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THE EFFECT OF CARBON DISULFIDE ON FOOD CONSUMPTION BY HOUSE MICE

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Abstract: We assessed whether carbon disulfide (CS_2) would increase attractiveness of baits and feeding sites to the house mouse (*Mus musculus*). Presence of CS_2 significantly enhanced consumption of bait by house mice and mouse entries into, and amount of time spent in, bait enclosures. Females were more responsive to CS_2 than males. We suggest ways CS_2 could improve the efficacy of poison baits, traps, and tracking powders in rodent control.

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When faced with a choice among feeding sites, rats (*Rattus* spp.) prefer locations that conspecifics are exploiting (Galef and Clark 1971, Galef and Heiber 1976). When faced with a choice among several novel foods, naive (observer) rats choose novel food eaten by conspecifics (demonstrators) with whom they previously have interacted (Galef and Wigmore 1983, Posadas-Andrews and Roper 1983, Strupp and Levitsky 1984). This socially mediated transfer of food preference has been observed even when demonstrators are anesthetized and wire-mesh barriers are placed between demonstrators and observers (Galef and Wigmore 1983). These findings, and results of other experiments by Galef and Stein (1985) suggest that transfer of diet preference is mediated in part by volatile cues.

Important volatile information could be the smell of food that a demonstrator has ingested before interacting with an observer. Alternatively, transmission might require a combination of the smell of ingested diet and some endogenous (demonstrator-derived) volatile cue. In a series of experiments designed to test these possibilities, Galef and Stein (1985) and Galef

et al. (1985) showed that the smell of ingested diet and demonstrator-produced volatile signals provided important information. In a series of gas chromatographic/mass spectroscopic experiments, Galef et al. (1988) found that CS_2 is present on the breath of rats at a concentration of approximately 1 ppm. When CS_2 is associated with diet on a surrogate rat (cotton batting), it elicits transfer of diet preference similar to that produced by exposure to a live demonstrator (Galef et al. 1988). Our experiments were performed to assess whether CS_2 could be used to enhance preference for, and ingestion of, food by the house mouse.

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METHODS

Adult house mice were obtained from Charles River Laboratory (Wilmington, Mass.). The animals were 60 days old on arrival and were tested within 90 days. Each mouse was individually housed in a plastic cage (13 cm × 17 cm × 21 cm) in a room with a 12:12 hour light : dark cycle and an ambient temperature of 20 ± 2 (SE) C. Purina 5001 Laboratory Rodent Chow (Ralston Purina Co., St. Louis, Mo.) (crude protein ≥23%) and tapwater were provided ad libitum, except as described below.

Aqueous solutions containing 0.001, 0.01, 0.1, 1.0, and 10.0 ppm of CS_2 (Chem. Abstr. No. 75-15-0) were prepared in distilled water. Because of the toxicity of CS_2 at concentrations >20 ppm, all stimuli were mixed under a fume hood. We also prepared 2 concentrations of butanol (BuOH): 1.0 ppm and 10.0 ppm in distilled water for use in 1 experiment. All stimulus solutions were stored in covered glass vials at room temperature (20 ± 2 C).

Prior to each test session, stimulus foods were prepared by applying 2 drops (0.05 cc/drop) of solution to each of 2 Purina Laboratory Rodent Chow pellets. Treated pellets were weighed and then placed in 1 of 2 bait enclosures with metal tongs to avoid handling by experimenters.

On the day before each experiment, 20 mice (10 M and 10 F) were deprived of food just prior to light offset. Test sessions commenced 3 hours following light onset. Each mouse was tested individually in an open field (Fig. 1). Two stimulus pellets were placed in each of 2 enclosures that were positioned in opposite corners of the testing apparatus. Immediately prior to each test session, the apparatus and bait enclosures were cleaned with 70% ethyl alcohol (EtOH); excess EtOH was evaporated with a hand-held blow-drier.

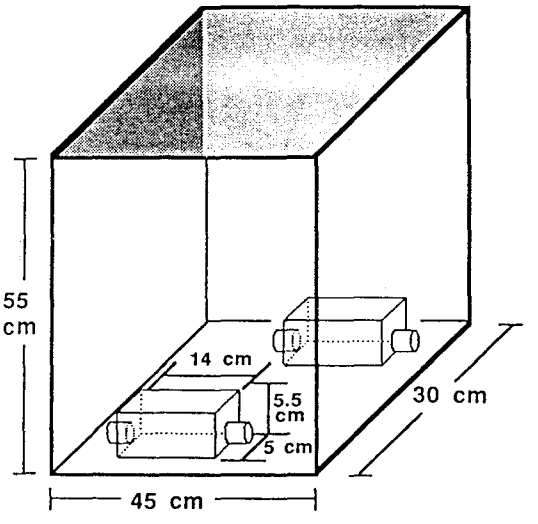

Fig. 1. Diagram of the open field testing apparatus and bait enclosures. At the beginning of a trial, the mouse was placed through the open top into the center of the apparatus, equidistant from the 2 enclosures.

Each mouse was placed in the center of the open field at the beginning of a trial. After 20 minutes, the mouse and remaining food were removed. Decreases in the weight of the food during the trial reflected consumption. Photoelectric circuits recorded entries and departures at each bait enclosure. These data, and the length of time (sec) spent in each enclosure by each mouse, were recorded automatically and stored for analysis by a Vic-20 microcomputer (Commodore Ltd., Agincourt, Ont.).

In each of our experiments, 20 mice were tested with treated and untreated stimulus pellets. The order in which stimuli were presented and subjects were tested were randomized. Results were assessed in 3 (no. entries, durations, and consumption) 3-way analyses of variance (ANOVA). Tukey *a*-tests (Winer 1962:198) were used to isolate significant differences among means ($P < 0.05$) for all experiments.

Experiment 1.—The first experiment investigated whether CS_2-scented pellets of Purina Laboratory Rodent chow were more attractive

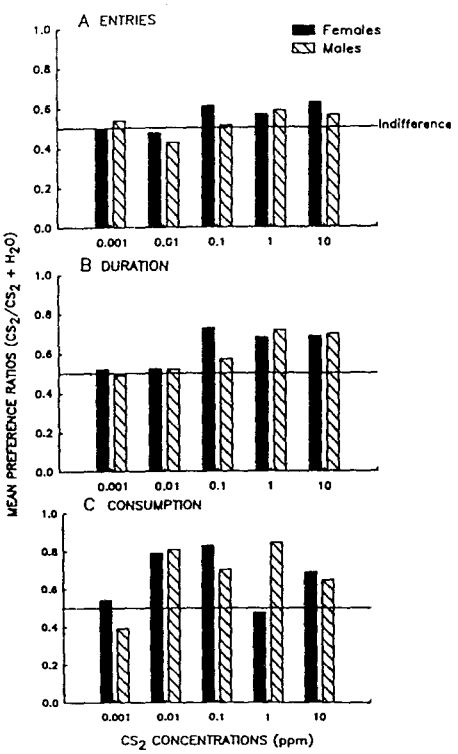

Fig. 2. Number of house mouse entries into bait enclosures (A), durations in enclosures (B), and consumption (C), expressed as mean preference ratios comparing CS_2-scented food pellets and H_2O-scented pellets. Ratios were calculated by dividing CS_2-related responses by total responding (CS_2 + H_2O). Ratios can vary from 1.0 (absolute preference for CS_2) to zero (absolute rejection of CS_2). A ratio of 0.5 reflects indifference.

than pellets wetted with 2 drops of distilled water. The factors in the ANOVA's were sex (between factor), CS_2 concentration (within factor, 5 levels), and bait enclosures (within factor, 2 levels).

Experiment 2.—The second experiment explored whether higher CS_2 concentrations were more attractive than lower CS_2 concentrations (or distilled water). Each mouse was given choice tests between chow pellets scented with a high concentration of CS_2 versus chow pellets scented with a low concentration. The factors in the ANOVA's were sex (between factor), CS_2 concentration (within factor, 5 levels), and bait enclosures (within factor, high vs. low concentration in each test).

Experiment 3.—The third experiment tested whether CS_2 was more attractive than BuOH, another highly volatile odorant. Butanol was chosen as an alternative stimulus because it is commonly used as a cue in studies of olfaction. Each mouse was given 2 20-minute choice tests between chow pellets scented with CS_2 and chow pellets scented with BuOH. In the first session, 10-ppm CS_2 and 1-ppm BuOH served as stimuli. In the second session, 10-ppm CS_2 and 10-ppm BuOH were used. Butanol concentrations were selected to bracket high concentrations of CS_2 used in the previous experiments. The factors in the ANOVA's were sex (between factor), session (within factor, 2 levels), and bait enclosures (BuOH enclosure vs. CS_2 enclosure, within factor).

RESULTS

Experiment 1

Entries.—There were differences between males and females ($F = 59.3$; 1, 18 df; $P < 0.0001$) and entries into enclosures containing CS_2-scented pellets versus enclosures containing water-treated food ($F = 7.4$; 1, 18 df; $P = 0.013$). Also, there was a significant interaction between CS_2 concentrations and bait-enclosures ($F = 3.7$; 4, 72 df; $P = 0.008$).

Females entered bait enclosures more often than males (29.5 ± 1.45 [SE] F entries, 19.7 ± 0.85 M entries). Also, enclosures containing CS_2-scented pellets were entered more frequently than enclosures containing water-scented pellets (CS_2, 26.7 ± 1.32; H_2O, 22.5 ± 1.30). Mice exhibited more entries when high CS_2 concentrations (1.0 and 10.0 ppm) served as stimuli than when low concentrations (0.001 and 0.01 ppm) were used (Fig. 2A).

Time Spent in Enclosures.—There were differences in the durations of visits to enclosures by males and females ($F = 6.7$; 1, 18 df; $P = 0.017$) and to enclosures containing CS_2-scented versus water-treated food ($F = 26.3$; 1, 18 df; $P < 0.0001$). Also, the interaction between CS_2 concentration and the amount of time spent in each of the 2 enclosures by subjects was significant ($F = 6.9$; 43, 72 df; $P < 0.0001$).

Females spent more time in enclosures than males (F duration = 214.5 ± 12.1 sec, M duration = 167.8 ± 9.72 sec). Also, subjects spent more time in enclosures containing CS_2-scented food than in enclosures containing water-treated food (CS_2, 234.4 ± 11.3 sec; H_2O, 148.0 ± 9.2 sec). Finally, males and females spent more time in enclosures when high CS_2 concentrations (1.0 and 10.0 ppm) had been placed on chow pellets than when low concentrations (0.001 and 0.01 ppm) were used (Fig. 2B).

Consumption.—There were differences in the

amount of CS_2-scented and H_2O-treated food consumed by subjects (F = 7.8; 1, 18 df; P = 0.012). Mice consumed more CS_2-scented food (0.106 ± 0.001 g) than H_2O-treated food (0.056 ± 0.007 g) (Fig. 2C).

Experiment 2

Entries.—There were differences in the number of entries into bait enclosures between males and females (F = 13.4; 1, 18 df; P = 0.002), among CS_2 concentrations (F = 2.6; 9, 162 df; P = 0.007), and between enclosures containing high (1.0 and 10.0 ppm) versus low (0.001 and 0.01 ppm) concentrations of CS_2 (F = 31.3; 1, 18 df; P < 0.0001). Also, there was a significant 3-way interaction among sex, CS_2 concentration, and entries into the 2 bait enclosures (F = 2.02; 9, 162 df; P = 0.04).

Females (29.0 ± 1.1) entered enclosures more frequently than males (21.7 ± 0.7). Also, higher CS_2 concentrations elicited more entries than the lower concentration (high = 28.1 ± 0.9, low = 22.6 ± 1.0). Females entered enclosures more frequently when both contained higher CS_2 concentrations (1.0 and 10.0 ppm) than when both contained relatively lower CS_2 concentrations (0.001 and 0.01 ppm) (Fig. 3A).

Time Spent in Enclosures.—There were differences in the amount of time spent by subjects in the 2 enclosures (F = 36.4; 1, 18 df; P < 0.0001). Longer durations were elicited by the higher CS_2 concentrations in nearly every pair (224.4 ± 7.0 sec) than low concentrations (157.0 ± 8.3 sec) (Fig. 3B).

Consumption.—There were differences in consumption within pairs of concentrations used in each choice test (F = 42.8; 1, 18 df; P < 0.0001). Specifically, mice consumed more in the presence of higher concentrations of CS_2 (0.10 ± 0.007 g) than in the presence of low concentrations (0.04 ± 0.004 g) (Fig. 3C).

Experiment 3

Entries.—There were differences between males and females (F = 13.2; 1, 18 df; P = 0.002), and between CS_2 and BuOH (F = 16.4; 1, 18 df; P = 0.001) in the number of entries into bait enclosures. Females (34.4 ± 2.2) exhibited more entries than males (22.5 ± 1.3), and CS_2 (32.2 ± 1.7) elicited more entries by mice than BuOH (24.7 ± 2.1) (Fig. 4A).

Time Spent in Enclosures.—There were differences in the amount of time spent by subjects in CS_2- and BuOH-scented bait enclosures (F = 102.9; 1, 18 df; P < 0.0001). Mice spent more time in enclosures containing CS_2-scented pellets (270.8 ± 17.1 sec) than in enclosures containing BuOH-scented pellets (115.6 ± 8.5 sec) (Fig. 4B).

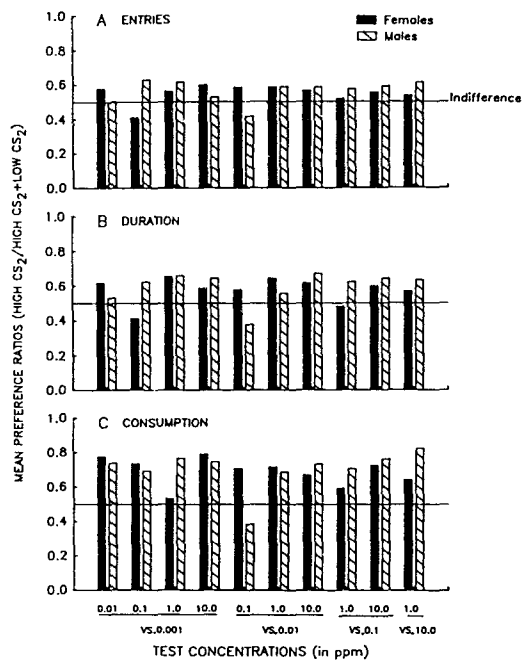

Fig. 3. Number of house mouse entries into bait enclosures (A), durations in enclosures (B), and consumption (C) expressed as mean preference ratios comparing high and low CS_2 concentrations. Ratios were calculated by dividing high CS_2 concentration by total responding (low + high).

Consumption.—There were differences in the amount of CS_2- and BuOH-scented chow consumed (F = 17.5; 1, 18 df; P = 0.001). More CS_2-scented food was consumed (0.05 ± 0.008 g) than BuOH-scented food (0.007 ± 0.002 g) (Fig. 4C).

DISCUSSION

Results of experiment 1 showed that, relative to water, CS_2 increased entries into bait enclosures, increased the amount of time spent in enclosures, and increased consumption of scented food pellets. Females were more responsive than were males, and higher concentrations of CS_2 were relatively more attractive to mice than were lower concentrations. These findings are consistent with the notion that CS_2 is an attractant for mice, as it is to rats (*Rattus norvegicus*) (Galef et al. 1988).

Experiment 2 directly tested our hypothesis that higher concentrations of CS_2 were more

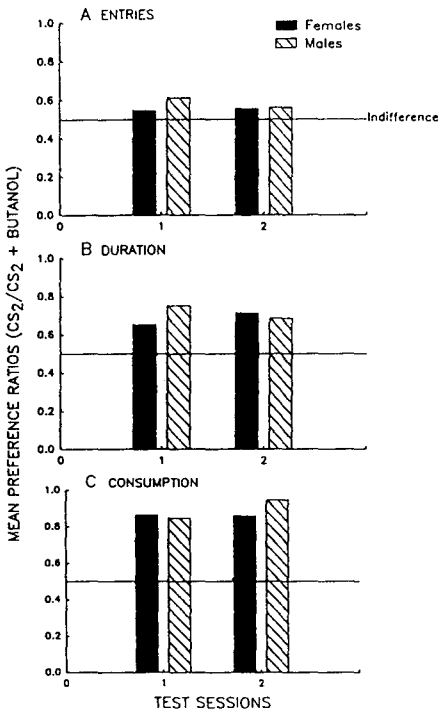

Fig. 4. Number of house mouse entries into bait enclosures (A), durations in enclosures (B), and consumption (C) expressed as mean preference ratios comparing CS_2 and BuOH (CS_2 responding/[CS_2 + BuOH responding]) (session 1: 10-ppm CS_2 vs. 1-ppm BuOH, session 2: 10-ppm CS_2 vs. 10 ppm BuOH).

attractive to mice than lower concentrations. The results were consistent with those of experiment 1; females were more responsive to CS_2 than were males. Higher concentrations of CS_2 elicited more entries into bait enclosures, longer duration visits to bait enclosures, and greater consumption of food than did lower concentrations of CS_2.

Experiment 3 addressed the possibility that a novel odor (not just CS_2) might increase attractiveness of food pellets to mice. Results showed that, relative to BuOH, CS_2 increased entries into bait enclosures, durations of visits to bait enclosures, and consumption. The possibility always remains that other untested odors may be as attractive to mice as CS_2. Regardless, our findings are consistent with the view that CS_2 in particular, not novel odors in general, are attractive to mice. When considered together with the results of the other studies (Galef et al. 1988), our results suggest that CS_2 is an endogenous, biologically meaningful odor to rodents that increases attractiveness of foods to which it is applied.

MANAGEMENT IMPLICATIONS

Carbon disulfide acts as an attractant to rats (Galef et al. 1988) and mice. Moreover, scenting a food with CS_2 enhances consumption of that food by mice. Hence we speculate that application of CS_2 could enhance effectiveness of rodenticide bait formulations to which it is applied. The odor of CS_2 also produces increased entries into areas where it is present. Application of CS_2 may, therefore, increase effectiveness of traps and tracking powders by increasing investigation of these devices and materials by mice.

Carbon disulfide may increase effectiveness of poison baits in ways that extend beyond simple enhancement of initial intake. Results of 4 recent sets of experiments (Galef 1986*a*,*b*; Galef et al. 1988) indicate that experience of the smell of a diet, either on the breath of a conspecific or in association with CS_2, interferes with rats' ability to acquire a subsequent aversion (bait-shyness) to that diet. Thus, it is possible that presence of CS_2 in a bait may not only increase initial consumption of that bait, but also may increase the probability that an individual eating a sublethal dose of bait on a first visit to a bait station will return for a second visit.

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COYOTE FOODS IN A CONIFEROUS FOREST IN OREGON

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Abstract: The dominant food items in 844 coyote (*Canis latrans*) scats from Oregon's Cascade Range were fruit, rodents, large ungulates, and hares. Diets changed by season in response to prey availability. Black-tailed deer (*Odocoileus hemionus*) and showshoe hares (*Lepus americanus*) dominated the winter diet. Rodents and hares, fruit and rodents, and black-tailed deer and rodents, dominated spring, summer, and fall diets, respectively. Many coyote food items were species associated with clearcut areas. The variety of animal prey used by coyotes was lowest in fall and winter and highest in the spring. Mean size of animal prey consumed by coyotes was smallest during summer and largest during fall and winter.

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Although coyote diets have been studied (Beckoff 1982), few studies have been conducted in coniferous forest habitats and none in the Cascade Range of Oregon and Washington where coyotes were rare or nonexistent until timber wolves (*Canis lupus*) were extirpated around 1930 (Bailey 1936, Young and Goldman 1944). Because range expansions by coyotes may lead to changes in populations of prey as coyotes compete for resources, the role of coyotes in these habitats should be assessed. We report the seasonal diets of coyotes in a coniferous forest and discuss implications relative to coyote management and timber harvest practices.

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STUDY AREA

Our study was conducted in Oregon's Cascade Mountain Range, in the Willamette National Forest about 55 km east of Eugene, Lane County, Oregon. Terrain was dissected by drainages of the North Fork of the Middle Fork Willamette River. Elevations ranged from 500 to 1,500 m. Climate was typical of the Western Cascade maritime area with mild, wet winters and warm, dry summers. Precipitation occurred about 160 days/year and averaged 150 cm annually. Annual temperature extremes ranged from −18 to 38 C. Mean annual snowfall averaged 163 cm (Lahey 1979).

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