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Laboratory Evaluation of some Additive Poison Baits for Controlling Commensal and Field Rodents

AMJAD PERVEZ
Vertebrate Pest Control Institute, Southern-zone Agricultural Research Centre, Pakistan, Agricultural Research Council, P.O. Box 8401, Karachi University Campus Karachi-75270, Pakistan

Abstract.- Laboratory studies were conducted to explore the potential of various additives for enhancing bait acceptance against commensal rat *(Rattus norvegicus)* and field rodents *(Bandicota bengalensis* and *Nesokia indica).* Whole egg, milk, yeast, fish meal and minced meat (beef) were incorporated at 3% (w/w) and 5% (w/w) individually. Under no-choice test, the rat species showed a variable level of liking for minced meat, yeast, fish meal and egg baits over plain bait. Under paired choice test, *R. norvegicus* preferred egg bait 64.96% and 62.97% in 3% and 5% combinations over plain bait. Similar pattern of preference for egg bait was recorded in *B. bengalensis i.e.* 58.61% and 54.23% and *N. indica* 46.20% and 57.20% in 3% and 5% combinations respectively. Under multiple choice tests, egg was emerged as the top-preferred candidate. In case of *R. norvegicus,* egg bait (3%) containing brodifacoum and bromadiolone (0.005% each) significantly enhanced the bait intake (68.21% and 60.09% respectively) compared with non- additive poison bait. Under *B. bengalensis* and *N. indica,* egg mixed brodifacoum *(0.005%)* significantly increased bait acceptance in rats (79.81 % and *60.59%)* over poison bait without additive. A prominent preferential trend was also noted in egg additive bromadiolone baits (58.92% and 50.30%) in both the field rats. It is therefore, concluded that egg additive in poison bait can be helpful in enhancing poison bait acceptance by commensal and field rodents.

Key words: Bait additives, brodifacoum, bromadiolone. commensal rat, field rats, palatability.

INTRODUCTION

Rodent pests, both commensal and field species pose a serious threat to stored food, field crops and human health. The economic losses due to rats on world wide basis have been reported to 33 million tonnes annually of bread grain and rice in storage (Jackson, 1977). It has been estimated that 130 million people could be fed each year with the food spoiled by world's rat population (FAO, 1999).

The Norway rat *(Rattus norvegicus* Berkenhourt) is a serious commensal rodent pest and is mainly confined to the coastal areas of Pakistan, though its presence has been reported from inner cities possibly through goods transportation (Hussain, 1998). *R. norvegicus* is also a serious threat to human and livestock health by transmitting infectious diseases like plague, dysentery, Japanese encephalitis, West Nile and Zika (Darwish *et al*., 1983).

The lesser bandicoot rat *(Bandicota bengalensis,* Gray) is endemic to the Oriental region and occurs throughout the Indo-Pakistan sub-continent and south-east Asia (Roberts, 1997). In Pakistan, it is a predominant field rodent and inflicts severe damage to wheat, rice, sugarcane and fodder crops (Beg *et al.,* 1980; Fulk *et al.,* 1981). *B. bengalensis* is well known for hoarding cereal grains in burrows (Fulk, 1977). It is also of considerable public health importance because of its association with plague (Bhatnagar, 1969).

The short-tailed mole rat *(Nesokia indica* Gray) is largely a palearctic rodent pest and inflicts extensive damage to wheat, rice and sugarcane crop in different agroecological zones of Pakistan (Greaves *et al.,* 1975; Ali *et al.,* 1984). It also causes considerable losses to irrigation water through burrowing in the banks of canals and water courses (Shafi *et al.,* 1992).

Although several methods are being used worldwide to minimize losses caused by rodents, but the most effective method is considered to be poison baiting. The development of bait shyness to acute rodenticides (Sterner, 1994) and resistance in case of anticoagulants (Greaves, 1994) are the main drawbacks in war against rodents. The discovery of the second generation anticoagulants *i.e.*

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brodifacoum and bromadiolone helped to overcome the problem of resistance to the first generation anticoagulants in several countries (Ashton and Jackson, 1984). But resistance (reduced susceptibility) to the second generation anticoagulants has also been reported in certain localities in Europe and elsewhere (Greaves *et al.,* 1982; Buckle, 1994).

Although several studies (Hausmann, 1932; Barnett, 1956; Shumake, 1978; Mathur *et al.*, 1992) have been reported on food preference in rats in view of their complicated behaviour yet, none of these authors attempted to work on bait enhancement study through incorporating various bait additives. Shafi *et al.* (1992, 1993) and Pervez *et al.* (2000, 2003) attempted to improve bait acceptance in some economically important pest species of rats. Present study was aimed to give a comparison of laboratory evaluation of various additives in poison baits for effective control of commensal and field rodents of Pakistan.

MATERIALS AND METHODS

Collection of rats

Norway rat, *Rattus norvegicus* used in the trials were live-trapped from the Empress Market, Karachi (280 40' N, 670 5' E*)* which deals in meat, fish, vegetables, dry and fresh fruits, poultry and groceries. Local made metallic traps measuring 33cm x 12cm x 10cm baited with pieces of fresh apple, guava, melon and onion were set in the evening and collected the following morning between 6.00-9.00 a.m. Traps were placed in the best localities to catch the rats. The fields rodents *i.e*. *B. bengalensts* and *N. indica* were live captured by the locally made live traps or by digging burrows in rice and sugarcane fields in the Thatta district, lower Sindh (24° 45' N, 67° 55 E), Pakistan. The traps baited with pieces of guava, melon onion were set in the evening and retrieved in the followed morning.

Acclimation of rats

The rats, on the arrival in the laboratory, were sexed and individually caged for acclimation for three weeks before undertaking various tests. Pregnant and lactating females and sub-adult were discarded. The rats were fed on laboratory diet containing wheat, rice, maize and fishmeal in a ratio of 33: 32.5: 32.5:2 respectively, before and between the various tests. Water was provided *ad libitum.*

Design of experiments

Following acclimation of rats, the experiments were designed as (i) No-choice tests, (ii) Free choice tests, (paired-choice and multiple feed choice test) and (iii) Poison bait acceptance test of brodifacoum and bromadiolone (0.005% each) with and without additives.

Under no-choice, paired choice, multiple choice and poison bait acceptance tests, 10 rats (5 male and 5 female) were caged singly to perform the tests. The weights of the rats were recorded before the start of each test. Each bait, weighing 50g was offered daily in especially designed metallic feeding cups having 28.5 cm circumference. The left-over bait and spillage were weighed to calculate mean daily consumption at accuracy of±0.1 g. Each day fresh bait was offered and the left over was discarded due to urine and faecal contamination by the rats. The positions of feeding cups were exchanged daily to avoid any place preference trend. Each test lasted for 5 days except poison bait acceptance test that ran for 3 days. A three-day rest period was maintained between various tests to nullify the previous feeding effects.

For the poison bait acceptance test, 10 rats (five of either sex) were offered poison bait with and without additives for three days. Although single dose poisons require only I-day feeding but 3-day feeding period was maintained following Shafi (1991).

Preparation of baits

The tests baits were prepared containing wheat flour and broken rice in equal quantities as bait base alongwith additives at 3% and 5% (w/w), respectively. Whole egg (fresh), milk (powder), yeast (powder), minced meat (powder) and fishmeal (powder) were used as bait additives. The poison bait containing brodifacoum (2.5% master mix by Kukbo Pharma Co., Korea) was prepared by mixing broken rice, wheat flour, additives (3% and 5%) and poison in a ratio of 46.0:46.0:3:5 and 45.0:45.0:5:5, respectively. Likewise, the bait containing bromadiolone (0.25% master mix by LIPHA of Lyone, France) was prepared with a mixture of wheat flour, broken rice, additives (3% and 5%) and poison in a ratio of 47.5:47.5:3:2 and 46.5:46.5:5:2, respectively. For comparative evaluation, poison bait without additives was prepared with a mixture of wheat flour, broken rice and poison in a ratio of 49.0:49.0:2, respectively.

The above mentioned materials were blended in an electric mixing machine adding enough water until a stiff dough was formed. Small pellets were prepared using an electric meat mincing machine with a sieve of 11 mm. diameter. Baits were fan-dried and stored in plastic bags.

Data analysis

Mean food consumption data was analyzed by one way analysis of variance (ANOVA) as outlined by Steel and Torrie (1984). Sex-wise bait intake values were pooled in the tables. Mean consumption values among various bait parameters were compared by Fisher's LSD test using Minitab Software Program. The 95% level of significance was used in all the tests. Percentage preference values for additive were calculated by dividing test food by total food consumption and then multiplying by 100 following Shafi *et al.* (1992, 1993).

RESULTS

No-choice test

This test was performed to determine the potential for preference of treated baits over plain bait when offered separately to rats before undertaking regular tests (Table I).

For *R.. norvegicus*, overall baits consumption among different baits remained significantly different both at 3% (F=14.26, df =1,16; P< 0.05) and 5% combinations (F=13.19; df 1,16; P< 0.05). Individual means comparison through LSD test showed non-significant difference among yeast, minced meat, fishmeal and egg baits over plain bait, however, intake was the lowest in case of milk bait. Under 5% (w/w) minced meat bait was sampled the most, however, the individual means separation remained non-significant among yeast, fishmeal and egg against the plain. A significant difference in intake was noted in fishmeal (high) and milk (low) against the remaining four baits.

In case of lesser bandicoot rat, *B. bengalensis*, pooled analysis of variance showed significant difference in consumption among the baits offered at 3% (F= 2.49; df=I,16; P< 0.05) and 5% (F= 4.15; df =1,16; P< 0.05) combinations. Mean separation by LSD test showed that in 3% formulations non-significant difference among all additive baits was noted, however, the difference was found significant over the consumption of plain bait. Under 5% (w/w) baits containing egg, fishmeal, minced meat and yeast showed non significant difference among each other, however intake of these four baits was recorded significantly higher as compared to the milk and plain baits.

Under short-tailed mole rat, *N. indica*, combined analysis of variance test showed significant difference in consumption among offered baits in 3% (F= 5.31; df = 1,16; P< 0.05) and 5% combinations (F = 13.10; df = 1,16; P< 0.05). In case of 3% (w/w) the individual mean separation through LSD test revealed that all additive baits were found non-significant except plain, which was least consumed. Under 5% (w/w), bait intake of milk, yeast, fishmeal and egg baits were similar, but these baits were consumed significantly more than the minced meat and plain baits.

Paired choice test

Under this test, mean daily consumption and percentage preference of additives baits over the plain as an alternative was individually examined (Table II). For *R. norvegicus* in 3% (w/w) bait combinations, percentage preference of egg bait over the plain bait was recorded 64.96% and remained top-preferred over all other combinations. Similar pattern of preference was noted in 5% (w/w) bait combination. Egg bait was the top-preferred candidate (62.97%) followed by milk bait (59.60%).

In case of *B. bengalensis*, results of paired choice test of additives baits versus plain bait combinations are shown in Table II. Bait containing egg was favoured with a mean preference of 58.61% and 54.23% under 3% and 5% combinations respectively. In case of milk vs. plain, mean preference of milk remained 54.48% and 54.09% under 3% and 5% respectively, ranking second in preferential order.

Table I.- Mean (±SEM) daily consumption and percentage preference of *Rattus norvegicus, Bandicota bengalensis* and *Nesokia indica* under no choice test.

Bait additives	No. of rats (M/F)	Body wt. (g)	3% Mean daily consumption (g/kg)	Body wt. (g)	5% mean daily consumption (g/kg)
			Norway rat, *Rattus norvegicus*		
Milk	10(5/5)	287.12±13.12	46.89±2.83b	222.81±4.43	58.34±7.92b
Yeast	10(5/5)	242.84±4.90	59.04±7.38ab	198.9±3.80	63.29±6.82ab
Minced meat	10(5/5)	251.32±12.92	60.78±6.16ab	235.84+5.96	81.67±.8.65a
Fish meal	10(5/5)	247.92±14.39	58.92±4.70ab	621.22±3.75	56.60±6.97b
Egg	10(5/5)	238.41±13)5	61.56±4.40ab	238.26±5.40	67.87±5.06ab
Plain	10(5/5)	278.40±16.87	59.05±8.55ab	199.43±3.48	68.85±5.23ab
			Lesser bandicoot rat, *Bandicota bengalensis*		
Milk	10(5/5)	173.23±8.26	55.27±8.83a	223.60±13.22	39.42±3.18b
Yeast	10(5/5)	279.80±19.61	54.93±4.23a	280.45±21.40	12.66 + 2.95ab
Minced meat	10(5/5)	117.39±1O.42	52.09±3.27Ia	217.57±13.95	46.43±3.62ab
Fish meal	10(5/5)	189.29±13.20	49.66±3.622a	14.33±13.67	46.06±5.78ab
Egg	10(5/5)	216.80±15.24	43.09±2.53ab	246.83±15.80	56.68±2.77a
Plain	10(5/5)	291.17±21.95	35.96±2.41b	299.96±26.07	35.96±.2.41c
			Short-tailed mole rat, *Nesokia indica*		
Milk	10(5/5)	164.19±6.87	75.23±5.28a	130.62±9.20	79.42±3.18a
Yeast	10(5/5)	171.23±6.51	63.46±4.58ab	140.68±10.94	66.86±3.03ab
Minced meat	10(5/5)	173.00±8.25	58.63±3.79ab	173.33±13.12	54.81±2.54bc
Fish meal	10(5/5)	I 64.79±13.00	70.08±2.58a	134.34±8.32	67.04±3.08ab
Egg	10(5/5)	144.17±10.93	68.89±2.62ab	167.78±8.50	75.99±2.77a
Plain	10(5/5)	15 1. 13±9.40	51.14±3.02c	165.09±7.69	51.14±3.02c

Means in columns followed by the same letter (s) are not significantly different at 5% level of probability using LSD test.

Under *N. indica*, unlike *R. norvegicus* and *B. bengalensis* percentage preference of milk (3% w/w) remained at the top (59.93%) while minced meat ranked second (52.00%), However at 5% (w/w), egg additive maintained the top position (57.20%) followed by milk *i.e.* 53.14%. Yeast and fishmeal additives showed lower preference than the plain bait.

Multiple choice tests

The test was performed to confirm or to re-establish the relative rank of most preferred additive candidates (Table III). Under *R. norvegicus,* data of 3% (w/w) mixing of additives showed significant difference in consumption among additive baits and plain bait (F=14.26; df = 1,16; P<0.05) however, it remained non-significant (F=3.36; df = 1,16; P<0.05) under 5% (w/w). Means separation among additives baits under LSD test showed significantly high intake of egg bait over all other additive baits. Egg was the most preferred (53.45%) followed by milk (9.97%) under 3% (w/w). The preference of minced meat additive was noted more (9.09%) over yeast and fishmeal additives. In sampled case of 5% (w/w) egg was at the highest (38.66%) among the offered additives followed by milk (24.04). The preferential order among the remaining additives was recorded different than 3%. Fishmeal additive was favoured (7.16%) over minced meat and yeast.

Under *B. bengalensis*, data of multiple choice tests showed non-significant in intake among additives and plain bait in 3% and 5% combinations. Mean separation using LSD test also showed non-significant (F= 4.35; df = 1,16; P<0.05) in bait consumption. On the average, egg bait was highly preferred (20.59% and 23.86%) in 3% and 5% respectively followed by milk which stood second in competition. Bait consumption data of multiple choice test confirmed that egg additive emerged as top preferred candidate among the additives.

The findings of multiple choice test under *N. indica* showed non significant difference in

Table II.- **Mean (±SEM) daily consumption and percentage preference of *Rattus norvegicus, Bandicoot bengalensis* and *Nesokia indica* under paired choice-test.**

Bait additive	No. of rats (M/F)	Body wt. (g)	3% Mean daily consumption (g/kg)			Body wt. (g)	5% Mean daily consumption (g/kg)		
			Additive	Plain	% Pref. (Add.)		Additive	Plain	% Pref. (Add.)
			Norway rat, *Rattus norvegicus*						
Egg vs plain	10 (5/5)	278.71±31.95	38.08±4.40	20.54±5.21	64.96	231.57±8.32	37.22±8.40	21.88±7.30	62.97
Milk vs plain	10 (5/5)	274.99±26.23	29.72±1.96	23.45±4.43	55.89	211.09±5.S5	48.65±8.25	32.97±8.79	59.60
Minced meat vs plain	10 (5/5)	275.59±16.86	22.71±3.93	34.45±2.92	39.73	227.34±7.38	39.81±4.86	31.87±4.68	55.53
Yeast vs plain	10 (5/5)	273.35±17.75	24.63±2.73	20.83±2.51	54.28	227.27±6.55	41.86±7.28	33.80±6.23	54.31
Fish meal vs plain	10 (5/5)	244.68±17.87	33.25±2.85	40.78±3.00	44.88	220.06±4.65	20.17±5.69	43.76±6.20	31.55
			Lesser bandicoot rat, *Bandicota bengalensis*						
Egg vs plain	10(5/5)	310.27±30.15	28.05±4.75	19.98±3.77	58.61	224.15±11.36	18.82±1.92	15.04±1.43	54.23
Milk vs plain	10(5/5)	281.68±8.99	24.67±1.20	21.84±6.10	54.48	260.81±16.13	17.47±Z15	15.99±1.99	54.09
Minced meat vs	10(5/5)	276.72±17.92	20.60±3.32	20.59±2.66	49.96	269.20±17.25	20.69±2.48	20.53±2.22 '	50.37
Yeast vs plain	10(5/5)	281.68±IS.76	18.40±1.95	IS.21±3.60	49.51	227.28±1 1.55	18.65±2.52	19.76±1.63	48.82
Fish meal vs plain	10(5/5)	312.84±29.87	19.99±3.56	27.S5±4.49	41.43	22S.02±15.54	17.12±1.62	18.19±2.67'	42.10
			Short-tailed mole rat, *Nesokia indica*						
Egg vs plain	10(5/5)	131.62±7.82	34.90±4.31	29.97±2.77	46.20	134.34±8.32	26.16±3.45	19.57±1.57	57.20
Milk vs plain	10(5/5)	150.97±9.43	35.88±4.31	23.99±3.79	59.93	140.68±10.94	22.43±3.27	19.293.47	53.14
Minced meat vs	10(5/5)	198.14±14.08	22.24±2.45	20.56±3.10	52.00	165.09±7.69	15.62±1.33	22.49±1.94	41.00
Yeast vs plain	10(5/5)	171.02±13.16	12.29±2.00	17.33±1.90	46.10	173.33±13.12	15.29±1.41	27.31±4.23	35.89
Fish meal vs plain	10(5/5)	290.27±20.57	18.47±2.44	30.83±2.99	37.46	167. 78±8.50	16.81±*2.08*	29.53±2.97	40.66

consumption among various additives baits versus plain bait. Under 3% (w/w) mean separation by LSD test showed non-significant difference in bait intake (F=1.94; df = 1,16; P<0.05). Egg bait preference was recorded at the highest (26.35%) followed by milk (22.70). The fishmeal was the least preferred additive (10.35%). In case of 5% (w/w) bait combinations, the difference in consumption was non-significant (F= 2.36; df= l,16; P<0.05). Egg appeared as the most favoured additive (24.27%) followed by the milk (17.36%), while fishmeal ranked at the lowest.

Poison bait acceptance test

The test was carried out to ascertain the relative position of additive poison baits over non-additive (reference) bait. Brodifacoum and bromadiolone (0.005% each) being second generation anticoagulant were used as rodenticides.

In case of *R. norvegicus*, results of 3-day poison bait acceptance test showed significant (F = 6.63; df = 1,16; P< 0,05) increase in mean daily consumption of brodifacoum-poisoned bait and bromadiolone bait with egg additive over the non--additive poison bait (Table IV). Brodifacoum additive bait was highly preferred (68.21 %) over reference (non-additive) bait. Similarly, bromadiolone bait with egg was preferred (60.09%) against poison bait without additive.

Under *B. bengalensis,* data of 3-day choice feeding test showed significant (F = 6.82; df=1,16; P<0.05) difference over non-additive poison bait, whereas non-significant difference was noted in case of bromadiolone poisoned bait over the non-additive. Brodifacoum bait with additive (egg) was preferred 79.81 % against non- additive poison bait whereas it showed 58.92% preference in bromadiolone bait with egg additive.

In case of *N. indica*, additive brodifacoum bait intake was recorded significant (F = 6.82; df= 1,16; P<0.05) when compared against non-additive poison bait, whereas non-significant difference

Table III.- **Mean (±SEM) daily consumption and percentage preference of *Rattus norvegicus, Bandicota bengalensis* and *Nesokia indica* under multiple choice test.**

Bait additive	No. of rats (M/F)	Body wt. (g)	3% Mean daily consumption (g/kg)	% Pref. (Add.)	Body wt. (g)	3% Mean daily consumption (g/kg)	% Pref. (Add.)
			Norway rat, *Rattus norvegicus*				
Egg			44:86±8:17a	53.44		27.84±6.08a	38.66
Milk			8.37±1.51b	9.97		17.31±2.6Iab	24.04
Yeast			5.52±1.77b	6.58		4.24±2.85b	5.89
Minced meat	10 (5/5)	247.92±14.39	7.63±1.09b	9.09	265.00±16.40	4.86±0.87b	6.75
Fish meal			5.71±2.21b	6.80		5.16±1.09b	7.16
Plain			11.84±2.74b	-		12.61±2.09ab	-
			Lesser bandicoot rat, *Bandicota bengalensis*				
Egg			6.18±l.13a	20.59		11.10±2.64a	24.33
Milk			5.27±1.03a	17.55		11.32±3.42a	23.86
Yeast			4.43±0.88a	14.76		5.95±0.64a	12.79
Minced meat	10 (5/5)	247.33±18.27	4.76±0.82a	15.85	265.10±15.40	5.35±0.99a	11.50
Fish meal			4.89±1.21a	16.29		5.36±1.43a	11.52
Plain			4.49±0.67a	-		7.44±0.99a	-
			Short-tailed mole rat, *Nesokia indica*				
Egg			12.99±.3.93a	26.35		10.90±1.42ab	24.27
Milk			11.19±3.93a	22.70		7.80±1.37ab	17.36
Yeast			9.71±1.82ab	19.70		7.49±1.1Oab	16.67
Minced meat	10 (5/5)	176.05±10.10	7.55±1.90ab	15.32	186.19±20.58	5.56±1.25ab	12.38
Fish meal			5.09±1.25ab	10.35		5.12±1.40ab	11.40
Plain			2.75±0.75b	-		8.05±1.60ab	-

Means in columns followed by the same letter (s) are not significantly different at 5% level of probability using LSD test.

Table IV.- **Relative poison bait acceptance of *Rattus norvegicus, Bandicota bengalensis* and *Nesokia indica,* with and without additives (3% egg) under three day paired choice test**

Poison	No. of rats (M/F)	Body wt. (gm)	With additive	Without additive	% Pref. (Additive)
		Norway rat, *Rattus norvegicus*			
Brodifacoum * (0.005%)	10 (5/5)	234.65±4.58	52.17±4.58	24.31±4.43	68.21
Bromadiolone* (0.005%)	10 (5/5)	222.50±11.36	41.39±7.02	27.44±3.15	60.09
		Lesser bandicoot rat, *Bandicota bengalensis*			
Brodifacoum * (0.005%)	10 (5/5)	179.72±4.85	49.86±12.60	12.61±4.09	79.81
Bromadiolone (0.005%)	10 (5/5)	219.99±13.40	38.74±7.02	27.01±3.15	58.92
		Short-tailed mole rat, *Nesokia indica*			
Brodifacoum * (0.005%)	10 (5/5)	200.43±20.15	27.72±3.49	18.03±4.10	60.59
Bromadiolone (0.005%)	10 (5/5)	145.50±19.20	29.72±3.85	28.06±5.26	50.30

* Significant at P< 0.05 by ANOVA

was noted in case of bromadiolone bait over the non-additive. Brodifacoum bait with additive was preferred 60.59% over non-additive, whereas in bromadiolone, the preference over non-additive bait was 50.30%.

DISUSSION

Additive bait acceptance

The palatability of the offered bait plays a vital role in successfully controlling the rodent population. If the bait is not well accepted by the pest, there will be a poor rodent kill and the whole rodent control operation will be a waste of time and money. Moreover, unpalatable bait may also lead to a bait aversion trend in rodents. The choice of food selection in rats is very complicated and may depend on the calorigenic content (Mathur *et al.,* 1992), palatability (Young, 1946), behavioural components (Barnett, 1956) and daily energy requirements especially according to the content of proteins and carbohydrates available in the food (Stenseth, 1977). The nutritive content of food items at a certain times plays it key role in the growth and reproduction of the animal.

R. norvegicus, a true omnivorous, selects different type of foods including egg, meat, grains, and melon (Barnett, 1956) but tends to reject highly flavoured food (Shuyler, 1954). The reason for the obvious success of *R. norvegicus* is its adaptability or lack of food specificity. The rat can eat almost any biological matter and can be extremely fastidious if it has the opportunity. In the present study, the high preference of *R. norvegicus* for egg additive bait could be due to its improvement in palatability.

Under *B. bengalensis,* egg bait was highly preferred (20.59% and 24.33%) in 3% and 5% combinations respectively. Similarly in *N. indica* egg additive was liked the most in both 3% and 5% combinations (26.36% and 24.27% respectively Table III). Food preference criteria in field rodents may be different than those of commensal rats. In case of commensal rodents *e.g. R. norvegicus,* the preferred food items are almost always available and known to the rat, but for field rodents *e.g. B. bengalensis* and *N. indica* it depends on the season and animal may have to switch to other kinds of foods, when the preferred food items become scarce. Sometimes, the food is selected more on the basis of availability than that of palatability, energy or protein content. *R. norvegicus* registered a low energy intake as compared to field rodents *B. bengalensis* and *N. indica* probably due to its living with human and thriving on easily accessible food success, thereby avoiding distance and extensive burrowing as field rats normally do (Mathur *et al.,* 1992). However the field rats *i.e. B. bengalensis* and *N indica* are extensive burrower (especially *N. indica)* so they select the food to compensate the daily energy requirements (Shafi *et al.,* 1992, 1993). According to Spillett (1968), field rats *i.e. B. bengalensis, N. indica* not always select food in its preferential nature but observing other individuals while foraging may also play a significant part in food sampling (Eibl-Eibesfeldt, 1958).

Under field situation, the rodenticide baits compete with the natural available foods, rats may react to the smell of bait (Petrusewicz, 1967), and it should be advantageous to add a small proportion of the preferred food in the bait. According to Shafi *et al.* (1993) minced meat additive incorporated at 2% (w/w) made the bait highly preferred for *B. bengalensis* over egg when the later was offered in parts (egg shell and egg yolk). In the present study, the additive of egg as a whole remained the most preferred. It is assumed that the addition of egg in the bait could have made the texture of bait more attractive and palatable (Pervez *et al.,* 2003). In a study conducted by Shafi (1991) the mixing of 2% egg shell for *N indica,* significantly increased the intake of bait in comparison to non-additive bait.

Poison bait acceptance

In case of *R. norvegicus,* results of 3-days poison bait acceptance showed higher preference for brodifacoum and bromadiolone (0.005% each) poison baits with egg additives over non-additive poison bait. Similarly the field rodents *e.g. B. bengalensis* and *N. indica* consumed egg mixed brodifacoum and bromodiolone baits more than non-additive poison baits (Table IV).

Studies conducted by Rennison and Dubock (1978) revealed that brodifacum was quite effective against warfarin resistant *R. norvegicus* and *Mus musculus.* In addition to single dose rodenticide, brodifacoum is also a potent multiple dose rodenticide when used in a manner similar to normal anticoagulant baiting practice. This efficacy of multiple dose activity of brodifacoum at low concentration was demonstrated for rats and mice by Redfern *et al.* (1976) and Row and Bradfield (1976). Brodifacoum was found very effective in urban situation as well as in village and farm level (Jackson, 1977; Maddaiah *et al.,* 1987; Pervez *et al.,* 2003). The high efficacy of brodifacoum (0.005%) after a two day feeding test against *R. rattus* has been reported by Redfern *et al.* (1976). Similarly bromadiolone works effectively well against warfarin resistant species and its activity against wide range of rodents including gopher, ground squirrels and various field mice and voles (Marsh, 1986). Marsh *et al.* (1980) conducted numerous field trials to control commensal rodents with bromadiolone and showed that this compound was very good for controlling any pest species. Resistant Norway rat population could be reduced by 85.5% by using bromadiolone (Ashton and Jackson, 1984). It was reported by Redfern and Gill (1980) that a 100% kill could be obtained with bromadiolone after three-day feeding and its high acceptability by *R. rattus.*

Practically, bait aversion trend in rodents can be overcome or minimized through making the bait more palatable by mixing of additives (Shafi *et al.*, 1993; Pervez *et al.*, 2000, 2003). The present investigations clearly indicate that egg additive (3%) has the potential to mask the adverse effects in rats associated with unpalatable bait material. Moreover, the highly palatable additive bait formulations have the advantage to address the control difficulties in field rodents due to constant availability of alternative food source.

It is, however, felt that there may be practical difficulties in incorporating such additives *e.g.* egg into bait used in large scale rodent control campaign. If bait was to be stored for longer period, before use, shelf life of bait may create problem due to addition of fresh egg in bait. The use of additive bait may be more advantageous for small-scale control by farm- holders or in food stores where fresh bait can be offered to rodents as an alternative food source thus achieving successful control.

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