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VOMITING BY FERAL PIGS AFTER 1080 INTOXICATION: NONTARGET HAZARD AND INFLUENCE OF ANTI-EMETICS

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Feral pigs (*Sus scrofa*) are a major pest of agriculture in Australia. They are responsible for damage to crops (Giles 1976, Pavlov 1980), pasture degradation (Hone 1980), physical damage (Pullar 1950), and lamb predation (Plant et al. 1978, Pavlov et al. 1981, Pavlov and Hone 1982), which may result in losses in excess of $A70m/year (Tisdell 1982). Further, feral pigs are potential vectors and reservoirs of a number of exotic diseases (Geering 1981).

Poisoning with sodium monofluoracetate (1080) is the most widely used method to control feral pigs. Most pigs vomit after ingesting 1080 under experimental conditions (Table 1). In addition, vomitus is frequently observed near bait stations during poisoning programs (P. H. O'Brien and R. E. Kleba, pers. obs.). The high incidence of vomiting following 1080 ingestion has 4 implications: (1) vomitus containing 1080 may cause secondary poisoning of nontarget species close to, and at distance from, 1080 bait stations, (2) secondary poison-

Table 1. Number of feral pigs vomiting after receiving 1080 in captivity and details of dose range and administration.

No. of pigs	No. vomiting	1080 dose	Administration	Source
29	24	Variable concentration 0.005–0.08%	Oral, in wheat	Hone and Kleba 1984
220	>95%	Unknown	Oral, in grain or meat	M.W. Sheehan, pers. commun.
20	20	1 mg/kg	Oral, in 200 ml water, pigs fasted >24 hours	Rathore 1985
20	4	0.75, 0.95, 1.20, 1.50 mg/kg	Oral via esophageal catheter[a]	McIlroy 1983

[a] Adult males only. Pigs vomited only at doses >0.95 mg/kg.

ing of target animals may enhance the effectiveness of poisoning campaigns, (3) vomiting may result in sublethal dosing of target animals, decreasing the overall mortality and effectiveness of poisoning programs, and (4) animals surviving a sublethal dose as a result of vomiting may develop an aversion to 1080 (or enhanced neophobia in response to baits), decreasing their susceptibility to subsequent poisoning programs.

To our knowledge, there are no published data concerning secondary poisoning caused by vomitus ingestion. Further, no information is available concerning the frequency of vomiting or amount of vomitus produced in relation to its 1080 concentration or content. As a result, the consequences of vomiting by feral pigs after 1080 ingestion, for both target and nontarget populations, are difficult to assess.

Because of concern about the nontarget hazard that vomitus may constitute, the effectiveness of an anti-emetic in preventing vomiting following 1080 intoxication has been evaluated in 2 recent studies. Rathore (1985) reported metoclopramide completely effective in suppressing emesis in feral pigs when administered in conjunction with 1080, whereas Hone and Kleba (1984) found it ineffective, with all animals vomiting in both treated and null groups. Because of the disparity between these results and methodological differences between the studies, no conclusion can yet be drawn about the efficacy of metoclopramide in suppressing 1080-induced emesis.

We report on vomiting by feral pigs after 1080 intoxication and the effectiveness of 3 anti-emetics (prochlorperazine, thiethylperazine, and metoclopramide) in suppressing emesis. Specific aims were (1) to examine the relationships between dose of 1080, frequency of emesis, and mortality; (2) to assess the potential for secondary poisoning by vomitus through measurement of its 1080 content; and (3) to determine the influence of metoclopramide dose on emesis and mortality, and the 1080 content of vomitus following 1080 intoxication.

MATERIALS AND METHODS

Animals and Husbandry

Feral pigs were trapped near Cobar (31°32′S, 145°5′E), Warren (31°44′S, 147°53′E), and Dubbo (32°16′S, 148°41′E), Australia. Pigs were weighed, eartagged, treated for external (Amitraz, Tactic®, F and B Chem.) and gastrointestinal (Levamisole, Nilverm®, I.C.I., Aust. Pty. Ltd.) parasites and given streptomycin (Strepolin®, Glaxo Aust. Pty. Ltd.) 25 mg/kg by intramuscular injection at capture. Pigs were maintained in holding yards for ≥14 days on ad libitum water and sorghum and/or wheat, which was mineral and vitamin supplemented (P Factor®, Pfizer Aust. Pty. Ltd.) at recommended rates. Subsequently, they were transferred to individual pens 14 days before the experiment.

Individual pens were 2 × 1 m and constructed of weldmesh and concrete, with mesh or concrete floors. Grain was fed to excess for 1 hour each day, which entrained feeding and ensured that most pigs con-

sumed their dose promptly on the day of experimentation. Water was available ad libitum throughout the experiment.

Design

We administered 1080 (2 dose levels: 1.1 and 2.1 mg/kg) in combination with metoclopramide (4 dose levels: 0, 1, 4 and 16 mg/kg), giving 8 treatments. Five pigs received each treatment. Twenty pigs of each sex were used, with sexes split equally between 1080 dose levels and pigs randomized for sex and body weight across metoclopramide dose levels. Average weight of pigs was 29.1 kg (range = 13–63, SD = 15.0). This weight range included juveniles and adults of both sexes. The 1080 doses represent the LD_{50} and LD_{99}, respectively, calculated using probit analysis from the combined data of McIlroy (1983) and M. W. Sheehan (Queensland Rural Lands Prot. Board, Aust., pers. commun.).

Procedure

A 3.3% aqueous solution of 1080 was mixed with wheat to produce a concentration of 0.033% for pigs allocated to LD_{99} treatments and 0.0173% for pigs allocated to LD_{50} treatments. (In New South Wales, the prescribed concentration of 1080 in wheat bait for feral pig control is 0.033%.) Metoclopramide (Metamide®, Fisons Pty. Ltd., Aust.) powder was combined with the wheat to give the appropriate doses. The dose for each pig was determined in relation to its body weight. Although the concentration of 1080 and metoclopramide in bait varied among treatments, the amount of bait/kilogram of pig body weight remained constant. All pigs were treated at 0830 hours on 23 October 1984. Temperature range on that day was 14–20 C. For each animal treated, a record was made of the time of each episode of vomiting (to the nearest minute) and the time of death (to the nearest 10 min).

In addition, 2 pigs from each treatment were selected at random for vomitus collection. These 16 pigs were assigned to pens with a mesh floor and removable tray. Vomitus was collected after each episode of vomiting, placed in a plastic bag and frozen at −1 C until determination of weight and 1080 content. To evaluate possible changes in 1080 concentration as vomitus dried, the fresh volume and weight of 20 samples were determined. These samples were then air-dried to constant weight (40 C for 17 days) and remeasured.

Eleven of 40 pigs failed to consume their entire dose, with intake averaging 77% of total dose for these pigs. Because there was no consistent pattern of failure to consume dose in relation to treatment (which may have indicated differences in the palatability of treatments), or in relation to mortality, we have analyzed the results on the basis that these pigs consumed entire doses.

We also conducted a pilot study to evaluate the influence of thiethylperazine (Torecan®, Sandoz Aust. Pty. Ltd.) and prochlorperazine (Stemetil®, May and Baker Aust. Pty. Ltd.) on 1080-induced emesis. Using the procedure outlined, 4 pigs were given an oral dose of 2.1 mg/kg of 1080 in grain, together with either thiethylperazine (0.33 mg/kg, 2 animals) or prochlorperazine (0.75 mg/kg, 2 animals).

Throughout these experiments, we treated pigs humanely, within the guidelines of the Australian Bureau of Animal Health (1983).

Assays

The first 3 vomitus samples from each of the 16 pigs were analyzed for 1080 content. The remainder of the samples were stratified into 4 chronological groups and 1 sample was selected at random from each group for analysis. All vomitus from 1 pig given 2.1 mg/kg 1080 was assayed. Vomitus samples were assayed for 1080 content using High Performance Liquid Chromatography (Kramer 1984). Test samples of vomitus containing no 1080 and samples spiked with metoclopramide were also analyzed. No components in these samples interfered with the assay for 1080. The stock solution of 1080 used to prepare baits assayed at 101.9% of measured concentration. Assays of 2 vomitus samples containing known amounts of 1080 yielded recoveries of 89.8% (SD = 3.8). This figure provided a correction factor for the assay results.

RESULTS AND DISCUSSION

Vomiting Frequency and Temporal Distribution

Median latency (time from doses ingested to first vomiting episode) for the 18 pigs that vomited after receiving 1.1 mg/kg 1080 was 117 min and for the 19 pigs that vomited after receiving 2.1 mg/kg 1080 was 86 min. Latency did not vary significantly in relation to dose (median test, $\chi^2 = 0.972$, 1 df, $P > 0.05$), although pigs ingesting 2.1 mg/kg of 1080 tended to begin vomiting earlier and vomit over a longer period than animals ingesting the lower 1080 dose (Fig. 1). Most vomiting (79%) occurred between 1 and 4 hours after intoxication. There was wide individual variation in the frequency (total no. vomits/pig) of vomiting (Table 2).

Analysis of variance showed that metoclopramide dose had no effect ($P > 0.05$) on the total number of vomits/pig (Table 2). Although there was a trend for pigs ingesting

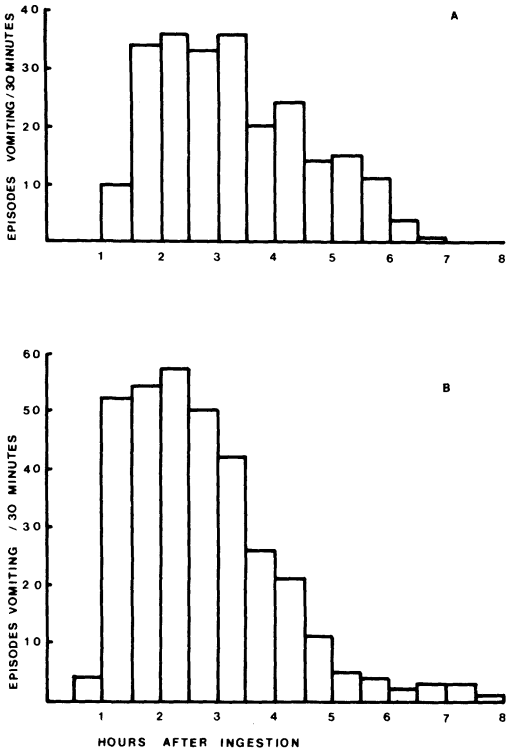

Fig. 1. Temporal distribution of vomiting by feral pigs after 1080 ingestion. A—1.1 mg/kg 1080, B—2.1 mg/kg 1080. Values are total number of episodes of vomiting for 20 pigs in each treatment over 30-min intervals. The distributions differ (Kolmogorov-Smirnov test, $D_{max} = 0.173$, $P < 0.05$).

2.1 mg/kg of 1080 to vomit less often with increasing metoclopramide dose, vomiting still occurred frequently at the highest metoclopramide dose (Table 2).

Under the rates we tested, metoclopramide does not suppress 1080-induced emesis in feral pigs. This finding is consistent with the results of Hone and Kleba (1984) but at variance with those of Rathore (1985). In addition to the range of doses used in the present study, this disparity may be attributable to 2 methodological differences. First, Rathore administered 1080 and metoclopramide to feral pigs fasted for 24–48 hours. Second, he administered the toxin and the anti-emetic in aqueous solution rather than bait. Both fasting and administration in aqueous solution may facilitate rapid gastric passage and absorption. We consider that the conditions in this study and that of Hone and Kleba (1984) more closely represent the field situation, where pigs are not fasted and consume 1080 in grain or pellet bait. Consequently, we conclude that metoclopramide is unlikely to suppress emesis in field-poisoned feral pigs.

Mortality

After arcsin transformation of proportion dying, analysis of variance indicated that there

Table 2. Mortality and number of episodes of vomiting by feral pigs in relation to 1080 and metoclopramide dose levels.

1080 dose / Variable	Metoclopramide (mg/kg) 0	1	4	16
1.1 mg/kg				
Mortality	0/5	0/5	1/5	0/5
Frequency[a]				
$\bar{x}$ (SD)	9.4 (6.8)	12.8 (7.1)	11.6 (8.6)	15.4 (14.2)
Range	0–16	2–21	0–21	2–38
2.1 mg/kg				
Mortality	3/5	4/5	1/5	2/5
Frequency[a]				
$\bar{x}$ (SD)	21.0 (7.7)	16.4 (10.8)	18.4 (9.9)	11.0 (5.5)
Range	9–28	0–28	8–28	6–20

[a] No. of vomiting episodes/pig.

Table 3. Wet weight (g), 1080 concentration (μg/g), and 1080 amount (mg) of feral pig vomitus and percentage of ingested dose ejected during vomiting in relation to 1080 and metoclopramide dose levels.

1008 dose Variable	Metoclopramide (mg/kg) 0	1	4	16
1.1 mg/kg				
Wet weight[a,b]	25.4	6.5	13.9	16.1
1080 concentration[c]	26.4 (8.0)	16.8 (4.80)	23.5 (8.70)	13.1 (6.60)
1080 amount[d]	2.62 (2.21)	0.30 (0.10)	0.85 (0.94)	0.52 (0.34)
% ejected	40.8	7.1	15.8	10.2
2.1 mg/kg				
Wet weight	24.9	25.1	16.9	11.2
1080 concentration	62.2 (11.7)	57.7 (28.3)	45.9 (12.9)	40.9 (20.3)
1080 amount	4.30 (2.70)	3.55 (2.20)	6.30 (4.90)	2.30 (1.20)
% ejected	41.9	39.3	27.6	13.5

[a] Wet weight of total vomitus output (g)/kilogram of pig body weight.
[b] Values are means for 2 pigs in each treatment.
[c] $\bar{x}$ (SD) μg/g, based on first 3 episodes of vomiting by 2 pigs in each treatment.
[d] $\bar{x}$ (SD) mg, based on first 3 episodes of vomiting by 2 pigs in each treatment.

was no effect ($P > 0.05$) of metoclopramide dose on mortality at 1.1 mg/kg 1080, 2.1 mg/kg 1080, or overall (Table 2). Mortality was related to 1080 dose, with 1 of 20 dying at 1.1 mg/kg 1080, and 10 of 20 dying at 2.1 mg/kg 1080. Given that the doses of 1080 employed were LD_{50} and LD_{99} values, calculated from published and unpublished data, observed mortality was lower than expected (LD_{50}, $\chi^2 = 8.1$, $P < 0.05$; LD_{99}, $\chi^2 = 4.9$, $P < 0.05$).

Similarly low mortality has been noted in 2 other studies (Hone and Kleba 1984; L. J. Hone, Canberra Coll. Adv. Educ., Aust., pers. commun.). Variability in mortality may be attributable to a number of factors, including the effects of stress, fasting, experimental environment, and toxin carrier. However, there is a clear need for a more precise determination of the dose-response for 1080 to feral pigs, under conditions relevant to the field. Should subsequent data support our results, a careful reassessment of the relative toxicity of 1080 to feral pigs and nontarget species is warranted.

That metoclopramide had no significant effect on mortality in this experiment is not surprising, given the wide variability in the response of feral pigs to both metoclopramide and 1080. Because metoclopramide did increase 1080 retention in poisoned feral pigs, we would expect it to increase mortality at specified doses.

Thiethylperazine and Prochlorperazine

Neither thiethylperazine nor prochlorperazine suppressed vomiting at the doses tested, with animals receiving either anti-emetic vomiting between 17 and 20 times. One of 2 animals survived in each treatment.

Vomitus Output

There was considerable individual variation in the total amount of vomitus produced ($\bar{x}$ = 395 g, SD = 170, range = 14–647). Total vomitus mass/kilogram body weight decreased in larger animals ($r = -0.685$, $n = 16$, $P < 0.05$), and increased with increasing vomiting frequency ($r = 0.594$, $n = 16$, $P < 0.05$).

Analysis of variance showed a significant effect of metoclopramide in decreasing the total vomitus mass/kilogram pig body weight (Table 3). That is, the amount of vomitus decreased as metoclopramide dose increased, although metoclopramide did not influence the frequency of vomiting.

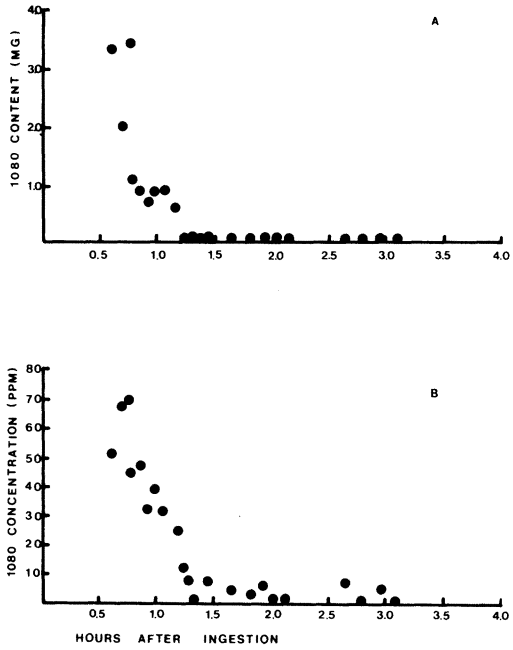

Fig. 2. Content (A) and concentration (B) of 1080 in feral pig vomitus in relation to time since ingestion for a single pig administered 2.1 mg/kg 1080.

Proportion of 1080 Dose Ejected

The decline in 1080 concentration and content of vomitus over time was well described by an equation of the form:

$$y = ae^{-kt},$$

where

y = 1080 content/concentration of vomitus,
t = minutes since 1080 ingestion,

and a and k were constants estimated by nonlinear regression for each animal sampled. The proportion of the variance explained by this relationship averaged 0.63 (range = 0.15–0.94). Estimates derived from this relationship for the unassayed samples were summed with values from the assayed samples to estimate the total amount of 1080 ejected. This value was divided by the known dose of 1080 to estimate proportion of ingested dose that was ejected (Table 3).

Pigs receiving 2.1 mg/kg 1080 ejected a greater ($P < 0.05$) total amount and a greater proportion of their ingested dose of 1080 than animals receiving 1.1 mg/kg. As metoclopramide dose increased, the proportion of the 2.1 mg/kg 1080 dose ejected decreased ($P < 0.05$). Metoclopramide also reduced ($P < 0.05$) the proportion of 1080 ejected after 1.1 mg/kg of 1080, but that effect was not increased at higher doses of metoclopramide.

1080 Content and Concentration of Vomitus

The 1080 content of vomitus was highest during the first bouts of vomiting following poisoning, and thereafter decreased rapidly to low levels (Fig. 2). The median 1080 content of vomitus from pigs given 1.1 mg/kg 1080 was 0.3 mg (range = 0–7.0, $n = 47$), significantly less (median test, $\chi^2 = 8.57$, 1 df, $P < 0.05$) than from pigs given 2.1 mg/kg 1080 (median = 1.0 mg, range = 0–11.6, $n = 52$) (Table 3).

The concentration of 1080 in vomitus was also initially high and declined rapidly (Fig. 2). The median concentration of 1080 in the vomitus of pigs given 1.1 mg/kg 1080 was 11.9 μg/g (range = 0–36.7, $n = 47$) and 19.6 μg/g (range = 0–90.5, $n = 52$) for the vomitus of pigs given 2.1 mg/kg 1080. This difference was not significant (median test, $\chi^2 = 3.72$, 1 df, $0.1 > P > 0.05$).

Drying of vomitus samples resulted in an average 4.4-fold decrease in weight, and a 1.8-fold decrease in volume. The proportion of weight lost during drying was correlated with time of vomiting in relation to dosing ($r = 0.513$, $n = 20$, $P < 0.05$), supporting the observation that later samples had a relatively higher moisture content.

The nontarget hazard of feral pig vomitus is a function of volume, 1080 concentration and content, availability, and palatability.

Vomitus samples from pigs dosed at 2.1 mg/kg 1080 (at the standard field concentration of 0.033%) contained median amounts of 1080 which exceeded the LD_{50} for 14 of 41 species reported by McIlroy (1983). Where nontarget animals ingest more than 1 vomitus, the hazard will be increased. The risk of poisoning will also increase as vomitus dessicates. We have demonstrated the potential for large increases in 1080 concentration with air-drying of vomitus.

Thus, in terms of its 1080 concentration and content, feral pig vomitus has the potential to kill a number of nontarget species. However, it is unlikely to enhance target mortality because of the large amount of vomitus that would need to be ingested by pigs. We recognize that vomitus ingestion by poisoned individuals might decrease the availability of vomitus to nontarget species. However, only 2 of 40 animals in this experiment attempted to eat their own vomitus.

Because pigs vomited repeatedly and for a number of hours after 1080 intoxication, it is likely that vomitus would be distributed over a wide area, in some cases remote from the site of poison placement. Where nontarget species have small home ranges, this effect may enhance the impact of feral pig poisoning programs on nontarget populations. It may also contribute to isolated domestic animal losses, even when these animals have no access to bait or carcasses. We have no data concerning the palatability of fresh or dessicated feral pig vomitus to nontarget species. However, we consider that the vomitus produced after poisoning with wheat bait, which contains a mixture of whole and fragmented grain in viscous suspension, may be palatable to many nontarget species. Other baits allowed for use with 1080 for feral pig control may have different palatability.

In addition, the number of episodes of vomiting and amount of vomitus produced may be influenced by bait type. For example, field operators consider that 1080 causes less vomiting when offered to feral pigs in cereal pellets than in whole wheat (P. Shersingh, Coonamble Pastures Prot. Board, New South Wales, pers. commun.) and Savarie et al. (1983) observed that the incidence of vomiting in coyotes (*Canis latrans*) is related to the bait used.

The presence of 1080 per se or illness resulting from its effects may limit the palatability of vomitus to some nontarget species (Sinclair and Bird 1984). Because metoclopramide decreased the proportion of 1080 dose ejected by poisoned pigs, it can be expected to reduce the amount of toxic vomitus available to nontarget species. However, if present in vomitus, metoclopramide may also restrict the capacity of nontarget species to eject vomitus containing 1080. It is difficult to assess the practical implications of these effects without detailed field evaluation.

Finally, the production of vomitus containing toxic levels of 1080 by feral pigs is an undesirable consequence of poisoning, both in terms of decreasing target impact and its potential for causing nontarget losses. Metoclopramide has some effect on the amount of 1080 ejected, but does not effectively eliminate either problem. Alternative approaches, which inhibit gastric absorption or enhance gastric passage of 1080, may prove more useful.

SUMMARY

We examined vomiting by feral pigs after 1080 intoxication and tested the effectiveness of metoclopramide in suppressing emesis. Most pigs vomited repeatedly after 1080 intoxication ($\bar{x}$ = 21.0 episodes after 2.1 mg/kg 1080 orally, SD = 7.7). At the doses tested (1, 4, and 16 mg/kg), metoclopramide did not reduce the frequency of vomiting, but decreased the proportion of a pig's 1080 dose that was ejected by decreasing the amount of vomitus produced. Because of wide individual variability in response, and the small sample size, there was no significant effect of metoclopramide on mortality. Overall mortality was lower than

expected. Vomitus varied widely in mass, 1080 concentration, and 1080 content. Typical levels of 1080 in vomitus would be hazardous to a number of nontarget species and peak levels hazardous to most. Other feral pigs are unlikely to be poisoned by consuming vomitus.

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