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Source: Journal of Wildlife Diseases, 34(1) : 13-22

Published By: Wildlife Disease Association

URL: https://doi.org/10.7589/0090-3558-34.1.13

Journal of Wildlife Diseases, 34(1), 1998, pp. 13–22

RESPONSES OF CAPTIVE AND FREE-RANGING COYOTES TO SIMULATED ORAL RABIES VACCINE BAITS

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ABSTRACT: The objective of this study was to develop a bait for delivering an oral rabies vaccine to free-ranging coyotes (*Canis latrans*) in southern Texas. Captive trials were conducted from January to April, 1994, to determine bait preferences and behavioral responses of coyotes (n = 42) to selected baits and attractants. Baits were hollow rectangular cubes made of polymer dog food or fish meal. Attractants had sweet (watermelon), fruity (raspberry), sulfurous (synthetic W-U), and lard (beef lard) fragrances. Captive coyotes did not exhibit a preference for either bait bases or attractants; however, coyotes chewed dog food baits 1.6 times more than fish meal baits. Average proximity of coyotes eliciting a response to baits was 2.2 ± 1.3 m ($\bar{x}$±SE). Captive coyotes readily accepted dog food baits containing 2 ml of liquid rhodamine B, a biological marker. Rhodamine B staining of the oropharyngeal region was evident in each captive coyote. Results from the field evaluation of baits and attractants were consistent with that of the captive trials. Of 2,070 bait station-nights conducted from February to April, 1994, coyotes comprised the greatest single species visitation and uptake rates with 31% and 28%, respectively. Bait uptake rates of free-ranging coyotes did not differ among bait-attractant combinations. Coyotes took baits 93% of the time they encountered a bait, regardless of bait type.

Key words: Baits, *Canis latrans*, coyote, preference, rabies, vaccination program.

INTRODUCTION

Rabies in coyotes (*Canis latrans*) was reported only sporadically in southern Texas until 1988. Subsequently, an ecotypically distinct variant of rabies virus, which had been previously reported in urban dogs (*Canis familiaris*), became established in the coyote population along the border of the United States and Mexico (Clark et al., 1994). In 1988, 17 cases of canine rabies were reported in Starr and Hidalgo counties, Texas (USA; Clark et al., 1994). The number of cases of canine rabies in these border counties increased to 40 and 34 in 1989 and 1990, respectively. During 1991, the epizootic rapidly expanded approximately 160 km northward to encompass a 10-county area, resulting in 42 confirmed rabies cases involving coyotes. By 1993, 13 southern Texas counties reported 133 confirmed rabies cases, and 153 human exposures (Clark et al., 1994). Presently, this rabies endemic area in Texas incorporates the area south from Corpus Christi north to San Antonio and west to Del Rio.

Typically, human exposure to rabid wild animals is minimal (Sikes, 1981). However, in southern Texas a broad and abundant food base allows coyotes to maintain high population densities (Knowlton, 1964; Andelt, 1985). Coyote densities in southern Texas were estimated from about 0.2 to 2.3/km^2 (Knowlton, 1972). This large coyote population served as a reservoir of rabies, which increased exposure to unvaccinated domestic dogs. This, in turn, has increased exposure to humans. In 1993, domestic dogs accounted for only 32% of the total rabies cases reported in southern Texas, yet they caused 81% of the human exposures (Clark et al., 1994). A lack of concern by the public about vaccinating their pets for rabies further increased the potential for human exposure. By January 1994, the epizootic had resulted in 2 human deaths, and approximately 1,400 rabies exposures in which prophylactic treatment was required (Meehan, 1995).

To investigate potential methods of halting the northward progression of the rabies epizootic and reduce the human health risk, the Texas Department of Health (Austin, Texas, USA) requested that a study be conducted to evaluate the effectiveness of oral vaccination of coyotes. Similar vaccine programs have been suggested for raccoons (*Procyon lotor*) in the northeastern United States (Hadidian et al., 1989), red foxes (*Vulpes vulpes*) in Canada (Bachmann et al., 1990), and mongooses (*Herpestes javanicus*) in the West Indies (Creekmore et al., 1994). An ideal bait for distributing and administering the rabies vaccine to free-ranging coyotes must be able to (1) attract and be consumed by the target species, (2) be species specific, (3) elicit a chewing response rather than swallowed intact because the liquid vaccine must be absorbed into the buccal mucosa in order to be effective, (4) withstand the impact from an aerial drop, (5) insulate the vaccine from solar radiation, and (6) have an acceptable cost for development and use (Wandeler et al., 1988).

Much research has been conducted on coyote baits and odor attractants, primarily to control coyote depredation (Linhart et al., 1968; Tigner et al., 1981; Roughton, 1982; Turkowski et al., 1983; Guthery et al., 1984). Past research indicated that coyotes chewed baits that contained fat more than baits made of meat (Tigner et al., 1981). Teranishi et al. (1981) reported that the addition of a sucrose solution to baits provoked a chewing response in coyotes. Turkowski et al. (1983) reported that scatologic, aldeydic, and fishy fractions evoked the greatest responses from coyotes whereas fruity, sulfurous, and sweaty fractions ranked lower. Guthery et al. (1984) reported that aldehydic, fruity, and scatological baits had high coyote uptake rates. Fagre et al. (1984) developed a synthetic attractant (W-U lure) which elicited a greater response from captive coyotes than other synthetic attractants. Although incorporation of odors into a bait may increase its attractiveness, coyotes took baits >85% of the time regardless of the bait type (Linhart et al., 1968; Guthery et al., 1984). Our objectives were to determine bait preference among captive and free-ranging coyotes, and to determine behavioral responses of coyotes to selected baits.

MATERIALS AND METHODS

Study areas

Bait preference of captive coyotes was evaluated at the South Pasture Facility of Texas A&M University-Kingsville (Kleberg County, Texas, USA; 27°27′N, 97°53′W), from January to April 1994. A coyote kennel consisting of 9 1.2 × 2.4 m pens with concrete floors, chain link walls, and tin roof was constructed along the periphery of a 0.81 ha enclosure. The exterior enclosure was constructed of V-mesh fencing 3 m above ground and 1 m buried below the soil surface. To assist in returning a coyote to its pen after a trial, a funnel-shaped drive fence constructed of 1.3-m-high chicken-wire was erected. An observation blind was constructed 7 m from the front of the kennels on a 2 m tall platform. All vegetation within the enclosure >0.25 m tall was removed to ensure an unobstructed view of coyote behavior.

Bait preference of free-ranging coyotes and non-target species was assessed on the Santa Gertrudis Division of the King Ranch (Kleberg County, Texas, USA; 27°25′N, 97°56′W), from February to April, 1994. The privately owned ranch consists of rangeland and is used primarily for cattle grazing and oil production. Predominant vegetation includes honey mesquite (*Prosopis glandulosa*), blackbrush (*Acacia rigidula*), Texas prickly pear (*Opuntia lindheimeri*), whitebrush (*Aloysia lycioides*), and spiny hackberry (*Celtis pallida*). Mammals occurring on the study area include coyotes, white-tailed deer (*Odocoileus virginianus*), javelina (*Dicotyles tajacu*), feral hogs (*Sus scrofa*), raccoons, bobcats (*Felis rufus*), armadillos (*Dasypus novemcintus*), striped skunks (*Mephitis mephitis*), eastern cottontail rabbits (*Sylvilagus floridanus*), black-tailed jack rabbits (*Lepus californicus*), eastern woodrats (*Neotoma floridanus*), hispid cotton rats (*Sigmodon hispidus*), and domestic cattle (*Bos* spp.).

Captive trials

Based on ideal bait characteristics and past research on coyote bait development (Roughton, 1982; Turkowski et al., 1983; Fagre et al., 1984; Guthery et al., 1984), two bait types and four attractants were assessed. The baits were hollow rectangular cubes made of either polymer dog food or fish meal (Bait Tech, Orange, Texas, USA). Due to differences in the manufacturing process, dog food and fish meal baits also differed in hardness, which may have represented a confounding variable between bait types. The baits were 5 × 3.3 × 2-cm in size with a 9 × 23-mm hole through the center. The 4 attractants, representing sweet, fruity, sulfurous, and lard odors, were watermelon extract (Aldrich Chemical Co., Milwaukee, Wisconsin, USA), raspberry extract (Medallion International Inc., North Haledon, New Jersey, USA), W-U (J-T Eaton and Co. Inc., Twinsburg, Ohio, USA), and beef lard (H.E.B. stores, San Antonio, Texas, USA), respectively. Each of the attractants (10% by volume) was incorporated into a heated mixture consisting of 60% beef lard and 30% paraffin wax. The hollow center of each bait was then filled with the attractant-lard-wax mixture and allowed to harden.

Fifty-four coyotes were captured by Animal Damage Control (ADC; San Antonio, Texas, USA) personnel using soft catch number 3 leg-hold traps and snares equipped with safety stops to reduce injury. Coyotes were placed individually in the kennels at the South Pasture facility and were given canned dog food (Old Roy, Walmart, Inc., Bentonville, Arkansas, USA) daily and water *ad libitum.* Each coyote was allowed a 3 to 5 day acclimation period.

Bait preference trials consisted of a dog food and a fish meal bait being placed at the front of the kennel approximately 10 cm apart. Bait order was random for each trial. Coyotes were observed from a blind for up to 1 hr to assess their response to the baits. Trials were repeated 5 times for each coyote to assess bait fidelity. Coyote behavior during each trial was videotaped with a variable speed power zoom camcorder. Data collected during each trial included time elapsed for a coyote to approach the bait (min), time coyote was in contact with bait (sec), time elapsed chewing a bait (sec), number of sniffs, number of chews, and bait choice. Bait choice was determined by the order of bait consumption. A bait that was consumed first received a rank of one, a bait that was consumed second received a rank of two, and a bait that was not consumed within the 1 hr observation period received a rank of three.

Captive coyotes were used to assess attractant preference in combination with dog food baits. Each attractant was incorporated into the lard-wax mixture as previously described. Two different randomly selected bait-attractant combinations were placed into each coyote kennel. Coyotes were then observed for up to 1 hr as previously described in the bait preference trials section. Each coyote encountered a bait-attractant combination only once to ensure that habituation did not occur. Data collection followed the procedures as outlined for the bait preference trials.

Captive coyotes were used to assess coyote proximity to a bait to elicit bait detection. The 4 attractants were incorporated into the attractant-lard-wax mixture and allowed to harden in the center of dog food baits. A 2 m wide swath approximately 30 m from the coyote kennel was cleared of vegetation and raked smooth. Two bait stations were spaced 30 m from each other within the cleared swath and were equidistant from the coyote kennel entrance. Bait stations consisted of a 1 m circular plot of sifted soil. A dog food bait with one of the four attractants incorporated into its hollow core was randomly placed in the center of a bait station. The other bait station was used as a control plot (no bait-attractant) to test for a difference between visual and olfactory cues by coyotes. Proximity trials were conducted under similar weather conditions; no precipitation, cloud cover <50%, and wind speed <4.8 km/hr to minimize potential biases of enhanced odor detection. Coyotes were released individually into the pasture and allowed to roam freely for up to 1 hr. Coyotes were observed from a blind to assess their response to the baits. The distance from where a coyote changed its behavior pattern from roaming to bait detection was recorded and measured to the nearest decimeter. Coyotes were then returned to their kennel at the end of the trial. Trials were repeated 4 times for each coyote; a different bait-attractant combination was used for each trial.

Evaluation of vaccine delivery

After the completion of the bait and attractant preference and proximity trials, each coyote was given one bait that contained a 2 ml sachet filled with rhodamine B (Sigma Chemical Co., St. Louis, Missouri, USA). The rhodamine B sachet was inserted into the hollow core of each bait to mimic the vaccine. The rhodamine B dosage was 342 mg/bait, or 30 mg/kg of body mass, based on the mean mass of coyotes from southern Texas (11.3 kg coyote; Knowlton, 1972). The ends of the hollow bait were then sealed with the attractant-lard-wax mixture. The presence of rhodamine B is readily assessed by discoloration of fur and skin and by fluorescence under ultraviolet light, and has been successfully used as a non-quantitative marking method for coyotes (Johns and Pan, 1981). After consumption of the bait, each coyote was euthanized and then examined for rhodamine B staining of the mouth, oropharynx, esophagus, and stomach. An ultraviolet light that enhanced the visual examination of each oral tract was used to reveal rhodamine B florescence. Quantification of the amount of dye that a coyote received was not performed.

Bait insulation property

Ten dog food and fish meal baits were made, each containing a 2 ml sachet filled with distilled water. The tip of a 90 cm long wire temperature probe was sealed inside the 2 ml sachet. The water-filled sachet was inserted into the hollow core of each bait and the ends of the hollow bait were sealed with the lard-wax mixture previously described. Baits were maintained at room temperature for 24 hr prior to the onset of a trial. Dog food and fish meal baits were placed in a drying oven maintained at 38 C. Each probe leading from the water-filled sachet was connected to a digital dual channel thermometer (Fisher Scientific, Pittsburgh, Pennsylvania, USA) and the temperature of the water within the sachet was recorded at 15 min intervals for 2 hr. Time elapsed for the lard-wax plug to melt was noted.

Field evaluation of baits and lures

Bait preference of free-ranging coyotes and non-target species was assessed using bait station transects as described by Linhart and Knowlton (1975) during February and April 1994. Ten transects were established along non-paved, limited-use roads. Each transect line was ≥3.2 km apart and consisted of 9 bait stations located at 0.81-km intervals on alternate shoulders of the road. Each station consisted of a 1 m circular plot of sifted soil that was cleared of vegetation. One of the eight bait-attractant combinations or a control plot was randomly assigned to each of the nine stations. Baits and the control plot were rotated in a cross-over design among the nine stations in each line. The stations were checked once every 24 hr for 27 days, and tracks left by an animal on the station were identified and recorded. Soil on each bait station was resifted daily. Additional behavioral responses such as digging, urinating, and defecating on the stations by target and non-target species and the presence and behavior of imported red fire ants (*Solenopsis invicta*) were recorded. Visitation rates (the ratio of visited stations to the number of operable station nights) were calculated for each bait-attractant combination as outlined by Roughton and Bowden (1979). If multiple species visited a station, bait disappearance was attributed to each species (Andelt and Woolley, 1996).

Statistical approach

A completely randomized design was used for preference trials on captive and free-ranging coyotes and for bait proximity trials. We used a completely randomized design with repeated measures to test for differences between insulation properties against temperature on bait type. Distributions of residual errors were tested for normality using the Shapiro-Wilk test (Neter et al., 1990). Non-normal datasets were log-transformed ($\log_{10}$) and retested to ensure that criteria for parametric statistical tests were met. Homogeneity of variances was verified with the Bartlett's test (Steel and Torrie, 1980). The effects of bait type (polymer dog food or fish meal) on coyote behavioral responses were tested using Student t-tests. General linear analyses of variance were used to test the effects of attractants on coyote behavioral responses and bait detection distances by coyotes, test for differences between main and interactive effects of temperature and time on bait type, and test the effect of bait-attractant combinations on the visitation and uptake rates of target and non-target species (PROC GLM; SAS Institute Inc., 1989). Multiple comparisons were made using the protected least significant difference procedure when a significant F-test occurred (Ott, 1993). All tests were considered significant at $P \leq 0.05$. Descriptive statistics are reported herein as the mean ± 1 standard error ($\bar{x}\pm$SE).

RESULTS

Captive trials

Of the 54 coyotes captured for the captive trials, 42 remained healthy during the acclimation period and exhibited normal behaviors. During the bait preference trials, coyotes did not exhibit a preference for either the polymer dog food or fish meal baits (Table 1). Differences were not observed ($P > 0.12$) between the two baits in elapsed time, bait time, encounter time, chew time, number of sniffs, or bait choice. However, a difference was noted ($P < 0.01$) between the two bait types in the number of chews. Coyotes chewed the dog food baits 1.6 times more than the fish meal baits. Both bait types were always completely consumed by coyotes during the trials. Bait fidelity was not exhibited by any coyote during the bait preference trials.

Captive coyotes also did not exhibit a preference in the selected attractants (Table 2). Differences were not observed ($P > 0.15$) between attractants in elapsed, bait, encounter, and chew times, number of sniffs and chews, and attractant choice.

TABLE 1. Coyote response (n = 42) to bait (dog food versus fish meal) in captive trials conducted in southern Texas, 1994.

Variable	Dog food bait		Fish meal bait		P[h]
	$\bar{x}$	SE	$\bar{x}$	SE	
Elapsed time[a]	29.10	3.40	22.70	2.90	0.156
Bait time[b]	334.50	174.10	225.40	87.60	0.577
Encounter time[c]	15.70	10.20	101.90	66.30	0.203
Chew time[d]	67.90	14.20	72.00	29.80	0.903
No. Sniffs[e]	0.86	0.21	0.57	0.12	0.247
No. Chews[f]	108.60	12.70	66.50	8.20	0.007
Choice[g]	1.31	0.11	1.20	0.15	0.123

[a] Time elapsed from beginning of trial until a coyote would approach a bait (min).
[b] Time coyote was with a bait (sec).
[c] Time elapsed from first encounter to chewing a bait (sec).
[d] Time elapsed chewing a bait (sec).
[e] Number of sniffs of a bait.
[f] Number of chews of a bait.
[g] Ranked preference of a bait (1 = consumed first, 2 = consumed second, 3 = not consumed).
[h] Calculated using Student t-tests at $P < 0.05$.

Coyote proximity to bait was important ($P < 0.04$) in determining whether they encountered a bait; however, coyote proximity only varied between stations with baits and control stations (no baits). Differences ($P > 0.05$) were not noted in coyote proximity that elicited a bait encounter between attractants. Generally, coyotes needed to approach within 2 m of a bait before a response to that bait was evoked. Average proximity to baits that provoked a bait encounter by a coyote was 1.9 ± 1.2, 2.3 ± 1.6, 2.1 ± 1.3, and 2.5 ± 0.9 m for lard, fruity, sweet, and sulfurous attractants, respectively. Coyotes investigated the control stations if they approached within <1 m.

Evaluation of vaccine delivery

Baits containing the 2 ml rhodamine B-filled sachet were accepted and consumed by each coyote. Rhodamine B staining of the tongue, upper palate, oropharyngeal region, and esophagus was evident in all coyotes (n = 42). On occasion some rhodamine B dye squirted from the mouth of coyotes or the sachet when bitten and stained the kennel floor.

Bait insulation property

Dog food baits were a better short-term insulator of the simulated vaccine than fish meal baits. The lard-wax core placed within the fish meal baits completely melted within 60 min after baits were placed in the drying oven; whereas the lard-wax core within the dog food baits required an average of nearly 90 min to completely melt.

Temperature and temperature-time differences were found between bait types ($P < 0.03$ and $P < 0.01$, respectively). Temperatures of the simulated vaccine were similar between bait types up to 15 minutes; however, temperatures became warmer in fish meal baits than in dog food baits during the 30, 45, and 60 min time intervals (Table 3). Temperatures of the simulated vaccine within dog food baits increased after 60 min in the oven and were not different from temperatures of the simulated vaccine within fish meal baits.

Field evaluation of baits and attractants

Of 2,070 bait-station nights, 1,600 bait stations (77%) were visited by some species and 1,327 baits (64%) were missing and presumed eaten. Coyotes comprised the greatest single species visitation and uptake rates during the field transects (Table 4). Coyotes had an overall visitation and uptake rate of 31% and 28%, respectively. However, coyote visitation rates did not differ (P = 0.12) between bait-attrac-

TABLE 2. Coyote response (n = 30) to selected attractants (lard, fruity, sweet, sulfurous) in captive trials conducted in southern Texas, 1994.

Variable	Lard[a] $\bar{x}$	Lard[a] SE	Fruity[b] $\bar{x}$	Fruity[b] SE	Sweet[c] $\bar{x}$	Sweet[c] SE	Sulfurous[d] $\bar{x}$	Sulfurous[d] SE	P[e]
Elapsed time[f]	24.10	4.40	30.60	2.80	22.40	3.90	19.80	4.30	0.345
Bait time[g]	319.40	93.60	414.80	174.50	333.50	115.70	358.60	105.80	0.476
Encounter time[h]	20.60	9.30	40.60	18.70	23.50	10.40	27.40	15.40	0.157
Chew time[i]	70.20	20.30	96.30	30.70	75.10	22.20	65.10	16.40	0.834
No. sniffs[j]	0.82	0.17	0.91	0.30	1.02	0.36	1.21	0.45	0.762
No. chews[k]	111.20	10.60	83.70	16.70	98.60	12.40	134.50	18.10	0.365
Choice[l]	1.63	0.33	2.13	0.43	1.47	0.47	1.40	0.26	0.213

[a] Lard attractants were made with beef lard.
[b] Fruity attractants were made with raspberry extract.
[c] Sweet attractants were made with watermelon extract.
[d] Sulfurous attractants were made with W-U synthetic lure.
[e] Calculated using F-tests at $P < 0.05$.
[f] Time elapsed from beginning of trial until a coyote would approach a bait (min).
[g] Time coyote was with a bait (sec).
[h] Time elapsed from first encounter to chewing a bait (sec).
[i] Time elapsed chewing a bait (sec).
[j] Number of sniffs of a bait.
[k] Number of chews of a bait.
[l] Ranked preference of a bait (1 = consumed first, 2 = consumed second, 3 = not consumed).

tant combinations (Table 4). Coyote visitation rates ranged from 35% for dog food-lard baits to 26% for fish meal fruity-baits. From the total mammalian visitation rate, coyotes comprised 39% of the visits (Table 4). The percent of coyote visits from the total mammalian visitation rate for each bait-attractant combination ranged from 45% for dog food-sulfurous baits to 32% for fish meal-fruity baits.

TABLE 3. Average temperatures of simulated vaccine sealed inside polymer baits with a lard-wax mixture and placed for two hours in a drying oven maintained at 38 C (n = 10).

Time interval (min)	Simulated vaccine temperature (C): Dog food baits $\bar{x}$	Dog food baits SE	Fish meal baits $\bar{x}$	Fish meal baits SE
0	24A[a]	0.2	24A	0.2
15	24A	0.2	26A	0.2
30	26A	0.3	30B	0.4
45	29A	0.4	36B	0.8
60	34A	0.4	38B[b]	0.2
75	36A	0.4	38A	0.0
90	38A[b]	0.1	38A	0.0
105	38A	0.0	38A	0.0
120	38A	0.0	38A	0.0

[a] Means with the same letter are not different ($P > 0.05$) between bait types within a time interval.
[b] Lard-wax sealant was completely melted.

Coyote bait uptake rates ranged from 34% for dog food-sulfurous baits to 21% for fish meal-fruity baits. However, coyote bait uptake rates did not differ ($P = 0.24$) between the bait-attractant combinations (Table 4). From the total mammalian bait uptake rate, coyotes comprised 44% (Table 4). Percent coyote uptake for each bait-attractant combination from the total mammalian bait uptake rate ranged from 39% for fish meal-fruity baits to 51% for dog food-sulfurous baits. However, the probability that the bait would be missing if coyote tracks were present on a bait station was 93% (Table 4). Of the mammalian non-target species, raccoons took the greatest number of baits, removing 19% and ranged from 16% for dog food-lard to 21% for fish meal-sulfurous and fish meal-sweet baits. However, the probability of a raccoon taking a bait if encountered was 97%. Cattle took 3% of available baits, whereas feral hogs and javelina took 4% and 1%, respectively. Infrequent visitors to bait stations with probabilities of bait uptake <1% included opossum (*Didelphis*

TABLE 4. Visitation and bait uptake rates of 8 bait-attractant combinations by selected mammals calculated from 2,070 bait-station nights conducted in southern Texas, 1994.

	Bait-attractant							
	Dog food				Fish meal			
Species	Lard[a]	Sulfurous[b]	Sweet[c]	Fruity[d]	Lard	Sulfurous	Sweet	Fruity
All mammals								
Visitation[e]	0.788	0.757	0.834	0.741	0.826	0.724	0.782	0.729
Uptake[f]	0.665	0.661	0.626	0.665	0.665	0.630	0.665	0.547
Coyote								
Visitation	0.352	0.344	0.299	0.312	0.317	0.265	0.293	0.255
Uptake	0.330	0.336	0.278	0.288	0.308	0.243	0.277	0.213
Raccoon								
Visitation	0.162	0.180	0.203	0.188	0.192	0.215	0.213	0.203
Uptake	0.159	0.180	0.190	0.182	0.189	0.207	0.207	0.198
Cattle								
Visitation	0.106	0.085	0.187	0.147	0.150	0.077	0.096	0.156
Uptake	0.017	0.016	0.070	0.041	0.030	0.028	0.037	0.021
Feral hog								
Visitation	0.070	0.050	0.048	0.047	0.042	0.044	0.037	0.052
Uptake	0.059	0.034	0.035	0.032	0.036	0.033	0.032	0.026
Javelina								
Visitation	0.003	0.019	0.016	0.006	0.018	0.028	0.011	0.005
Uptake	0.003	0.016	0.016	0.002	0.018	0.028	0.011	0.005
Other mammals[g]								
Visitation	0.095	0.079	0.080	0.102	0.107	0.095	0.132	0.084
Uptake	0.095	0.079	0.037	0.041	0.084	0.091	0.101	0.058
Percent coyote visitation[h]	44.7	45.4	35.8	42.1	38.4	36.6	37.5	32.2
Percent coyote uptake[i]	49.9	50.8	44.4	43.3	46.3	38.6	41.6	38.9
Probability of coyote uptake[j]	94.3	97.7	93.0	92.3	97.2	91.7	94.5	83.5

[a] Lard attractants were made of beef lard.
[b] Sulfurous attractants were made of synthetic W-U lure.
[c] Sweet attractants were made of watermelon extract.
[d] Fruity attractants were made of raspberry extract.
[e] Visitation rate based on the percentage of total operable bait stations that were visited by each species.
[f] Bait uptake rate based on the percentage of baits taken by each species from the total operable bait station-nights.
[g] Other mammals include opossum, skunk, bobcat, white-tailed deer, eastern cottontail, black-tailed jackrabbits, and badger.
[h] Percentage of coyote bait station visits from the overall mammalian visitation rate for each bait-attractant combination.
[i] Percentage of coyote uptake of each bait-attractant combination from the total mammalian bait uptake rate.
[j] Probability of a coyote taking a bait-attractant combination, if the coyote encountered the bait.

virginiana), skunk, bobcat, wild turkey (*Meleagris gallopavo*), white-tailed deer, eastern cottontail, black-tailed jackrabbit, badger (*Taxidea taxus*), and birds.

DISCUSSION

Although coyotes did not exhibit a preference between polymer dog food and fish meal baits, dog food baits had several desirable characteristics that made them superior to fish meal baits. Due to the differences in bait manufacturing, the comparative hardness of the dog food baits was nearly twice that of the fish meal bait. This, in turn, caused the dog food baits to be chewed nearly twice as much as the fish meal baits. For the vaccine to be effective, it must be absorbed into the buccal mucosa (Rupprecht et al., 1989). Therefore, a direct correlation may exist between the number of chews, rupture of the vaccine sachet, and the amount of vaccine received. If true, then a harder bait eliciting a stronger chewing response is desirable. Because the rabies vaccine is heat sensitive (Brochier et al., 1990), a bait that protects the vaccine from extreme temperatures is preferable. Dog food baits provided longer protection in a heated environment than did fish meal baits, which may be a function of the hardness and lighter color of dog food baits. However, the lard-wax core eventually melted in both bait types, suggesting that bait applications should be conducted during cooler seasons of the year to minimize heat-related problems. Although anecdotal, dog food baits also appeared superior in their ability to withstand moist environmental conditions. In contrast, the fish meal baits during the field evaluation quickly became soggy and moldy when exposed to rain or high (>80%) humidity. This appeared to reduce coyote acceptance of fish meal baits. However, as technology of bait manufacturing improves, a harder fish meal bait may render these advantages obsolete.

No definite choice was apparent of the attractants tested. Data from the proximity trials suggest an olfactory component is used by coyotes for the detection of food items. However, the addition of attractants to the baits did not increase uptake rates or increase the proximity from which a bait was detected. Therefore, the additional cost of adding an attractant to baits did not seem justified based on captive trial data.

If it is assumed that a coyote will become immunized regardless of the quantity of vaccine received in the mucosa of the oropharynx, then we believe that the vaccine delivery system worked satisfactorily. All captive coyotes readily accepted baits and broke open the sachets containing rhodamine B, which contacted the target area of the animal needed for vaccine absorption. However, quantification of the amount of liquid reaching the buccal mucosa was not evaluated. If future research indicates that a specific quantity of vaccine is needed to immunize a coyote, then quantification of the vaccine delivered by this method will be required.

Free-ranging coyotes did not exhibit a definitive preference for any of the bait-attractant combinations. However, dog food-sulfurous and dog food-lard produced the greatest visitation and uptake rates, whereas fish meal-fruity was the least accepted. Results from our study concur with Linhart et al. (1968) and Guthery et al. (1984), who reported that coyotes took baits >85% of the time regardless of bait type. Although bait-attractant combinations tested in our trials were not species-specific, coyotes did represent the species with the greatest visitation and uptake rates, whereas raccoons accounted for the majority of bait-takes by non-target species in southern Texas.

The results of the field evaluation are consistent with our captive trial data. Among free-ranging coyotes, dog food-lard baits had superior or equal visitation and uptake rates in comparison to each tested bait-attractant. Dog food-lard baits also had the lowest rate of bait uptake by raccoons. Lower rates of bait uptake by the dominate non-target consumer could possibly allow increased bait availability for coyotes.

This study demonstrates that delivery of a bait containing an oral vaccine to coyotes is feasible. However, ingestion of a vaccine-laden bait does not indicate successful immunization. Therefore, before any conclusions as to the ultimate value of this baiting system can be determined, further studies of coyote immunoconversion resulting from consumption of a vaccine-bait are necessary.

ACKNOWLEDGMENTS

The authors thank the Texas Department of Health for financial support and Texas Animal Damage Control Service for financial assistance, personnel, and equipment. Appreciation is extended to J. Young, R. Sramek, L. Vetterman, R. Johnson, M. Acklin, B. Everet, A. Combs, G. Kraatz, J. Eichman, F. Whitely, and D. Brown for technical assistance. We also thank A.M. Fedynich, F. S. Guthery, and S.L. Beasom for comments on an earlier draft of the manuscript. The use of live animals in this study was approved by the Animal Use and Care Committee, Texas A&M University-Kingsville, Kingsville, Texas, USA. This is contribution manuscript number 91-121 of the Caesar Kleberg Wildlife Research Institute.

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Received for publication 3 October 1996.