Wilson Bull., 109(2), 1997, pp. 218–225

CONSUMPTION OF COLORED AND FLAVORED FOOD MORSELS BY HARRIS' AND AMERICAN TREE SPARROWS

ROBERT J. ROBEL,[1,4] JEFFREY F. KEATING,[1] JOHN L. ZIMMERMAN,[1] KEITH C. BEHNKE,[2] AND KENNETH E. KEMP[3]

ABSTRACT.—Extruder-produced food morsels of different colors and flavors were offered to Harris' Sparrows (*Zonotrichia querula*) and American Tree Sparrows (*Spizella arborea*). The consumption of these morsels was measured to determine positive or negative selection by these two species of birds. Birds consumed more brown and yellow morsels than blue or orange morsels and more butter-/and nut-flavored morsels than lime-flavored morsels. In this study, color selection probably reflected avoidance of blue and orange morsels, rather than a preference for brown and yellow morsels. Color discrimination among our birds was stronger than flavor discrimination. Elucidation of color and flavor preferences and avoidance characteristics may prove useful in developing granular pesticide delivery systems that reduce potential hazards for birds. *Received 21 June 1996, accepted 15 Jan. 1997.*

Animals use various cues to locate and select food items. Eyes enable animals to discern size, shape, and color of potential food items, whereas taste buds allow them to discriminate among food items by flavor. The large size of birds' eyes, up to 1.5% of total body mass (Welty 1982), reflects the importance of the sense of vision to birds. The structure of the avian eye resembles that of other vertebrate eyes, and visual pigments in cone cells of birds convey color vision (Govardovskii and Zueva 1977). Selection and avoidance of certain colored food items by several avian species confirm that birds can discern among colors (Pank 1976, Slaby and Slaby 1977).

The existence of flavor perception in birds is supported by the presence of taste receptors (Duncan 1960) and by preference testing experiments. Positive and negative responses by birds to sweet, bitter, acid, and salt solutions reflect their ability to taste (Warren and Vince 1963, Brindley 1965, Grieg-Smith 1985). Reduction in the consumption by birds of food contaminated by toxic materials is further evidence for flavor perception in avian species (Bennett and Prince 1981; Robel et al. 1982, 1985).

Both flavor and color discrimination have become important in developing delivery systems for aversion learning techniques to reduce depredation damage caused by birds (Mason and Reidinger 1983a, b; Mason

[1] Div. of Biology, Kansas State Univ., Manhattan, Kansas 66506-4901.
[2] Dept. of Grain Science and Industry, Kansas State Univ., Manhattan, Kansas 66506-2201.
[3] Dept. of Statistics, Kansas State Univ., Manhattan, Kansas 66506-0801.
[4] To whom correspondence should be sent.

TABLE 1
DYE SOLUTION ADDED TO BASE MIX TO PRODUCE COLORED FOOD MORSELS

Dye dissolved in 300 ml H_2O		Color of food morsel[a]	Termed in text
25 g Warner-Jenkinson[b]	05601 FDC-blue No. 1	Black10Cyan-blue70Yellow 40	Blue
25 g Stange[c]	CO1355 Chocolate	Black40Yellow50Magenta-red30	Brown
25 g Warner-Jenkinson	08005 FDC-yellow No. 5	Yellow60Magenta-red20Cyan-blue10	Yellow
8 g Warner-Jenkinson plus	07700 FDC-red No. 40	Yellow50Magenta-red50Cyan-blue10	Orange
17 g Warner-Jenkinson	08006 FDC-yellow No. 6		

[a] Color compared to Color Atlas plates (Keuppers 1982).
[b] Source: Warner-Jenkinson, Inc., St. Louis, Missouri 63106.
[c] Source: Stange Co., Chicago, Illinois 60612.

et al. 1989). Little research has been conducted to increase acceptability of bird feeds by altering their color or incorporating a flavor additive. This study was conducted to determine the effect of different colors and flavor additives on consumption of extruder-produced food morsels by Harris' Sparrows (*Zonotrichia querula*) and American Tree Sparrows (*Spizella arborea*).

METHODS

Food morsels were formulated and processed through an extrusion cooker (Wenger X-20 LBM). The food morsels were composed of yellow corn (66%, dry weight), grain sorghum (16%), hard red wheat (6%), soybean meal (5%), and soybean oil (3%) plus minerals and vitamins. Extruder-produced food morsels were used because they could be made uniform in energy content, shape, size, firmness, and surface texture. (Keating 1989, Keating et al. 1990)

The spherical food morsels measured 1.59 mm in diameter, and their natural color was tan [Black10Yellow40Magenta-red10 (Keuppers 1982)], closely resembling seeds of white proso millet (*Panicum miliaceum*). Food morsels were colored by adding a solution of organic food dye to the base mix in the extruder. Dyes used, dilution factors, and colors of food morsels produced are shown in Table 1. After morsels were dried, they were placed in paper feed bags and stored in dry conditions at room temperature until used.

An excess of yellow-colored morsels was produced for use in flavor preference studies. These morsels were coated with liquid fruit, butter, or nut flavors. Fries and Fries brand liquid flavors were used; artificial lime (flavor No. 139121) for fruit, artificial butter (flavor No. 153979) for butter, and equal portions of artificial pecan (flavor No. 153972) and artificial nut (flavor No. 153973) for nut. The undiluted lime flavoring constituted 0.75% by weight of the finished feed, whereas the undiluted nut and butter flavorings constituted 1.0 to 2.0% by weight of the finished feed. Flavored morsels were placed into air-tight containers and stored in darkness until used.

Harris' Sparrows and American Tree Sparrows were captured in mist nests (Federal Permit No. PRT-689136) and confined individually in 39 × 22 × 27-cm wire cages inside a walk-in environmental chamber maintained at 5°C and 75% relative humidity under a 10-h light:

14-h dark photoperiod. Birds were captured in late November and acclimated to chamber conditions for at least 10 days before any feeding preference data were gathered. Birds were provided white proso millet, sunflower (*Helianthus* spp.), and a mixture of grass seeds when first confined and gradually weaned to a diet of only chick starter mash (ingredients and composition in Keating [1989]) by the end of their 10-day acclimatization period. All test morsels were included in the rations eight days prior to initiation of feeding trials to reduce unfamiliarity/novelty biases. Water and food were provided *ad libitum*.

Separate feeding trials were conducted to determine if the birds preferentially selected food morsels by color or flavor. Color preference trials preceded flavor preference trials. One replicate of a 6 × 6 Latin Square experimental design, incorporating 12 birds of each species, was used in color feeding trials; birds (6) and days (6) were the blocking factors. One replicate of a 3 × 3 Latin Square design, using six birds of each species, was used for flavor feeding trials; birds (3) and days (3) were the blocking factors. The Harris' Sparrows had a mean body mass of 35.7 g (range 31.6 to 39.4 g), whereas the mean body mass of American Tree Sparrows was 18.4 g (range 15.6 to 20.8 g).

Feeding trials consisted of pair-wise presentations of all combinations of colored or flavored morsels for two consecutive days to each of the 24 birds. At the onset of the daily light period, pre-weighed amounts of paired morsels (singly and in excess of expected daily consumption) were placed in clear plastic feeders at opposite ends of each bird's confinement cage. Four times each day, all feeders were refilled so that no feeder ever became half-depleted. Feeder positions were exchanged when they were refilled to avoid position bias. Food remaining in each feeder and spilled food was removed at the end of the light period, and the total mass of each morsel type consumed during the day was determined. Bird preferences for morsels of different colors or flavors were determined by subjecting consumption data (mass) to analysis of variance (ANOVA) procedures (Kemp et al. 1990) with significance at $P = 0.05$. The above methodology was also used to compare the consumption of naturally colored and naturally flavored food morsels to that of the most preferred artificially colored and artificially flavored morsels.

RESULTS

When brown-colored morsels were paired with yellow morsels in feeding trials, no differences in the consumption of the two occurred (Table 2). However, when brown- or yellow-colored morsels were paired with blue- or orange-colored morsels, greater masses of yellow and brown morsels were consumed. Total consumption by the larger Harris' Sparrows exceeded that of the smaller American Tree Sparrows by approximately 50%. No birds died and mean body masses of experimental birds did not change by more than ±5% during any of the feeding trials. Consumption of colored and flavored food morsels on the first and second day of a test replication did not differ (ANOVA, $P < 0.05$), indicating no learning by the birds during the feeding trials.

Harris' Sparrows ate significantly (ANOVA, $P < 0.05$) more brown and yellow morsels than orange morsels (Table 3). Blue morsels were consumed significantly (ANOVA, $P < 0.05$) less than brown, yellow, or orange morsels by Harris' Sparrows. American Tree Sparrows consumed similar amounts (ANOVA, $P > 0.05$) of brown and yellow morsels, but

TABLE 2

MEAN (±SE) MASS (G) OF COLORED AND FLAVORED FOOD MORSELS CONSUMED DURING PAIR-WISE PRESENTATIONS

Pair-wise presentations	Mean[a] daily consumption	
	Harris' Sparrow	American Tree Sparrow
Colored morsels		
Brown	6.15 ± 0.30	3.96 ± 0.29
Blue	3.44 ± 0.33	2.12 ± 0.30
Blue	4.17 ± 0.39	2.73 ± 0.42
Orange	5.23 ± 0.38	3.28 ± 0.40
Yellow	6.29 ± 0.31	4.05 ± 0.37
Blue	3.18 ± 0.33	2.10 ± 0.40
Brown	5.60 ± 0.29	4.01 ± 0.21
Orange	3.83 ± 0.35	2.12 ± 0.20
Brown	4.88 ± 0.24	2.86 ± 0.30
Yellow	4.45 ± 0.30	3.17 ± 0.26
Yellow	5.58 ± 0.32	4.17 ± 0.25
Orange	3.87 ± 0.30	1.99 ± 0.29
Flavored morsels		
Butter	5.12 ± 0.42	3.94 ± 0.38
Lime	4.16 ± 0.33	2.33 ± 0.23
Butter	4.95 ± 0.37	3.30 ± 0.29
Nut	4.59 ± 0.39	3.05 ± 0.22
Nut	5.07 ± 0.38	3.92 ± 0.25
Lime	4.37 ± 0.30	2.20 ± 0.28

[a] Means of 2 daily measurements for 12 birds, N = 24.

significantly (ANOVA, $P < 0.05$) more than amounts of orange and blue morsels, whose consumptions also did not differ significantly (ANOVA, $P > 0.05$) from each other (Table 3).

The daily consumptions of brown (5.00 ± 0.27 g) and yellow (4.25 ± 0.27 g) morsels by Harris' Sparrows were not significantly (ANOVA, $P > 0.05$) different than the 4.24 ± 0.27 g consumption of uncolored morsels. However, the daily consumptions of brown (3.34 ± 0.33) g and yellow (3.10 ± 0.33 g) morsels by American Tree Sparrows were significantly (ANOVA, $P < 0.05$) greater than the 2.00 ± 0.33 g consumption of uncolored morsels.

When butter-flavored morsels were paired with nut-flavored morsels in feeding trials, no differences in the consumption of the two occurred (Table 2). However, when lime-flavored morsels were paired with butter-

TABLE 3
RANKED MEAN MASSES (G) OF COLORED AND FLAVORED MORSELS CONSUMED DAILY DURING FEEDING TRIALS

Morsels	Harris' Sparrows	American Tree Sparrows
Colored		
Brown	5.56a[a]	3.60a
Yellow	5.44a	3.81a
Orange	4.34b	2.46b
Blue	3.59c	2.33b
Flavored		
Butter	5.03a	3.62a
Nut	4.83a	3.46a
Lime	4.26b	2.26b

[a] Means (N = 72 for color, 48 for flavor) within a column in the same morsel category sharing a common letter do not differ (ANOVA, $P > 0.05$).

or nut-flavored morsels, the consumption of these latter morsels tended to increase. The total consumption of flavored morsels by the larger Harris' Sparrows was approximately 50% greater than that by the smaller American Tree Sparrows.

The amounts of butter-flavored morsels consumed by Harris' Sparrows were not significantly (ANOVA, $P > 0.05$) different than the amounts of nut-flavored morsels consumed (Table 3). However, the consumptions of both butter- and nut-flavored morsels by Harris' Sparrows were significantly (ANOVA, $P < 0.05$) greater than that of lime-flavored morsels. The same relationship held for American Tree Sparrows.

Harris' Sparrow's daily consumption of butter-flavored morsels (5.01 $\pm$ 0.14 g) was not significantly different (ANOVA, $P > 0.05$) than the 4.73 $\pm$ 0.14 consumption of unflavored morsels. Likewise, the daily consumption by American Tree Sparrows of butter-flavored morsels (3.11 $\pm$ 0.13 g) was not significantly different (ANOVA, $P > 0.05$) than the 3.17 $\pm$ 0.13 g consumption of unflavored morsels.

DISCUSSION

Both Harris' Sparrows and American Tree Sparrows demonstrated the ability to discern color by selecting certain colors of food morsels over others. These results support other studies that reported color perception in birds. The reduced consumption of blue and orange morsels may reflect avoidance of novel food colors rather than a positive selection of brown and yellow colors. Rabinowitch (1968) found that birds selected food items to which they became familiar in early life and avoided novel-

colored items. Blue- and orange-colored seeds are not frequently encountered by wild Harris' Sparrows or American Tree Sparrows in the midwestern United States, whereas brown- and yellow-colored seeds are common. Thus, it appears that rather than selecting brown and yellow morsels, our birds were actively avoiding blue and orange morsels. This agrees with conclusions advanced by Kalmback (1943) and Ridsdale and Granett (1969) that food consumption by birds is deterred by certain colored seeds. Gionfriddo and Best (1996) also reported that color affected avian consumption of differently colored granules. Knowing which colors are avoided by which avian species could be helpful in the development of safer applications of pesticides, but the issue is complex (e.g., see Best and Fischer [1992]).

Our Harris' Sparrows and American Tree Sparrows showed selective tendencies based on flavor, supporting results from studies reported by Westbrook et al. (1980) and Grieg-Smith (1985). However, flavor discrimination was not as strong as color discrimination in the earlier feeding trials, e.g., differences in daily consumption of different flavored morsels were less than among different colored morsels. Flavored morsels used in the study were not consumed in greater amounts than unflavored morsels, further reflecting the weakness of discrimination for these flavors by Harris' and American Tree sparrows. Grieg-Smith (1985) reported that certain polyphenols are distasteful to some birds and, if consumed, interfere with protein digestion. Thus, flavor recognition by birds may assist them to avoid distasteful or harmful food items but may not be a significant positive force to increase consumption of any specific food item. Certain distasteful flavors might be used commercially to reduce consumption by birds of surface-applied granular pesticides.

Additional experimental research, involving more avian species, will provide a clearer understanding of the influences of color and flavor on food choice in birds. That knowledge, in conjunction with such information on morsel shape and size (Keating et al. 1992) and surface texture and shape (Best and Gionfriddo 1994), may be useful in producing (1) granular formulations of pesticides that are less attractive to birds and/or (2) extruded food morsels that are more attractive to birds. Further, such information may also aid the development of effective conditioned avoidance delivery systems to reduce bird damage (Clark and Mason 1993, Avery et al. 1995).

ACKNOWLEDGMENTS

This research was supported by the Div. of Biology, the National Science Foundation (Grant No. DEB-8022568), and the Kansas Agricultural Experiment Station, Kansas State

Univ. (Contribution No. 92-314-J). The cooperation of Wenger Manufacturing, Inc., is appreciated. L. B. Best and two anonymous reviewers provided helpful comments that improved this paper.

LITERATURE CITED

AVERY, M. L., D. D. DECKER, J. S. HUMPHREY, A. A. HAYES, AND C. LAUKERT. 1995. Color, size, and location of artificial fruits affect sucrose avoidance by Cedar Waxwings and European Starlings. Auk 112:436–444.

BENNETT, R. S. AND H. H. PRINCE. 1981. Influence of agricultural pesticides on food preference and consumption by ring-necked pheasants. J. Wildl. Manage. 45:74–82.

BEST, L. B. AND D. L. FISCHER. 1992. Granular insecticides and birds: factors to be considered in understanding exposure and reducing risk. Environm. Toxicol. Chem. 11: 1495–1508.

——— AND J. P. GIONFRIDDO. 1994. Effects of surface texture and shape on grit selection by House Sparrows and Northern Bobwhite. Wilson Bull. 106:689–695.

BRINDLEY, L. D. 1965. Taste discrimination in Bobwhite and Japanese Quail. Anim. Behav. 13:507–512.

CLARK, L. AND J. R. MASON. 1993. Interaction between sensory and postingestional repellents in starlings: methyl anthranilate and sucrose. Ecol. Appl. 3:262–270.

DUNCAN, C. J. 1960. The sense of taste in birds. Ann. Appl. Biol. 48:409–414.

GIONFRIDDO, J. P. AND L. B. BEST. 1996. Grit color selection by house sparrows and northern bobwhites. J. Wildl. Manage. 60:836–842.

GOVARDOVSKII, V. I. AND L. V. ZUEVA. 1977. Visual pigments of chicken and pigeon. Vision Res. 17:537–543.

GRIEG-SMITH, P. W. 1985. The importance of flavour in determining the feeding preferences of bullfinches for the buds of 2 pear cultivars. J. Appl. Ecol. 22:29–37.

KALMBACH, E. R. 1943. Birds, rodents, and colored lethal baits. Trans. N. Am. Wildl. Conf. 8:408–416.

KEATING, J. F. 1989. Selection responses of avian granivores to various morphological food characteristics. M.S. thesis. Kansas State Univ., Manhattan, Kansas.

———, R. J. ROBEL, K. C. BEHNKE, AND K. E. KEMP. 1991. Extruded wild bird feed. Feed Manage. 42:18–24.

———, ———, A. W. ADAMS, K. C. BEHNKE, AND K. E. KEMP. 1992. Role of handling time in selection of extruded food morsels by two granivorus bird species. Auk 108: 863–868.

KEMP, K. E., J. F. KEATING, AND R. J. ROBEL. 1990. The misuse of the Dayton-Morrill Model in the analysis of palatability experiments. J. Dairy Sci. 73:1239–1243.

KEUPPERS, H. 1982. Color atlas. Barron's Educational Series, Inc. Woodbury, New York.

MASON, J. R., R. W. BULLARD, R. A. DOLBEER, AND P. P. WORONECKI. 1989. Red-winged Blackbird (*Agelaius phoeniceus* L.) feeding response to oil and anthocyanin levels in sunflower meal. Crop Prot. 8:455–460.

——— AND R. F. REIDINGER. 1983a. Effect of color type generalization of and pre-exposure decrements in aversion learning by Red-winged Blackbirds (*Agelaius phoeniceus*). Auk 100:461–468.

——— AND ———. 1983b. Importance of color for methiocarb-induced food aversions in Red-winged Blackbirds (*Agelaius phoeniceus*). J. Wildl. Manage. 47:383–393.

PANK, L. R. 1976. Effects of seed and background colors on seed acceptance by birds. J. Wildl. Manage. 40:769–774.

RABINOWITCH, V. E. 1968. The role of experience in the development of food preference in gull chicks. Anim. Behav. 16:425.

RIDSDALE, R. AND P. GRANETT. 1969. Responses of caged grackles to chemically treated and untreated food. J. Wildl. Manage. 33:678–681.

ROBEL, R. J., S. M. ARRUDA, M. E. MORROW, AND D. H. O'NEILL. 1985. Chronic effects of a prescribed field application of a carbamate insecticide on bobwhites. J. World Pheasant Assoc. 10:47–64.

———, R. W. FELTHOUSEN, AND A. D. DAYTON. 1982. Effects of carbamates on bobwhite food intake, body weight, and locomotor activity. Arch. Environm. Contam. Toxicol. 11:611–615.

SLABY, M. AND F. SLABY. 1977. Color preferences and short term learning by Steller's Jays. Condor 79:384–386.

WARREN, R. AND M. A. VINCE. 1963. Taste discrimination in Great Tit (*Parus major*). J. Comp. Physiol. Psychol. 56:910–913.

WELTY, J. C. 1982. The life of birds. 3rd. ed. Saunders Coll. Publ., Philadelphia, Pennsylvania.

WESTBROOK, R. F., J. C. CLARK, AND S. PROVOST. 1980. Long-delay learning in the pigeon: flavor, color, and flavor-mediated color aversions. Behav. and Neural Biol. 28:398–407.