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Food Preference in the Nile Rat *Arvicanthis niloticus*

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Abstract. Individually tested Nile rats, *Arvicanthis niloticus* Desm., consistently preferred sorghum to wheat, groundnuts and standard laboratory food, and whole sorghum to cracked and ground sorghum. The addition of 5% sugar enhanced their consumption of sorghum bait. Similar results were obtained with groups of 2–4 animals in enclosures. Whole sorghum to which 2% by weight groundnut oil and 5% sugar had been added was preferred over all other foods. Small groups of rats in four enclosures were exposed to 0.18% zinc phosphide baits with either the normal cracked sorghum or the experimental whole sorghum-oil-sugar formulation. During pre-baiting the rats consumed twice as much of the experimental bait as they did of the normal. During toxic baiting, however, consumption and mortality were similar for both baits. It is suggested that the experimental bait could be useful for attracting more rats to bait stations and that zinc phosphide may be effective at lower levels than usually applied for the control of *A. niloticus* populations.

Introduction

Food selection in rats is determined by factors such as taste, odour and texture cues (Jackson, 1965; Bullard and Shumake, 1977). Norway rats (*Rattus norvegicus* Berkenhout) select different types of food, including meat, eggs, grains and melons, but they tend to reject highly flavoured foods (Shuyler, 1954). Cereal grains and seeds are preferred and represent typical baits: oats and maize in England (Cornwell and Bull, 1967) rolled oats in sugarcane fields of Hawaii (Crabb and Emik, 1946), wheatmeal in the USA (US Public Health Service, 1970), and binlid (broken rice) in the Philippines (Kuehnert, 1976). Brooks and Bowerman (1973) reported that particle size may be more important than the choice of bait material, particularly with hard, dense seeds. Flavouring agents, enhancers and spices also influence food preference behaviour (Shumake, 1978). For example, Johnson (1946) found that rolled oats with mineral oil and sugar were accepted more readily than meat and fruit. Barnett and Spencer (1953) found that rats in colonies preferred wheat meal mixed with sugar to wheat meal alone.

Because rodenticidal baiting is the main method for controlling local populations, information on the behaviour and food preferences of rats is important for any control campaign. Many species, including important crop pests, have not been studied to any extent in their feeding habits. This research investigated feeding behaviour of the Nile rat (*Arvicanthis niloticus* Desm.) under controlled laboratory and closed colony conditions, and preferences for some food materials available in the fields of Sudan. In addition, the effects of bait additives, texture and a commonly used rodenticide (zinc phosphide) were examined in an attempt to develop an improved bait formulation for controlling this important agricultural pest species.

Materials and methods

Nile rats trapped in the Gezira Region of Sudan were shipped by air to the Denver Wildlife Research Center. These animals were sexed, marked and individually caged before testing. Adaptation to the laboratory environment and stabilisation of food consumption took place over three weeks before the tests.

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We used 18 laboratory preference test devices that allowed automatic presentation and rotation of the two food-choice positions. Each device contained a four-compartment food cylinder (10.0 cm diameter x 3.8 cm height). Two compartments were used for presenting the standard reference food, and the other two for presenting comparison or treated foods. The cylinder was attached to the shaft of a 4 rev/min synchronous motor which was programmed by relay-switching circuits to operate at 5-min time intervals to expose alternate positions of the two foods. Test foods were wheat, sorghum (Martin X), shelled red-skin groundnuts and Purina Laboratory Rodent Chow (No. 5001). Molasses, sugar, groundnut oil, and technical grade zinc phosphide (98% purity) were also available as bait ingredients. All formulations were prepared and stored for a day before each test.

The test room was 3 x 5 m and was illuminated with white fluorescent light on a 12:12 h schedule. Temperature was held at 24–27°C and relative humidity at 20–40%. For the enclosure tests, a circular rodent test building 11 m in diameter was used to house eight 1.5 x 3 m colony enclosures constructed with galvanised sheet metal. A 12:12 h light cycle was programmed, and temperature was controlled within the range of 22–29°C.

Laboratory test

Paired preference tests were performed with singly caged rats by first adapting them to 60, 30, 15 and finally 5 min alternations of the food compartment positions over a five-day period. Position habits were thereby eliminated during the tests as a source of bias using the 5 min alternation of food positions. Selected test foods, textures and bait additives were evaluated with separate rat groups. A series of four preference tests was conducted on small groups of four males and two females with each animal individually tested. The control or reference foods were either ground laboratory food or whole sorghum. Each day over four days, consumption of the test and control foods was measured for each rat after 20 h of exposure.

Initially, three groups were tested for preference between ground laboratory food and either whole wheat, groundnuts or sorghum. The second test entailed two groups evaluated for preference using either cracked or ground sorghum *versus* whole sorghum. The third and fourth tests consisted of evaluations of two levels (2% and 5%) of molasses and sugar as additives to whole sorghum. Previously used animals were selected and rearranged into three groups so that their previous test food exposures were evenly distributed among the new groups. To further reduce carry-over effects, we gave these animals laboratory food *ad libitum* for seven days before their preference tests. Foods were whole sorghum treated with molasses, sugar or groundnut oil (2% wt/wt) *versus* whole sorghum. All rats in these last three groups were then given two days of feeding on laboratory food, after which additive levels were raised to 5%, and the test was repeated for another four days. At both levels, the sugar was first dissolved in water, a comparable amount of water was added to the reference bait, and both were air-dried 24 h before the preference test.

Enclosure tests

Three colony preference evaluations involving previously used bait materials, bait texture and additives and ɿc phosphide sorghum baits were conducted in eight 3 x 1.5 x 1.5 m enclosures. Each enclosure was covered with movable 1.3 cm wire mesh screens, provided with a compacted mound of top soil (150 x 60 x 30 cm) at one end for burrowing, and used for housing a total of two to four randomly assigned male and female rats. In all tests, the rats were given at least ten days to stabilise food consumption and social interactions, and to establish burrows. Test foods were presented in 100 g capacity aluminum covered bowls fastened to metal-shielded wooden boards to minimise spillage and contamination with earth or excreta. Each food bowl had eight openings (2.5 x 2.5 cm) to allow simultaneous feeding by all rats in the enclosure. Food container positions were alternated daily except during the final zinc phosphide baiting trial.

The first two preference tests involved placing 100 g of each of the foods in separate containers and measuring daily consumption for each colony for seven to eight days. In the test for preference between wheat, groundnuts and sorghum, food location in relation to burrow entrances was also evaluated. In four enclosures, food containers were centrally placed. In the other four enclosures, groundnuts and wheat were placed either centrally (two enclosures) or near burrow entrances (two enclosures). The second test involved three baits: cracked sorghum, whole sorghum, and whole sorghum with 2% oil and 5% sugar added. To reduce carry-over effects, the rats were then offered laboratory food for three days before the third and final enclosure test. Colonies in the eight enclosures received either cracked sorghum bait in four enclosures or the experimental bait (whole sorghum treated with 2% groundnut oil and 5% sugar) in the other four enclosures. All rats were given three days of pre-baiting with each bait with wheat as the alternative food. Toxic baiting was then begun with all rats given the choice between untreated wheat *versus* sorghum baits (traditional *vs.* experimental) treated with zinc phosphide at 0.18% wt/wt. Baiting continued for three days and was followed by four days of post-baiting to examine bait shyness effects in survivors. Consumption levels for all foods and baits were measured throughout the test.

The bait concentration lethal to half of the exposed animals (LC_{50}) was determined to be 0.18% for zinc phosphide (Zn_3P_2) in the laboratory. Starting with 1% Zn_3P_2 in cracked sorghum, 30 g of the toxic bait was presented to five individually caged rats for five days. Each day new animals were used, and the concentration of Zn_3P_2 was decreased by 50%, until no kill was obtained with five days of post-treatment observation. The number of rats killed in each of the successively decreasing Zn_3P_2 groups was 5, 4, 5, 1 and 0 respectively. The LC_{50} value was calculated from methods outlined by Thompson and Weil (1952).

Data analyses

Percentage preference values for laboratory data were calculated by dividing test food by total food consumption and then multiplying by 100. Correlated *t*-tests were used to analyse for differences in percentage preference for treated *versus* reference bait. Laboratory data were also subjected to three-way analysis of variance with repeated measures using treatment (test foods), days and sex as the main factors. Parameters analysed were: amounts of treated bait and reference food consumed, total food consumption, and percentage preference values for treated bait. Where significant effects were found individual mean comparisons were made using Duncan's multiple range test. Consumption data for the enclosures were analysed using a one-way repeated measures analysis of variance with food type as the main factor and days as the repeated measure. The multiple range test was again used for mean separation when significant effects were observed.

Results and discussion

Laboratory tests

Nile rats in all groups preferred the test foods (groundnuts, sorghum, wheat) to the reference food (Table 1). Animals tended to increase their preference toward the test foods over the four days and there was a corresponding decrease in reference food intake. Based on the consumption measures, there was a preference for sorghum over wheat and groundnuts. Results are consistent with a previous study (Arafa *et al.*, 1975) in which sorghum was found

TABLE 1. MEAN PREFERENCE (%) AND CONSUMPTION (g) FOR THREE FOODS WITH LABORATORY FOOD AS THE ALTERNATIVE

Days	Groundnuts		Sorghum		Wheat	
	Females	Males	Females	Males	Females	Males
1	71.8 (9.05)	67.6 (8.90)	89.4 (9.35)	76.6 (10.98)	80.3 (6.75)	65.0 (8.15)
2	43.5 (3.00)	66.0 (7.50)	86.3 (9.45)	86.6 (11.58)	81.7 (8.75)	70.9 (7.80)
3	89.8 (8.09)	66.0 (5.45)	97.0 (8.10)	92.0 (13.75)	97.8 (9.00)	86.4 (7.65)
4	74.5 (7.45)	78.6 (5.88)	88.8 (6.80)	90.4 (10.25)	79.2 (8.40)	81.6 (7.68)
Mean ± s.d.						
Preference (%)	69.9 ± 19.3	69.5 ± 6.1	90.3 ± 4.6	86.4 ± 6.9	84.8 ± 8.8	75.9 ± 9.8
Consumption (g)	(6.89 ± 2.68)	(6.93 ± 1.58)	(8.42 ± 1.24)	(11.64 ± 1.51)	(8.22 ± 1.01)	(7.82 ± 0.23)

Each test food consumed more than laboratory food: $P < 0.01$ by correlated *t*-tests.
Decrease in reference food consumption: $P < 0.001$, and increase in preference for test foods: $P < 0.03$ by repeated measures ANOVA.
Sorghum *versus* wheat and groundnut consumption: $P < 0.05$ by ANOVA.

to be preferred to 12 other naturally occurring food items in Nile rat habitat. Our results also agree with those of Schein and Orgain (1953) and Barnett and Spencer (1953), who found that wild Norway rats consumed more low caloric value food (sorghum) and less energy-rich food (groundnuts).

Correlated *t*-tests indicated that whole sorghum was preferred to both the cracked and ground sorghum (Table 2). These data are consistent with those of Barnett and Spencer (1953) in which Norway rats were found to prefer whole meal and whole wheat to wheat flour. Similarly, Keffer (1967) found Purina pellets and meat packets well

TABLE 2. MEAN PREFERENCE (%) AND CONSUMPTION (g) FOR CRACKED *VERSUS* GROUND SORGHUM WITH WHOLE SORGHUM AS THE ALTERNATIVE

Days	Cracked sorghum		Ground sorghum	
	Females	Males	Females	Males
1	25.8 (2.35)	33.7 (5.65)	14.5 (1.70)	30.9 (5.13)
2	20.9 (1.85)	37.5 (5.25)	21.8 (2.30)	8.7 (1.03)
3	22.6 (3.05)	26.9 (4.45)	13.5 (1.60)	18.6 (2.53)
4	3.2 (0.40)	12.9 (1.88)	13.8 (1.90)	26.3 (3.45)
Mean ± s.d.				
Preference (%)	18.1 ± 10.02	27.8 ± 10.8	15.9 ± 3.96	21.1 ± 9.7
Consumption (g)	(1.91 ± 1.12)	(4.31 ± 1.69)	(1.88 ± 0.31)	(3.03 ± 1.72)

Each test food texture less preferred to whole sorghum $P < 0.01$ by *t*-tests.

accepted by wild Norway rats, but ground forms of these same foods ranked lower in preference. Related to this effect, Jackson (1965) found that the rodent's ability to hold and handle, as well as carry, the food material played an important role in preference behaviour.

Molasses and groundnut oil led to weaker preference when added to whole sorghum (Table 3) at 2% (wt/wt). Although sugar at this level did not increase sorghum preference or consumption, there was a gradual increase in both preference for and consumption of the sugar-treated sorghum over the four-day test period. At 5% (wt/wt)

TABLE 3. MEAN PREFERENCE (%) AND CONSUMPTION (g) OF WHOLE SORGHUM WITH THREE ADDITIVES AT 2% BY WEIGHT WITH UNTREATED WHOLE SORGHUM AS THE ALTERNATIVE

Days	Test food additive					
	Molasses*		Groundnut oil*		Sugar†	
	Females	Males	Females	Males	Females	Males
1	9.9 (1.10)	19.1 (2.53)	33.1 (3.50)	15.8 (1.95)	27.2 (2.40)	31.2 (4.35)
2	5.7 (0.60)	26.3 (3.20)	33.3 (3.60)	21.7 (3.03)	38.2 (3.00)	56.8 (6.63)
3	18.5 (2.15)	28.3 (4.28)	31.9 (3.75)	19.5 (3.10)	49.7 (4.70)	54.3 (9.90)
4	8.5 (1.05)	41.9 (5.68)	33.7 (2.90)	12.7 (1.95)	57.6 (5.65)	60.8 (10.93)
Mean ± s.d.						
Preference (%)	10.7 ± 5.5	28.9 ± 9.5	33.0 ± 0.77	17.4 ± 4.0	43.2 ± 13.3	50.8 ± 13.3
Consumption (g)	(1.22 ± 0.66)	(3.92 ± 1.38)	(3.44 ± 0.37)	(2.51 ± 0.64)	(3.94 ± 1.50)	(7.95 ± 3.02)

*Untreated sorghum preferred to these treatments: $P < 0.01$ by *t*-tests.
†Increase in preference: $P < 0.05$, and increase in consumption of sugar-treated sorghum over 4 days: $P < 0.03$ by ANOVA.

molasses and groundnut oil again led to weaker preference when added to whole sorghum (Table 4). However, at this level sugar-treated sorghum was preferred to the untreated sorghum. Males tended to eat more sugar-treated sorghum than did females but the reverse was indicated for groundnut oil.

TABLE 4. MEAN PREFERENCE (%) AND CONSUMPTION (g) OF WHOLE SORGHUM WITH THREE ADDITIVES AT 5% BY WEIGHT WITH UNTREATED WHOLE SORGHUM AS THE ALTERNATIVE

Days	Test food additive					
	Molasses*		Groundnut oil*		Sugar†	
	Females	Males	Females	Males	Females	Males
1	4.7 (0.55)	13.1 (1.88)	42.4 (4.95)	19.6 (2.80)	60.7 (4.80)	80.9 (12.48)
2	4.4 (0.50)	6.1 (0.88)	51.3 (5.55)	17.4 (2.68)	80.5 (7.25)	87.0 (10.95)
3	12.0 (1.40)	5.9 (0.88)	50.0 (7.65)	14.4 (2.55)	71.2 (6.70)	91.3 (11.55)
4	7.4 (0.90)	1.3 (0.23)	25.5 (3.15)	17.7 (3.30)	72.1 (7.25)	77.0 (12.00)
Mean ± s.d.						
Preference (%)	7.1 ± 3.5	6.6 ± 4.9	42.3 ± 11.9	17.3 ± 2.2	71.1 ± 8.1	80.1 ± 6.3
Consumption (g)	(0.83 ± 0.41)	(0.87 ± 0.68)	(5.33 ± 1.80)	(2.83 ± 0.33)	(6.50 ± 1.16)	(11.74 ± 0.55)

*Untreated sorghum preferred to treated sorghum: $P < 0.01$.
†Sugar-treated sorghum preferred to untreated: $P < 0.01$ by *t*-tests on percentage preference variable.
Males consumed more sugar-treated sorghum than females: $P < 0.01$ by ANOVA.
Total intake of all foods increased over the 4-day period: $P < 0.05$ by ANOVA.

Nile rats showed a stable preference response to the sugar treatment at 5%, a result agreeing with those for many small mammals (Jacobs *et al.*, 1978). Nile rat responses to groundnut oil were similar to those shown by Philippine rice rats (*R. r. mindanensis*) (Kuehnert, 1976). In contrast, Norway rats have been shown to increase acceptance when wheat or whole meal was treated with groundnut oil (Barnett and Spencer, 1953). We should emphasise that Nile rats may have preferences for other vegetable oils even though groundnut oil tended to be rejected by the animals in our study. Many reports (Crabb and Emik, 1946; Barnett and Spencer, 1953; Shumake, 1978) have indicated that rats of a given species will show varying degrees of preference for certain oils added to their food.

Enclosure tests

In the initial test, sorghum was found to be by far the most preferred food ($P < 0.01$) followed by groundnuts, wheat and laboratory food (Fig. 1). Sorghum was consumed to a greater degree than all other available foods when all test foods were centrally located (left panel; Fig. 1) and also when the wheat and groundnuts were placed near burrow entrances (right panel; Fig. 1). Wheat consumption, however, increased at the burrow entrances when compared with the central locations. Thus, making both wheat and groundnuts more readily available had the effect of increasing consumption of these foods by the rats ($P < 0.01$). We also observed more hoarding of groundnuts inside the burrows compared with wheat and sorghum. Larger food materials tended to stimulate caching behaviour, an effect previously observed by Calhoun (1963) in colonies of wild Norway rats.

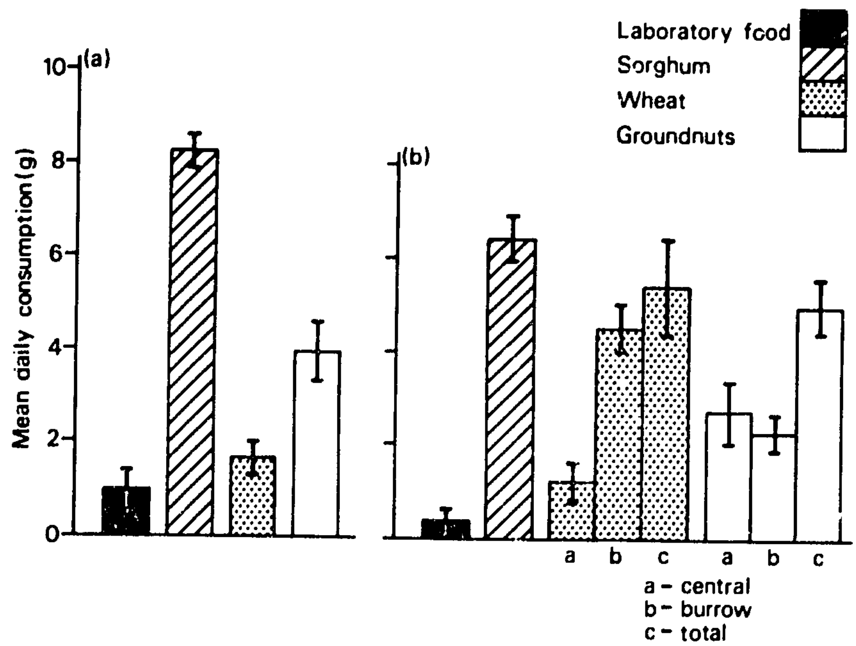

Fig. 1. Mean daily consumption in (a) four enclosures with containers centrally located *versus* (b) four enclosures with wheat and groundnuts located either centrally or near burrow entrances. Lines above histograms represent standard errors of the means.

The second enclosure test results are shown in Fig. 2. The mixture of whole sorghum, 2% oil and 5% sugar was highly preferred to both whole and cracked sorghum ($P < 0.01$) with consumption levels differing by factors of 8 and 25 respectively. This result was viewed as extremely significant in that cracked sorghum has been one of the most frequently used zinc phosphide bait bases in Sudan and other North African countries.

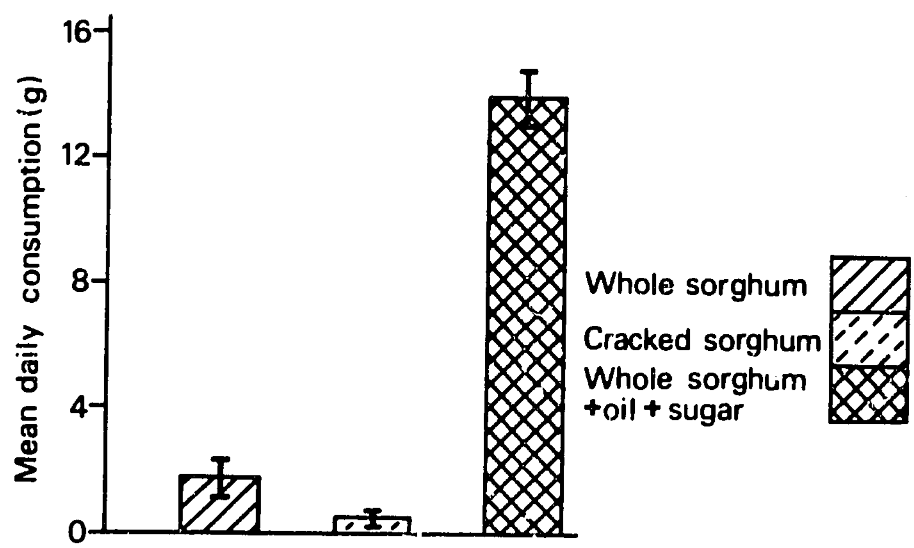

Fig. 2. Means and standard errors for daily consumption in eight enclosures housing small colonies.

The third and final enclosure test involved the experimental bait (whole sorghum with 2% oil and 5% sugar) in comparison with the traditional bait (cracked sorghum). The experimental sorghum bait was consumed in larger amounts ($P < 0.01$) than the traditional bait during the three-day pre-baiting period (Fig. 3). However, during the three days of toxic baiting, equal amounts of traditional and experimental sorghum + zinc phosphide bait were eaten by Nile rats in both groups. All rats except one in each group were killed and, during the post-baiting period of four days, data were only available for the two surviving animals. The rat surviving the experimental bait treatment showed bait shyness as indicated by the preference for wheat; the animal that survived the traditional bait treatment also consumed no sorghum on the first day of post-baiting.

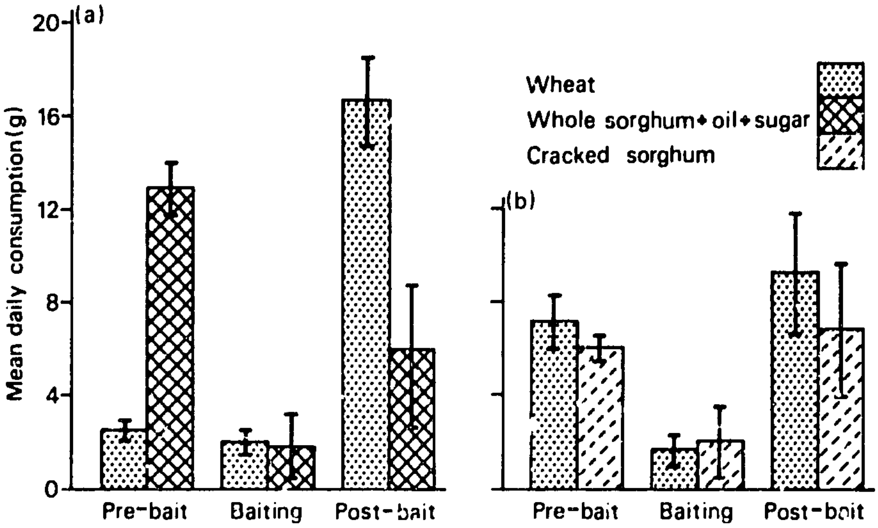

Fig. 3. Means and standard errors for daily consumption in (a) four experimental bait enclosures *versus* (b) four enclosures provided with cracked sorghum bait.

Although our results have been obtained with confined colonies of Nile rats, they suggest that the advantage of bait additives such as oil and sugar may be in enhanced recruitment of more rats to bait stations. This could occur when the pre-bait period is fairly long (i.e. a week or more) or when sustained baiting (Fall, 1977) with anti-coagulant poisons has been undertaken to control localised rat populations. With animals made more thoroughly habituated to the oil and sugar flavour additives during an extended pre-bait or sustained-bait period, perhaps the experimental bait would lead to increased field efficacy for the zinc phosphide or anticoagulant rodenticides. With a limited three-day exposure period for pre-baiting in our study we observed no evidence that sublethal exposures to the bait and subsequent bait-shyness could be reduced with these additives. However, and more importantly, the Nile rat appeared highly sensitive to technical grade zinc phosphide in these enclosure trials suggesting that, in many instances, the 3% wt/wt levels used for control in Sudan and other nations are excessive.

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