Effects of a Milo Diet, Mineral Supplementation, and Native Seed Use in Pen-Raised Northern Bobwhites

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Abstract: Stocking of pen-raised northern bobwhites (*Colinus virginianus*) into natural habitat is a common management strategy for this species, as is supplemental feeding of the cultivated seed milo (*Sorghum bicolor*) to wild bobwhites. However, milo may be deficient in minerals and/or other nutrients, leading to negative effects for bobwhites eating only milo. Additionally, pen-raised bobwhites with no experience eating seeds may be reluctant to eat native seeds they may find when released. We studied the effects of a milo-only diet on pen-raised bobwhites during the non-breeding season, and we tested the effects of mineral supplementation on bobwhites fed a milo diet. We also studied use and selection of native seeds by pen-raised bobwhites, and we tested the hypothesis that exposure to a cultivated seed (milo) diet improves the willingness of pen-raised bobwhites to eat native seeds. Bobwhites maintained body mass over a 28-day period on a milo-only diet, whether or not mineral supplementation was available. Pen-raised bobwhites with no seed diet experience ate only small amounts (≤16 cm^3) of native seeds over a 48-hr period, even when no other foods were available; bobwhites with experience eating a milo diet ate twice as much. Bobwhites preferred native seed common ragweed (*Ambrosia artemisiifolia*) over native seeds partridge pea (*Chamaecrista fasciculata*) and Illinois bundleflower (*Desmanthus illinoensis*). Unwillingness to eat native seeds may limit survival of pen-raised bobwhites stocked into the wild.

Key words: *Colinus virginianus*, milo, minerals, native seeds, northern bobwhite

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The northern bobwhite (*Colinus virginianus*, hereafter "bobwhites" or "quail") is a popular and economically important game species in Tennessee and elsewhere throughout its distribution (Burger et al. 1999). In recent decades, however, populations of bobwhites have declined dramatically, primarily due to habitat change/loss and fragmentation (Hernandez et al. 2013). This decline threatens recreational opportunities and economic returns generated from bobwhite hunting. One approach to habitat management for bobwhites has been the use of supplemental feeding either through wildlife food plots or direct feeding of seeds (Madison and Robel 2001, Doerr and Silvy 2006). Although agricultural seeds commonly fed to bobwhites (e.g., milo [*Sorghum bicolor*]) are high in carbohydrates, they often are low in other nutritional components compared to seeds of native species (Hayslette and Mirarchi 2001, Applegate 2015). Deficiencies in specific nutrients can have negative impacts on wild birds eating a milo-only diet. For example, white-winged doves (*Zenaida asiatica*) eating only milo exhibit reduced reproductive output compared with those including native seeds in their diet, likely due to protein deficiency (Pruitt et al. 2008).

Because levels of some minerals (e.g., calcium, magnesium) are lower in milo than in some native seeds (Hayslette and Mirarchi 2001), we hypothesized that a milo-only diet would be deficient in minerals for bobwhites. Thus, two objectives of our study were to document the effects of a milo-only diet on bobwhites during the non-breeding season and to evaluate the hypothesis of mineral deficiency in a milo diet by testing the prediction that mineral supplementation mitigates negative effects of a milo diet on bobwhite performance.

Early studies (Davidson 1949, Michael and Beckwith 1955, Ellis 1961) suggested adaptability of bobwhites to novel/new food items. Klimstra and Scott (1973), however, found that pen-raised bobwhites have problems recognizing native foods and that a learning period is required for adaptation to a natural diet. These authors also suggested the need for research into methods to facilitate this adaptation. Our own experience also indicated that pen-raised bobwhites, raised exclusively on a commercial game bird diet, are unwilling to eat native seeds even when no other foods are available. Thus, additional objectives of this study were to document the general willingness of pen-raised bobwhites to eat native seeds and to test the hypothesis that previous experience with agricultural grains improves the willingness of pen-raised birds to eat native seeds.

Methods

Our study was conducted at the Tennessee Tech University (TTU) Avian Research Facility during January–March 2017. We conducted feeding trials to examine the effects of a milo diet and mineral supplementation during two 28-day periods, 13 January–10 February and 17 February–17 March 2017. We used different bobwhites, obtained from a local breeder, during each period. During non-trial periods, we housed bobwhites in a 7.3 × 3.7 × 1.8-m free flight aviary and fed them Purina Game Bird Chow (game bird complete diet, GBCD) *ad libitum*. During trials, we housed bobwhites individually in 1.2 × 1.8 × 1.2-m pens. We randomly assigned each bobwhite used in feeding trials to one of three feeding treatments: milo alone, milo supplemented with an all-purpose mineral supplement (Producer's Pride General Purpose Mineral), and GBCD (control). We attempted to balance sample sizes and gender ratios among birds in each treatment, but failure of birds to adapt to experimental feeders and other non-treatment-related health issues resulted in imbalances. Sample sizes were 9 (4M, 5F), 8 (3M, 5F), and 7 (4M, 3F) in the milo-only, milo with mineral, and control groups, respectively.

We provided each bobwhite assigned to a milo treatment 240 g milo in 3 cups (80 g each) at the start of each period. Cups were housed in a plastic box with a lid; bobwhites accessed milo through a slot in the side of the box. In each pen, we placed the food box on a 1.8-m wooden tray, which served to catch any milo spilled outside the box. We offered powdered mineral supplement (100 g, volumetrically equivalent to 80 g milo) to bobwhites (in the supplemented treatment group) in a fourth cup, which was housed in a 3.8-L plastic milk jug with a slot in the side. We provided control bobwhites with 180 g game bird chow in 3 cups (60 g each, volumetrically equivalent to 80 g milo) in the same manner as milo cups. We measured remaining food (milo or game bird chow) and replenished them at 3- to 4-day intervals throughout the 28-day period. We measured and replaced mineral supplement similarly for bobwhites receiving it. We measured body mass (nearest g) of each bobwhite at the beginning and end of each 28-day trial period, and at 3- to 4-day intervals during the period (concurrent with food measurements).

At the end of each 28-day period, we calculated total food consumption by subtraction for each bobwhite and subsequently expressed consumption as g food eaten/g original quail body mass/day. We also calculated mineral consumption for birds receiving it and expressed it as g eaten/day. We calculated body mass change of each bobwhite during the period and expressed it as proportion of original body mass/day. We compared food consumption and body mass change among treatment groups using 1-way analysis of variance (ANOVA) and Tukey's means separation test, pooling bobwhites across study periods and genders. We used SAS software (Version 9.4; SAS 2015) and $\alpha = 0.05$ for these and all subsequent analyses. We present means ± standard errors.

To address the hypothesized problem of pen-raised bobwhites in recognizing native foods upon release, we conducted a second study of native seed use by pen-raised bobwhites. We used 14 pen-raised bobwhites from the milo-mineral study, 7 from the unsupplemented milo group (hereafter 'milo-conditioned') and 7 from the control group (hereafter 'naïve', for their lack of exposure to a seed diet). We included two additional bobwhites not used in the milo-mineral study and maintained on GBCD throughout in the naïve group. Within the milo-conditioned group, 3 birds (2M, 1F) received native seeds with GBCD, and 4 (1M, 3F) received native seeds alone. Within the naïve group, 4 (2M, 2F) received native seeds with GBCD, and 5 (4M, 1F) received native seeds alone. We housed bobwhites individually in 1.2 × 1.8 × 1.2-m pens during trials. Native seed types used were partridge pea (*Chamaecrista fasciculata*), Illinois bundleflower (*Desmanthus illinoensis*), and common ragweed (*Ambrosia artemisiifolia*).

Each native seed trial lasted 48 h. We offered each bobwhite 50 cm^3 of each seed type (and GBCD, if used) separately in 41 × 41 × 4-cm wooden trays. We used volumetric measurements of foods, rather than masses, because volume/unit mass varied greatly among foods. We collected, measured (by volume, cm^3), and replenished remaining food after 24 h, and we measured remains again after the second 24-h period. We calculated consumption of each food (seeds and GBCD; by volume, cm^3) by each bobwhite by subtraction for each 48-h trial. To test the effects of GBCD availability, milo conditioning, and their interaction on native seed consumption, we summed consumption of all native seeds over the 48-hour period for each bobwhite, and we compared total native seed consumption between bobwhite types (milo-conditioned versus naïve) and treatments (GBCD versus none) using 2-way ANOVA and Tukey's means separation test (hereafter "total native seed ANOVA"). To assess native seed selection and interactions with milo conditioning and GBCD availability, we compared consumption of the three seed types using split-plot ANOVA and Tukey's means separation test (hereafter 'native seed selection ANOVA'). Bobwhite type (milo-conditioned vs. naïve) and treatment (GBCD vs. none) were whole-plot factors, and seed type was a split-plot factor.

Results

In our milo-mineral study, food consumption varied among treatment groups ($F = 13.0$, df = 2, 21; $P < 0.001$) and was greater in the control (GBCD) group than in either milo group (Table 1). Body mass change did not vary among treatment groups ($F = 0.6$, df = 2, 21; $P = 0.544$). All bobwhites with access ate mineral supplement; daily mineral consumption ranged 0.3–0.7 g day^{-1} ($\bar{x} = 0.4$ g day^{-1}).

In our native seed use and selection study, both milo-conditioning and GBCD availability affected native seed consumption (Figure 1). In the total native seed ANOVA, milo-conditioned bobwhites with

Table 1. Food eaten by, and body mass change of, pen-raised northern bobwhites in captive trials, January–March 2017, Tennessee.

	Food eaten (g g body mass^{-1} day^{-1})			Body mass change (proportion original mass day^{-1})		
Treatment	***n***	$\bar{x}$[a]	**SE**	***n***	$\bar{x}$[a]	**SE**
Milo with mineral	9	0.074 A	0.003	9	0.00004 A	0.00056
Milo without mineral	8	0.073 A	0.003	8	0.00041 A	0.00046
Control (GBCD)[b]	7	0.096 B	0.005	7	0.00091 A	0.00062

a. Column means with the same letter do not differ ($P > 0.05$) using Tukey's means separation test.
b. Game bird complete diet.

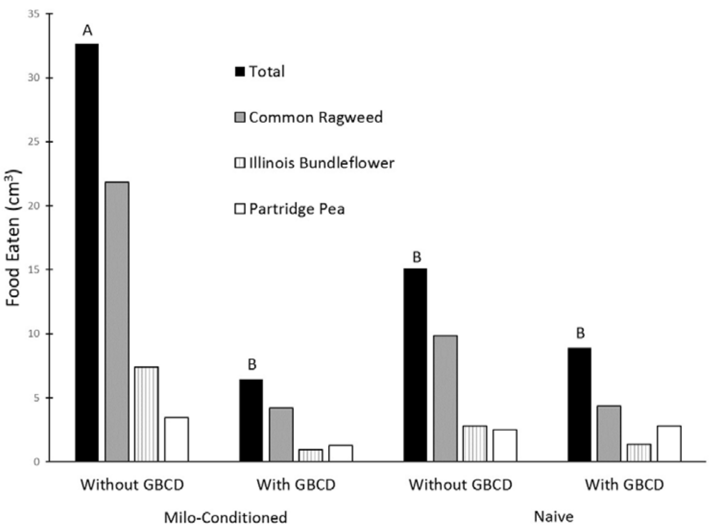

Figure 1. Seed consumption by pen-raised northern bobwhites in captive trials, January–March 2017, Tennessee. Milo-conditioned bobwhites previously were exposed to a milo diet for 28 days; naïve bobwhites were maintained on game bird complete diet (GBCD) and had no previous milo exposure. Total columns with the same letter do not differ ($P > 0.05$) using Tukey's means separation test.

no access to GBCD ate more total native seeds ($\bar{x} = 32.7 \pm 4.1$ cm^3) than naïve bobwhites without GBCD ($\bar{x} = 15.1 \pm 4.9$ cm^3) and both bobwhite types with GBCD ($\bar{x} < 9$ cm^3; milo experience × GBCD interaction: $F = 6.1$, df = 1, 12; $P = 0.030$). In the native seed selection ANOVA, consumption varied among seed types (seed type main effect: $F = 6.8$, df = 2, 24; $P = 0.005$), but there was no interaction of seed selection with either GBCD availability or milo conditioning ($F \leq 2.7$, df = 2, 24; $P \geq 0.085$). Bobwhites (averaged across all four groups) ate more ragweed ($\bar{x} = 10.5 \pm 2.7$ cm^3) than partridge pea ($\bar{x} = 2.6 \pm 0.7$ cm^3) or Illinois bundleflower ($\bar{x} = 3.3 \pm 1.0$ cm^3). Milo-conditioned and naïve bobwhites that were provided GBCD ate 76.5 cm^3 (44.4 g equivalent) and 66.7 cm^3 (38.7 g equivalent) of GBCD, respectively.

Discussion

Our results suggest that a milo-only diet is not deficient in minerals and is adequate for maintaining bobwhite body mass over a 28-day winter period. Similarly, Madison and Robel (2001) found that captive bobwhites fed a milo-only diet maintained body mass over a shorter (4-day) period. Supplemental feeding with milo increases body fat (Doerr and Silvy 2006) and survival (Townsend et al. 1999) of wild bobwhites during fall and winter. Milo is high in energy, averaging 4.3 kcal/g (Robel et al. 1979, Madison and Robel 2001), and metabolic efficiency is high in bobwhites eating sorghum (84%, Madison and Robel 2001). A milo-only diet, although adequate for maintaining mass during non-breeding periods, may not be adequate for during the breeding season, however, when requirements for protein and minerals are higher (Robbins 1993, Barboza et al. 2009).

Our results indicate a general unwillingness among pen-raised bobwhites to consume native seeds if they have no pen experience eating seeds at all, even if no other foods are available. Bobwhites with experience eating milo for 28 days were more willing to eat native seeds, although native seed consumption by milo-conditioned birds was considerably less than consumption of GBCD by these birds when it was available. Klimstra and Scott (1973) noted difficulty among pen-raised bobwhites in identifying new foods and suggested that a learning period is required. It is possible the seeds we provided in our pens, particularly partridge pea and Illinois bundleflower, were little eaten because they are generally poor-quality foods for bobwhites. In a more recent study of seed nutritional characteristics, Partridge pea and Illinois bundleflower ranked 14th and 19th out of 26 plant species tested, respectively, based on crude fat, gross energy, and crude protein (Applegate 2015). Bobwhites are known to prefer common ragweed over partridge pea and Illinois bundleflower (Ellis 1961), and a diet of partridge pea or Illinois bundleflower exclusively induces significant body mass loss in bobwhites (Madison and Robel 2001). Based on our results and those of other studies, we question the nutritional benefits of using partridge pea and Illinois bundleflower in bobwhite habitat management.

Our results, if representative of pen-raised bobwhite behavior, could have important implications for programs stocking pen-raised quail into natural environments. Survival of pen-raised bobwhites generally is low when stocked into the wild (Barbour 1950, Buechner 1950, Roseberry et al. 1987, Perez et al. 2002). Although predation likely plays a major role in this low survival in many situations (Rollins and Carroll 2001), inability to identify native foods and/or unwillingness to eat them may further limit survival of pen-raised quail in the wild. If more than short-term survival is desired in stocking programs using pen-raised bobwhites, an acclimation period during which milo is fed prior to release may increase use of native foods and allow such quail to maintain nutritional condition in the wild. Further research is warranted to better understand native seed use by pen-raised bobwhites and factors that promote it, as well as the effects of nutritional acclimation on the long-term success of pen-raised bobwhite stocking programs.

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