EVALUATION OF DIMETHYL ANTHRANILATE AS A NONTOXIC STARLING REPELLENT FOR FEEDLOT SETTINGS

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Few objective estimates are available, but starling (*Sturnus vulgaris*) and, sometimes, blackbird (e.g., *Agelaius phoeniceus*) depredations at feedlots are considered serious economic problems (Besser et al. 1967, 1968; Feare 1975, 1980; Stickley 1979; Twedt and Glahn 1982). Losses may result either from feed contamination and disease transmission or, more likely, from feed consumption (Besser et al. 1968; Russell 1975; Twedt and Glahn 1982). These problems are exacerbated by the use of complete diets (Rickaby 1978) which are presented in open troughs to which starlings have access. Feare and Wadsworth (1981) have shown that these birds can take up to 9% of the high protein fraction of the diet, thus depriving cattle of their high energy source and altering the composition of the entire ration. Efforts to control problem birds at feedlots have focused mainly on attempts to trap or kill birds with mechanical devices or chemical agents (Besser et al. 1967; Bogadich 1968; Levingston 1967; West et al. 1967; Feare et al. 1981). These approaches, however, fail to create a suboptimal environment for avian feeding activity, and birds rapidly reinfest feedlots when control measures are relaxed (Twedt and Glahn 1982). Additional problems arise when lethal chemicals; such as Starlicide (1% C-chloro-p-toludine hydrochloride on poultry pellets) are used, including: (1) potential primary and secondary hazards to nontarget animals (e.g., Cunningham, 1979), (2) bait aversion by target birds, (3) expense and labor in prebaiting, baiting and monitoring (Glahn 1981) and (5) rather short-term effectivenses when large numbers of birds are in the area (Feare et al. 1981).

Twedt and Glahn (1982) outlined a variety of management practices that could be implemented at feedlots to produce sustained reductions in bird damage. They suggested that feed could be made less available by physically separating it from birds, by using a form, size or texture of feed that discourages consumption by birds, or by using feeds that are either unpalatable or that cannot be metabolized by birds. Although passerine species apparently lack a well-developed sense of taste (e.g., Welty 1975: 72), tastants do exist that are unpalatable to birds (but readily accepted by mammals). One such tastant is demethyl anthranilate (DMA), an inexpensive and nontoxic food flavoring approved for human consumption, but offensive to birds in both feeding and drinking contexts (Kare and Pick 1960). Here we report assessments of the repellency of several concentrations of DMA in food otherwise acceptable to starlings. Starlings were tested in groups as well as when housed individually, when food deprived as well as when satiated, and in 1-choice and 2-choice tests.

EXPERIMENT 1

METHODS

Sixty adult starlings were decoy-trapped at Sundusky, Ohio. The birds were brought to the laboratory and housed 3 to a cage (dimensions 75 x 75 x 40 cm) under a 10/14 light-dark cycle in a room with an ambient temperature of 23 ± 2°C. Each group was visually isolated with pieces of cardboard (75 x 40 cm). Water was always available and, before the experiment began, the birds were permitted free access to Purina Flight Bird Conditioner (PFBC) in food hoppers attached to the front of each cage.

STIMULI

Six concentrations of DMA (w/w) in food were prepared by mixing 1 kg of PFBC with various quantities of lipophyllic starch containing 20% DMA. Plain lipophyllic starch was also added to each food sample, so that all contained 80 g of starch. The DMA concentrations were (a) 0.0% [i.e., 80 g plain starch, 1 kg PFBC]; (b) 0.4% [i.e., 20 g DMA starch, 60 g plain starch, 1 kg PFBC]; (c) 0.6%; (d) 0.8%; (e) 1.0%; and (f) 1.6%. The same batches of treated food were used for the duration of the experiment, and each batch was stored in a covered plastic tub at room temperature (23 ± 2°C).

REPELLENCY TESTS

The birds (n = 3/cage) were assigned to four groups (n = 5 cages/group). Then, the various DMA concentrations were presented to each group under four conditions. These conditions were: (a) 1-choice test, 14 hrs food deprived; (b) 1-choice tests, no food deprivation; (c) 2-choice test, 14 hrs food deprived; and (d) 2-choice test, no food deprivation. Among groups, the sequence of test situations was completely counterbalanced. Testing occurred during the first hour of light (0800 - 0900 hrs), 6 days/week, for 4 consecutive weeks. Food deprivation (i.e., removing the food bins from the front of the cages) occurred between dark onset of one day (1800 hrs), and light onset of the next (0800 hrs).

For the 1-choice test, food was removed from the cages of the birds that had not been food deprived, and then all groups were given 50 g of one of the six DMA concentrations (A-F) in a standard food cup (7.5 cm diam.). The food cups were presented in plastic tubs (28 x 18 x 12 cm), so that spillage could be collected and assessed. All birds were tested once with each concentration, and the order of presentation of the different mixtures was counterbalanced, so that 5 (1/cage) of the 6 mixtures were presented daily to each group. After one hour, the tubs were removed, and consumption and spillage were measured.

For the 2-choice tests, food was removed from the cages of the birds that had not been food deprived, and then all groups were given 2 covered food cups, each containing 50 g of food. The cups were presented in plastic tubs that had been divided into 2 equal sections by a cardboard insert (2 cm high). This permitted collection of spillage from each cup. One food cup in each tub contained 50 g of one of the six DMA mixtures (0.0-1.6%). The other cup in every case contained 50 g of mixture 0.0% (PFBC mixed with plain starch). Presentation of the 6 stimulus combinations was completely counterbalanced, such that 5 of the 6 stimulus combinations were present daily. Each cage within each group received the combination in a different order. In addition, the relative position of the 2 food cups presented each day was randomized to control for the possibility of position learning of DMA-containing samples by the birds. As in the 1-choice tests, the tubs were removed from the cages after one hour, and consumption and spillage from each food cup were assessed.

A 2-way analysis of variance (ANOVA) with repeated measures on both factors was used to assess consumption in 1-choice tests. One factor (2 levels) of this analysis was consumption of food when food deprived versus consumption when satiated. The other factor (6 levels) was consumption of food treated with each of the 6 concentrations of DMA. A 3-way ANOVA with repeated measures on all factors was used to assess consumption in 2-choice tests. The factors in this analysis were: (1) consumption when food deprived versus consumption when satiated (2 levels); (2) consumption of food across days (6 levels); (3) consumption of DMA-treated food versus plain food within trials (2 levels). Tukey *b* post-hoc comparisons (Winer 1962: 198) were used to isolate significant differences ($\underline{P} < 0.05$) among means. Spillage was statistically assessed in the same fashion as consumption, but was not reported here because it simply reflected consumption.

EXPERIMENT 2

METHOD

Twenty starlings were randomly selected from the groups of birds used in Experiment 1. These birds were individually housed, visually isolated, and tested as described in Experiment 1. That is, the birds were assigned to 4 groups (n = 5/group) and the repellency of DMA for each bird was tested in 1- and 2-choice tests under conditions of food deprivation or satiation. The concentrations of DMA presented during these tests were the same as those used in Experiment 1. Testing occurred during the first hour of light (0800 - 0900 hrs), 6 days a week (Monday through Saturday), for 4 weeks.

A 2-way ANOVA with repeated measures on both factors was used to assess the data from the 1-choice tests, and a 3-way ANOVA with repeated measures on all factors was used to assess the data from the 2-choice tests. The factors (and levels of factors) in these analyses were identical to those reported for use in Experiment 1. Tukey $\underline{b}$ post-hoc comparisons were used to isolate significant differences ($\underline{P} < 0.05$) among means. Spillage data were assessed in the same fashion as consumption, but are not reported as they merely reflected consumption.

RESULTS

EXPERIMENT 1

In 1-choice tests, birds ate more after deprivation, regardless of the DMA concentration present in starch on the food ($\underline{F} = 6.9$; df = 1,228; $\underline{P} < 0.009$). However, both food deprived and satiated birds exhibited clear differences in consumption as a function of the DMA concentration ($\underline{F} = 16.6$; df = 5,228; $\underline{P} < 0.0001$). Tukey tests indicated that more was eaten of plain food than of any of the DMA-treated samples ($\underline{P} < 0.05$). Within DMA-treated samples, the most was eaten of the weakest concentration (0.4%) ($\underline{P} < 0.05$), and the least was eaten of the strongest concentration (1.6%) ($\underline{P} < 0.05$). There were no differences in consumption among the other DMA-treated samples ($\underline{P} > 0.10$) (Figure 1A).

In 2-choice tests, birds again ate more after 18 hrs of food deprivation, regardless of DMA concentration present on the food ($\underline{F} = 4.2$; df = 1,456; $\underline{P} < 0.04$). However, within each test, plain food was reliably preferred to food treated with DMA ($\underline{F} = 291.3$; df = 1,456; $\underline{P} < 0.00001$), and there were again differences in consumption, depending on the concentration of DMA presented ($\underline{F} = 7.4$; df = 5,456; $\underline{P} < 0.00001$). Tukey tests indicated that within DMA-treated samples, the most was eaten of 0.4% ($\underline{P} < 0.05$), and the least was eaten of samples containing high DMA concentrations (1.2% and 1.6%), respectively; ($\underline{P} < 0.05$). There were no differences in consumption among the other DMA-treated samples ($\underline{P} > 0.10$) (Figure 1B).

EXPERIMENT 2

In 1-choice tests, there were no significant differences between consumption when food deprived versus consumption when satiated ($\underline{P} > 0.06$). However, there were significant differences in consumption depending on the concentration of DMA presented ($\underline{F}$

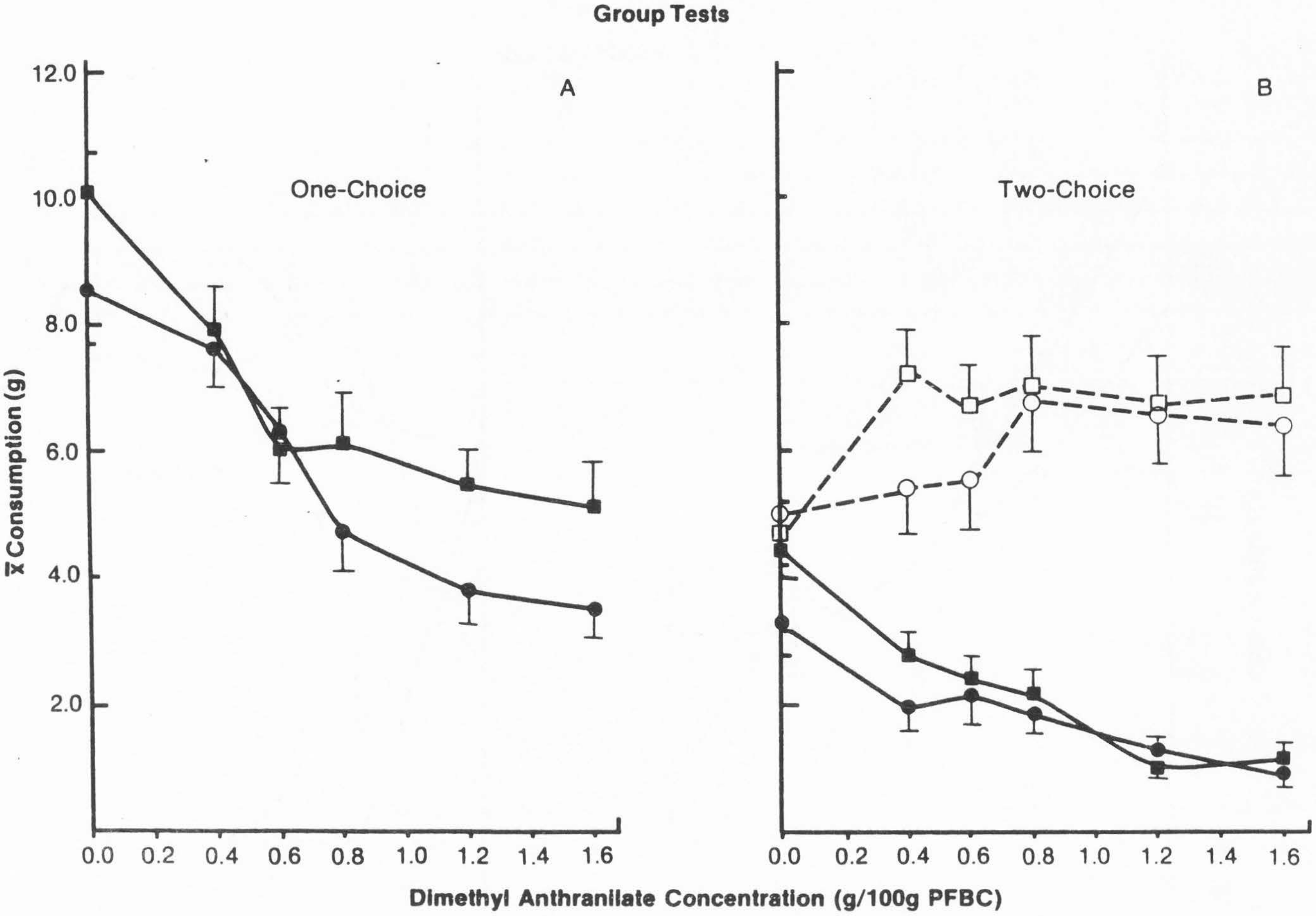

Figure 1. (A) Mean consumption (g) of DMA-treated food by deprived (■) or satiated (●) groups of starlings in 1-hour, 2-choice tests. (B) Mean consumption (g) of DMA-treated food by deprived (■,□) or satiated (●, ○) groups of starlings in 1-hour, 2-choice tests. Closed squares and circles represent consumption of plain food. For both panels (A,B), vertical capped bars represent standard errors of the means.

= 9.2; df = 5,228; $\underline{P} < 0.0001$). Tukey tests indicated that the most was eaten of untreated food (0.0%, $\underline{P} < 0.05$) and least was eaten of food containing 1.6% DMA ($\underline{P} < 0.05$). Among the other treated samples, less was eaten of 0.8% and 1.2% DMA than of 0.4% and 0.6% DMA ($\underline{P} < 0.05$, respectively; Figure 2A).

In 2-choice tests, there were significant differences in consumption depending on the concentration of DMA presented ($\underline{F} = 13.5$; df = 5,456; $\underline{P} < 0.00001$), and within tests, plain food (0.0%) was reliably preferred to treated food ($\underline{F} = 246.5$; df = 5,456; $\underline{P} < 0.00001$). However, because the 3-way interaction among: (a) consumption when food deprived or satiated; (b) consumption of plain versus treated food; and (c) consumption of food treated with different concentrations of DMA was significant ($\underline{F} = 2.4$; df = 5,456; $\underline{P} < 0.04$), we interpreted the analysis in terms of that higher order effect. Tukey tests indicated that the birds ate more when food deprived ($\underline{P} < 0.05$), but that overall consumption in 2-choice tests depended on the concentration of DMA presented ($\underline{P} < 0.05$). The higher the concentration of DMA present, the less was eaten of either DMA-treated or plain food (Figure 2B).

DISCUSSION AND MANAGEMENT IMPLICATIONS

In the present experiments, DMA was shown to repel both groups of birds and individuals effectively in 1- and 2-choice tests, and when food deprived and satiated. Repellency was concentration-dependent and long-lasting; even after repeated experiences, the birds continued to exhibit strong rejection of DMA. Such durability was especially striking, given that at the end of individual tests, the birds had been exposed to DMA in food 6 days per week for 4 weeks. Similar concentrations of DMA are not rejected by mammals in feeding tests, and in some cases, preferences for the compound are observed (pers. obs.).

Consumption of DMA-treated food was consistently higher for groups of birds than for individuals, and food deprived than for satiated birds. Even so, relatively low concentrations of DMA significantly reduced consumption. For example, 1.6% of DMA reduced consumption (relative to consumption of 0.0% treated food) in 1-choice tests by 40% and 54%, respectively, for groups of birds and individuals that had

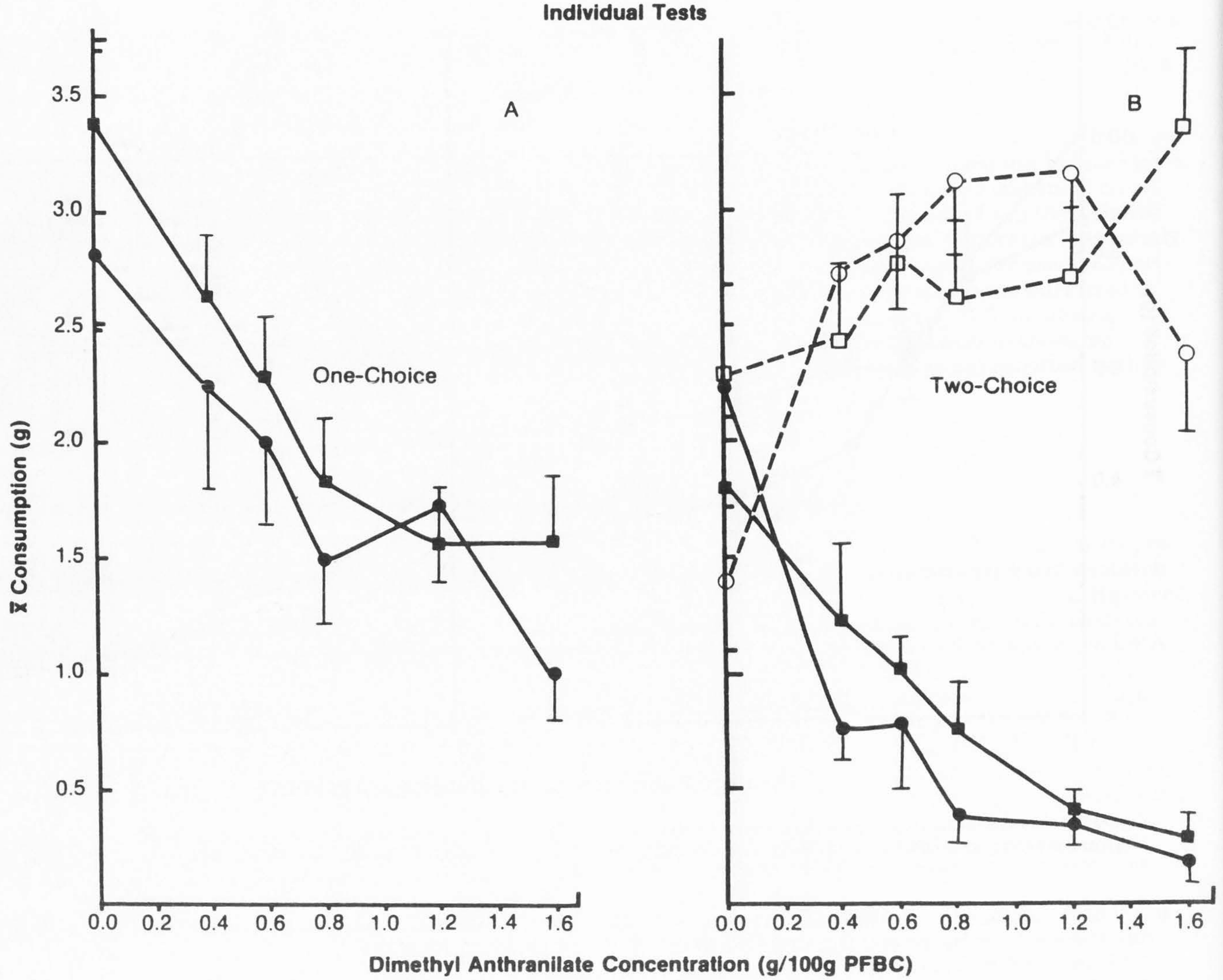

Figure 2. (A) Mean consumption (g) of DMA-treated food by food-deprived (■) or satiated (●) individual starlings in 1-hour, 1-choice tests. (B) Mean consumption (g) of DMA-treated food by deprived (■,□) or satiated (●,○) individual starlings in 1-hour, 2-choice tests. Closed squares and circles represent consumption of treated food. Open squares and circles represent consumption of plain food. For both panels (A,B), vertical capped bars represent standard errors of the means.

been food deprived. Similar but more dramatic reductions in consumption were observed in 2-choice tests. Because DMA is offensive to a wide variety of birds besides starlings, including Japanese quail (*Coturnix japonica*), pigeons (*Columba livia*), red-winged blackbirds (*Agelaius phoeniceus*), jungle fowl (*Gallus gallus*) and herring gulls (*Larus argentatus*) (Kare 1965; Rogers 1974; Yang and Kare 1968), the usefulness of the compound as a bird repellent may also be general. Whether the compound is repellent (as well as offensive) to a variety of avian species remains to be tested. However, in preliminary tests carried out in our laboratory, red-winged blackbirds exhibited decreases in consumption of DMA-treated food similar to those we report here for starlings.

While cautious about extrapolating the present results to the field, we speculate that DMA may prove useful for bird control in some feedlot settings. First, use of the compound would result in a less optimal food source, without primary or secondary hazards to nontarget animals. Second, because starlings do not become accustomed to the taste of the compound, reduction in damage is likely to be long-lasting. Third, because the chemical would be applied directly to the feed, learned aversions by target birds to animal feed, feeding troughs, etc. would enhance the efficacy of DMA, and not serve as a drawback as it does for toxicants that are applied to bait materials separate from feed. Fourth, DMA sprayed dried starch is relatively inexpensive, even when produced in small test quantities. Concentrations as high as 1.6% (the highest concentration used here) would only cost about $2.00/50 lb. bag. Substantial reductions in cost would occur if DMA sprayed dried starch were produced in large quantities, and/or if less expensive procedures (e.g., plating DMA on starch) were substituted for spray drying. Costs for pre-baiting and monitoring would be eliminated.

Of course, DMA is unlikely to act as a repellent in all feedlot situations, with all avian pests. As suggested by Rogers (1978: 151-165), differences in the materials to be protected from damage often influence the efficacy of control compounds. Preferred foods, for example, may be harder to protect, and the relative palatability of alternative foods may influence the repellency of DMA-treated foods. The nature of the pest species may also be important. As such, DMA may be most effective with omnivorous birds such as starlings or pigeons that use both taste and vision for food selection (Reidinger and Mason 1983). Further laboratory and field tests designed to address these and other questions appear warranted.

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