop and moist-soil seeds. Wild millet was the most resistant to dry matter loss, and soybeans the least, with nodding foxtail, corn, milo and largeseed smartweed falling in between. Most dry matter loss occurred within the first 30 days of exposure. This rapid initial loss of material followed by a period of slower deterioration has been observed for seeds and other plant parts (Neely 1955, Schnauss 1976). Such losses may result from leaching of water-soluble compounds (McDonough and Chadwick 1970, Kaushik and Hynes 1971) or breakdown of compounds by fungi and bacteria (Christensen and Kaufmann 1974, Clark and Paul 1970). The loss of soluble substances from leaves primarily takes place during the first day of immersion, with temperature having little effect (Kaushik and Hynes 1971). Subsequent microbial degradation of plant tissues is greatly enhanced by higher temperatures, up to a point (Kaushik and Hynes 1971, Schnauss 1976, White 1982, Abdul-Baki and Anderson 1972, Christensen and Kaufmann 1974, Waksman and Gerretsen 1931). Seed samples in this study were placed in the field in late October and retrieved in late January. Lower temperatures during the latter part of the exposure period probably had some effect on the slower rate of deterioration during this period.

Different responses by seed species may have resulted from differences in seed composition. Soybeans had a much higher fat content than the other seeds (Table 1). Fat hydrolysis in seeds proceeds much more rapidly than protein or carbohydrate breakdown (Owen 1956).

The weight gain for some wild millet samples probably resulted from the accumulation and adherence of foreign debris as was observed by Schnauss (1976). Insufficient washing may have failed to remove such matter.

Most seeds experienced some change in energy content during exposure (Table 21). Such changes have been noted for decomposing plant matter (Kaushik and Hynes 1971). These changes are difficult to explain for seeds. McGinn and Glasgow (1963) showed that the proximate content of seeds did not change much when exposed to flooded and non-flooded conditions. Thus, the energy content would not be expected to change either. Leaching of seed constituents may have had some effect on the pattern of energy change. Flooded samples of smartweed, wild millet and foxtail all lost more energy after 90 days than non-flooded samples of the same species. Microbial synthesis of protein might have increased energy to some extent.

When one examines the total available energy (based on metabolic efficiencies (Table 16) from Chapter 3 of this study) of 100 g of seeds before and after exposure to flooded and non-flooded conditions (Table 22), the same pattern as

Table 22. Total available energy of 100 g DM of seeds before and after exposure to flooded and non-flooded conditions for 30 and 95 days

Seed	Total available energy (kcal) in 100 g DM of seeds prior to exposure	Total available energy (kcal) remaining after exposure			
		Non-flooded		Flooded	
		30 days	95 days	30 days	95 days
Corn	386	358	365	335	323
Milo	402	354	357	327	308
Soybean	411	336	322	222	104
Largeseed smartweed	268	236	236	218	203
Nodding foxtail	353	321	331	313	307

was observed for dry matter deterioration is evident. Very little of the original energy of soybeans remained after exposure to flooding for 95 days. Managers can also use this to estimate the amount of energy available from a known amount of seeds produced on an area under different conditions.

CHAPTER V

SUMMARY AND MANAGEMENT RECOMMENDATIONS

Rowcrop and moist-soil seeds provide needed energy, protein and essential amino acids for Canada geese (Table 23). They are an integral part of an effective management program for migrating and wintering geese. Corn and milo contained readily available energy needed for thermoregulation and fat deposition. Nodding foxtail and rice cutgrass were able to satisfy the protein and essential amino acid requirements of geese. Soybeans and beggarticks appeared to be excellent sources of energy and protein, but were unsuitable for geese for other reasons. Corn, milo, smartweeds and wild millet were deficient in protein and many essential amino acids. Most seeds, except for soybeans, resisted deterioration when flooded, making them well-suited for inclusion in wetland management programs for Canada geese.

The following management recommendations are made based on the results of this study:

1. Corn and milo should be provided as primary sources of energy for wintering geese.

2. Nodding foxtail and rice cutgrass should be considered as sources of protein and amino acids.

Table 23. Suitability of seeds for use in Canada goose management programs

Seed	Metabolizable energy	Protein and amino acids	Flooding resistance
Corn	Excellent	Poor	Good
Milo	Excellent	Poor	Good
Soybean	Good	Excellent[a]	Poor
Wild millet[1]	-	Poor	Excellent
Largeseed smartweed	Poor	Poor	Good
Nodding smartweed	-	Poor	-
Rice cutgrass	-	Good	-
Nodding foxtail	Good	Good	Good
Beggarticks	-	Excellent	-

[a]Availibility of protein and amino acids is poor due to antinutritional factors in soybeans

[1] - Denotes *E. crusgalli*

3. Soybeans should not be provided as goose foods because of their problems with antinutritional factors and susceptibility to deterioration, as well as the possibility of crop impaction.

4. Smartweeds and wild millets should not be viewed as excellent waterfowl foods because of their low protein, amino acid and TME levels. They do, however, resist flooding deterioration well and are readily utilized by geese.

5. In general, the best management strategy appears to be the provision of a variety of food types (rowcrops, moist-soil plants and green browse) in order to meet the many nutritional demands of Canada geese.

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The undersigned, appointed by the Dean of the Graduate Faculty, have examined a thesis entitled

THE NUTRITIONAL QUALITY OF SELECTED ROWCROP AND MOIST-SOIL SEEDS FOR CANADA GEESE

presented by CHAD E. BUCKLEY

a candidate for the degree of MASTER OF SCIENCE

and hereby certify that in their opinion it is worthy of acceptance.

[redacted]

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