EVALUATION OF METHYL ANTHRANILATE AND STARCH-PLATED DIMETHYL ANTHRANILATE AS BIRD REPELLENT FEED ADDITIVES

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Abstract: We conducted 3 experiments to evaluate the effectiveness of methyl anthranilate (MA) as a bird repellent. In Experiment 1, we examined the repellency of several technical MA concentrations in 6-hour tests—a time period similar to the duration of exposure of livestock feed in feedbunks. In Experiment 2, we determined the lowest concentration of technical MA that was as effective as 1.0% dimethyl anthranilate starch (DMA; our field-tested standard). Finally, in Experiment 3, we explored the repellency of starch-encapsulated MA to grouped red-winged blackbirds (*Agelaius phoeniceus*) and European starlings (*Sturnus vulgaris*) in an outdoor aviary. Experiments 1 and 2 indicated that 0.4–0.5% MA was as repellent as 1.0% DMA-starch. Experiment 3 showed that although 1.0% MA reduced consumption by grouped starlings and red-wings in 2-choice tests, only starlings avoided treated food in 1-choice tests. Red-wings habituated to the substance, and consumption returned to baseline levels by treatment Day 3. We conclude that MA is an economical alternative to DMA, although species and/or social factors may influence repellency.

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Both dimethyl (DMA) and methyl (MA) anthranilate show promise as bird repellent livestock feed flavorings (Mason et al. 1985, Glahn et al. 1989, Mason et al. 1989). In field tests, a 1.0% concentration of encapsulated DMA reduced feed losses through consumption by starlings and also reduced the number of birds (mainly starlings) present at treated sites (Glahn et al. 1989). (Percentages refer to the amount of active ingredient on a mass/mass basis.) However, 1.0% DMA is not economical for most feedlot applications. Technical MA has been evaluated in cage and pen tests, and a 0.5% concentration significantly reduced consumption of feed by starlings in short-term tests (Mason et al. 1989). This anthranilate derivative is 4–5 times less costly than DMA, and our experiments were designed to test whether MA might provide an economical alternative to DMA.

In Experiment 1, we examined the repellency of 5 concentrations of technical MA in 6-hour tests—a time period similar to the duration of exposure of livestock feed in feedbunks. In Experiment 2, we investigated whether the 2 lowest effective MA concentrations identified in Experiment 1 were as repellent as 1.0% DMA-starch (our field standard). Finally, in Experiment 3, we tested the aversiveness of starch-encapsulated MA to grouped red-winged blackbirds and starlings in an outdoor aviary. Our goals in the aviary test were to (a) evaluate the repellency of MA in a field-usable matrix, (b) examine the impact of socially facilitated feeding (Mason and Reidinger 1981) on repellency, and (c) investigate species' differences in sensitivity.

MATERIALS AND METHODS

General.—Experiments 1 and 2 were conducted at the Monell Chemical Senses Center, Philadelphia, Pennsylvania. Eighty European starlings were decoy-trapped (U.S. Fish Wildl. Serv. 1973) near Bowling Green, Kentucky and transported to our laboratory where they were housed in pairs (cage dimensions: 61 × 36 × 41 cm) under a 6:18 hour light:dark cycle. During the 2 weeks before pretreatment, birds were provided free access to Purina Flight Bird Conditioner (feed; Purina Mills, St. Louis, Mo.), water, and oyster shell grit (United Volunteer Aviaries, Nashville, Tenn.).

Experiment 3 was conducted at the Florida Field Station of the Denver Wildlife Research Center, Gainesville, Florida. Thirty-two male red-winged blackbirds and 32 starlings (16 M, 16 F) were decoy-trapped near Gainesville and housed in groups of 4 (cage dimensions: 1.8 × 1.2 × 1.2 m) in a roofed, outdoor aviary. During the 2-day adaptation period, birds had free access to layer crumbles (Flint River Mills, Bainbridge, Ga.), water, and grit.

Stimuli.—In Experiments 1 and 2, feed was adulterated with MA (gold label, Aldrich Chemical Co., St. Louis, Mo., CAS #134-20-3). For Experiment 2, DMA was entrapped in food grade starch (Natl. Starch and Chemical Co., Bridgewater, N.J., CAS #85-91-6) to enhance persistence, and the encapsulated material was mixed with feed. Similarly, in Experiment 3, MA was entrapped in food grade starch and mixed with layer crumbles. Propylene glycol (Aldrich Chemical Co., St. Louis, Mo., CAS #57-55-6) was used as a diluent to assure an even distribution of MA in food.

Experiment 1.—We followed the procedures outlined in Mason et al. (1989) for 1-choice tests. Briefly, members of 20 caged pairs of birds were randomly selected and weighed, and then pairs were assigned to 5 groups (4 pairs/group) on the basis of mass. The pair with the greatest mean mass was assigned to group 1, that with the second greatest mean mass was assigned to group 2, and so forth.

After assigning groups, we began the pretreatment period. Within 1 hour of light onset on 5 consecutive days, each cage was presented with 50 g of feed in a single metal cup positioned in the center of the front of each cage. After 6 hours, food cups were removed, and consumption and spillage were recorded.

From Day 6 to Day 15, treatment trials were conducted. Each group was given a different MA concentration in 50 g of feed. As in pretreatment, food samples were presented in a single metal cup positioned in the center of the front of each cage. Groups 1–5 were presented with 0.5, 0.4, 0.3, 0.2, and 0.1% MA, respectively. Test food samples were presented within 1 hour of light onset. After each test session, food cups were removed, and consumption and spillage were recorded.

Experiment 2.—We followed the procedures outlined in Mason et al. (1989) for 1-choice tests. The remaining 20 pairs of starlings were assigned to 4 groups on the basis of pair mean mass. Five days of pretreatment identical to that described above followed group assignment. On each day, all groups were presented with 50 g of feed mixed with 1 mL of propylene glycol. Propylene glycol is apparently tasteless and odorless to starlings and acted as a sticking agent for DMA-starch presented during the treatment phase of the experiment. After 6 hours, food cups were removed, and consumption and spillage were recorded.

From Day 6 to Day 17, treatment trials were conducted. Each group was presented with the lowest effective MA concentration determined in Experiment 1, the next highest MA concentration, 0.5% DMA-starch, and 1.0% DMA-starch. Because propylene glycol was used to bind DMA-starch to food, MA samples were also mixed with propylene glycol. Each stimulus food was presented to each group for 2 days (6 hr/day in 1-choice tests), followed by a day on which feed mixed with propylene glycol only was presented. Different orders of the 4 stimulus foods were presented to the 4 groups, according to a Latin square design.

Experiment 3.—We followed the procedures outlined in Mason et al. (1989) for 2- and 1-choice aviary tests. During a 4-day pretreatment period, trays containing 180 g of layer crumbles were placed in the center of the front of each cage at 0800 hours. At the end of 8 hours, trays were removed and consumption was measured. Overnight, birds were deprived of food. Four days of treatment immediately followed. Four cages of red-wings and 4 cages of starlings were given 180 g of layer crumbles mixed with 1% MA-starch in 1-choice tests. The remaining 4 cages of red-wings and starlings were given 2-choice tests between plain layer crumbles and crumbles containing 1% MA-starch. We chose this high MA concentration to ensure that detectable amounts of MA were released from the experimental starch encapsulation during the test sessions.

Analysis.—Analysis of variance (ANOVA) was used to assess consumption in all experiments. Spillage reflected consumption and is not reported. For Experiment 1, consumption appeared relatively stable by Day 5, and therefore that day was used to represent baseline consumption. We used the REPEATED and CONTRAST options of PROC GLM in SAS (SAS Inst., Inc. 1985:434–506) to analyze data from Days 5–15 in a 2-factor repeated measures analysis. Concentration of MA represented the fixed

Table 1. Analysis of variance used to analyze mean treatment consumption among methyl anthranilate concentrations in Experiment 1.

Source	SS	df	MS	*F*	*P*
Concentration	2,048.72	4	412.18	19.83	0.0001
Error	387.46	15	25.83		
Days	2,421.86	10	242.19	13.67	0.0001
Concentration × days	1,008.00	40	25.20	1.42	0.14
Error	2,656.95	150	17.71		

treatment factor in the analysis, and day of measurement was the repeated measure. Significance levels were adjusted by the Greenhouse and Geisser (1959) method due to failure of necessary assumptions regarding covariance matrices. Bonferroni post hoc tests (Snedecor and Cochran 1980:166–167) were used to identify significant differences among treatment means.

In addition to overall tests of significance of main effects and interactions, we performed 2 sets of significance tests for specific contrasts. In the first set, we compared the difference between the baseline level of consumption (Day 5) and each of the 10 treatment days. Our objective was to assess the length of time that treatment reduced food consumption from baseline levels. The second set involved analysis of successive differences in consumption over time. Our objective was to determine when changes occurred in effectiveness of the treatments.

In Experiment 2, consumption of stimulus food during the 2 presentations of each treatment was averaged and subjected to a Latin square ANOVA. Bonferroni tests were used to identify individual treatment differences.

For Experiment 3, 2-choice data were evaluated in a 3-factor ANOVA with repeated measures over days and trays. One-choice data were assessed in a 2-factor ANOVA with repeated measures over days. As in Experiments 1 and 2, consumption on the final pretreatment day was included as a level of the days factor in analyses of both 2-choice and 1-choice tests to provide a measure of baseline performance. Tukey HSD tests (Winer 1962:198) were used to isolate significant differences among means.

RESULTS

Experiment 1.—The 2-factor repeated measures analysis of consumption (Table 1) showed that there were pronounced differences among MA concentrations ($P < 0.0001$) and days ($P < 0.0001$), but the relative performance of the various concentrations did not change over time ($P = 0.1431$). More specifically, contrasts between the baseline level on the last pretreatment day and each of the treatment days revealed that consumption of treated food averaged over all concentrations was significantly reduced ($P < 0.001$) on all 10 treatment days (Fig. 1). Analysis of successive differences indicated that, although significant ($P < 0.05$) changes in the average treatment performance occurred between pretreatment and Day 1 and Days 3–4, 4–5, 5–6, 7–8, and 8–9, the only meaningful change took place on the first treatment day, when average consumption dropped from 21.4 g per bird to 10.7 g per bird. Successive changes during the remainder of the treatment period were both positive and negative and revealed no important patterns. Consumption on the last day of the treatment period averaged 10.9 g per bird. None of the significance tests indicated changes in the differential effectiveness of the concentrations between successive days. Although all MA concentrations significantly reduced consumption (i.e., a significant concentration main effect), only 0.4 and 0.5% produced decreases in consumption from pretreatment (13.4 ± 1.7 [SE], 14.6 ± 2.0, respectively) to treatment (7.6 ± 0.8, 9.0 ± 1.6, respectively)

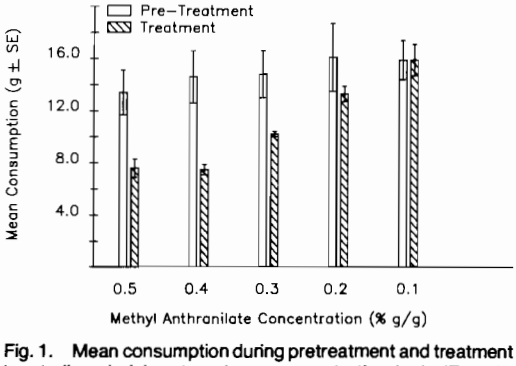

Fig. 1. Mean consumption during pretreatment and treatment by starlings in laboratory 1-cup concentration tests (Exp. 1). Capped vertical bars represent standard errors of the means.

Table 2. Analysis of variance used to analyze mean consumption of methyl anthranilate and dimethyl anthranilate in Experiment 2.

Source	SS	df	MS	*F*	*P*
Treatment	220.59	3	75.53	8.68	0.01
Group	87.19	3	29.06	3.43	0.09
Time	51.49	3	17.16	2.03	0.21
Birds (group)	240.84	16	15.05	4.01	0.0001
Error	50.85	6	8.48		

that were significantly greater than that for 0.1% (16.0 ± 1.5 to 14.3 ± 2.0).

Experiment 2.—The ANOVA (Table 2) revealed significant ($P = 0.0133$) treatment differences in consumption. Post hoc tests showed that 0.5% DMA was significantly ($P < 0.05$) less effective than all other treatments (Fig. 2). No differences were detected among the MA treatments and 1.0% DMA. Average consumption of food treated with 0.4% MA was 73% less (3.8 ± 0.2) than the average consumption of untreated food (13.8 ± 0.4) during the pretreatment period.

Experiment 3.—The ANOVA (Table 3) for 2-choice aviary tests revealed significant differences between species ($P < 0.0001$); starlings showed higher overall consumption (63.9 ± 0.8) than red-wings (42.0 ± 0.5). Although MA was repellent to both species ($P < 0.0001$), there were significant interactions between species and tray ($P < 0.003$), day and tray ($P < 0.00001$), and species, day, and tray ($P < 0.001$). Post hoc examination of these effects showed that red-wings ate less MA-treated feed (2.9 ± 0.2 g) than did starlings (7.9 ± 0.4 g). Although both species ate significantly less MA feed (5.4 ± 0.5 g) than untreated feed (80.8 ± 6.2 g) on all

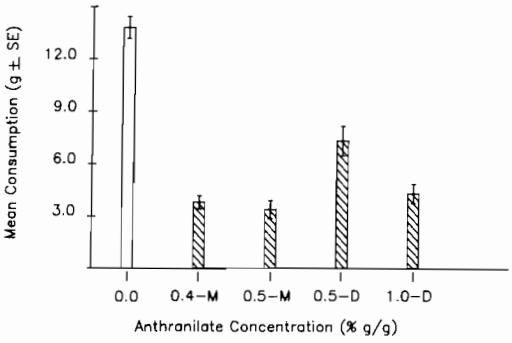

Fig. 2. Consumption of plain (pretreatment) and methyl and dimethyl anthranilate feed (treatment) by starlings in Experiment 2. Capped vertical bars represent standard errors of the means. Abbreviations: M = methyl anthranilate, D = dimethyl anthranilate.

treatment days, starlings showed slight increases in MA consumption over the course of testing (Fig. 3). In addition, consumption of untreated feed increased significantly during the treatment period relative to pretreatment, and these increases were greater for starlings than for red-wings (Fig. 3).

As in 2-choice tests, the ANOVA showed that starlings exhibited significantly higher ($P = 0.0013$) overall consumption (63.9 ± 6.0 g) than red-wings (42.0 ± 0.8) in 1-choice tests (Table 4). There were also significant differences among days and a significant interaction between species and day. Post hoc examination of these effects revealed that although red-wings decreased consumption on treatment Days 1 and 2, consumption returned to pretreatment levels on Days 3 and 4 (Fig. 4). Conversely, starlings showed persistently decreased consumption on all treatment days (Fig. 4).

Table 3. Analysis of variance used to analyze mean consumption during aviary 2-tray tests between methyl anthranilate adulterated and plain feed (Exp. 3).

Source	SS	df	MS	*F*	*P*
Between groups					
Species	24,060.97	1	24,060.97	245.42	0.0001
Error	588.23	6	98.04		
Within groups					
Day	433.34	4	108.34	7.86	0.0005
Species × day	139.86	4	34.96	2.54	0.66
Error	330.86	24	13.79		
Cup	78,563.10	1	78,563.10	181.55	0.0001
Species × cup	11,843.84	1	11,843.84	27.37	0.003
Error	2,596.34	6	432.72		
Day × cup	20,955.91	4	5,238.98	44.57	0.0000
Species × day × cup	3,285.41	4	821.35	6.99	0.001
Error	2,821.27	24	117.55		

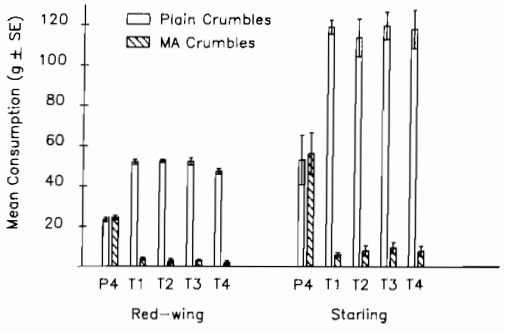

Fig. 3. Mean consumption during pretreatment and treatment by red-winged blackbirds and starlings in aviary 2-choice tests (Exp. 3). Capped vertical bars represent standard errors of the means. Abbreviations: P4 = pretreatment Day 4, T1–T4 = treatment Days 1–4.

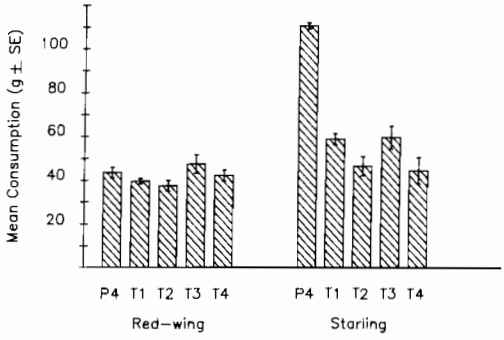

Fig. 4. Mean consumption during pretreatment and treatment by red-winged blackbirds and starlings in aviary 1-choice tests (Exp. 3). Capped vertical bars represent standard errors of the means. Abbreviations: P4 = pretreatment Day 4, T1–T4 = treatment Days 1–4.

DISCUSSION AND MANAGEMENT IMPLICATIONS

The results of Experiment 1 showed that all MA concentrations significantly reduced consumption. However, 0.4 and 0.5% MA elicited the greatest reductions, and for that reason, were used in Experiment 2. The results of that experiment showed that both 0.4 and 0.5% MA were as repellent as 1.0% DMA-starch to birds housed in pairs. In addition, both MA concentrations were more repellent than 0.5% DMA-starch. Thus, 0.4–0.5% MA might represent an effective avian feeding deterrent, although species and/or social factors may diminish the repellency of MA at concentrations as high as 1.0% (Exp. 3).

On the basis of our experiments, we can draw several tentative conclusions with management implications. First, in 6-hour, 1-cup tests, both 0.4 and 0.5% technical MA appear to be as repellent as 1.0% DMA-starch. Because 1.0% DMA is an effective bird repellent in field settings (Mason et al. 1985, Glahn et al. 1989) and because 6 hours is the approximate daily exposure of livestock feeds in feedbunks, we propose that 0.4 or 0.5% MA could be substituted for 1.0% DMA in livestock feeds in some situations without substantial loss of effectiveness. This substitution is significant because technical MA is 4–5 times less expensive than technical DMA and may be 20 times less expensive than DMA-starch. However, the species causing damage and the number of birds present must be considered. Red-winged blackbirds do not appear to be as sensitive as starlings to MA, and socially facilitated feeding may increase the acceptability of an otherwise unpalatable diet.

If 0.4% is truly the minimum effective field application rate, then approximately 4.0 kg of MA are required to treat 1 metric ton of feed. At current prices (assuming purchases ≥4,500 kg) this application rate would cost between $28.20 per metric ton ($7.05/kg) and $32.12 per metric ton ($8.05/kg). Because the mean retail price of dairy cattle protein pellets is about $283.00 per metric ton, treatment with 0.4% MA would raise the price of a ton of feed by about 10–11%. Thus, if feed losses to birds in feedyards approach or exceed 10% (Feare and Swannack 1978, Glahn 1984), the 10–11% in-

Table 4. Analysis of variance used to analyze mean consumption in aviary 1-choice tests with methyl anthranilate adulterated feed (Exp. 3).

Source	SS	df	MS	*F*	*P*
Between groups					
Species	4,782.95	1	4,782.95	37.87	0.001
Error	757.87	6	126.31		
Within groups					
Day	6,489.69	4	1,622.42	49.82	0.0000
Species × day	5,401.57	4	1,350.39	41.47	0.0000
Error	781.57	24	32.56		

crease in cost for bird repellent feed approaches the economic breakeven point, under the assumption that 0.4% MA would substantially reduce bird losses. However, 2 intangible factors remain to be addressed. First, the use of MA feeds for short periods (perhaps in combination with other control strategies such as toxic baiting) could result in reduced bird numbers for extended periods after the use of MA feed is ended. Glahn et al. (1989) suggested that carry-over effects for periods of a week or two may exist. If carry-over effects are substantial, then the relatively high cost of treatment may be balanced by subsequent reduced losses of untreated feed. Second, bird problems in feedlots are not simply those associated with depredation. Starlings, for example, are implicated as vectors of important diseases, including swine gastroenteritis (Pilchard 1965, Gough and Beyer 1982). Thus, the economic benefits derived from the use of MA may exceed the value of saved livestock feed alone. Only an extensive field evaluation of MA will provide sufficient information to decide whether this material provides potentially economical bird control.

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