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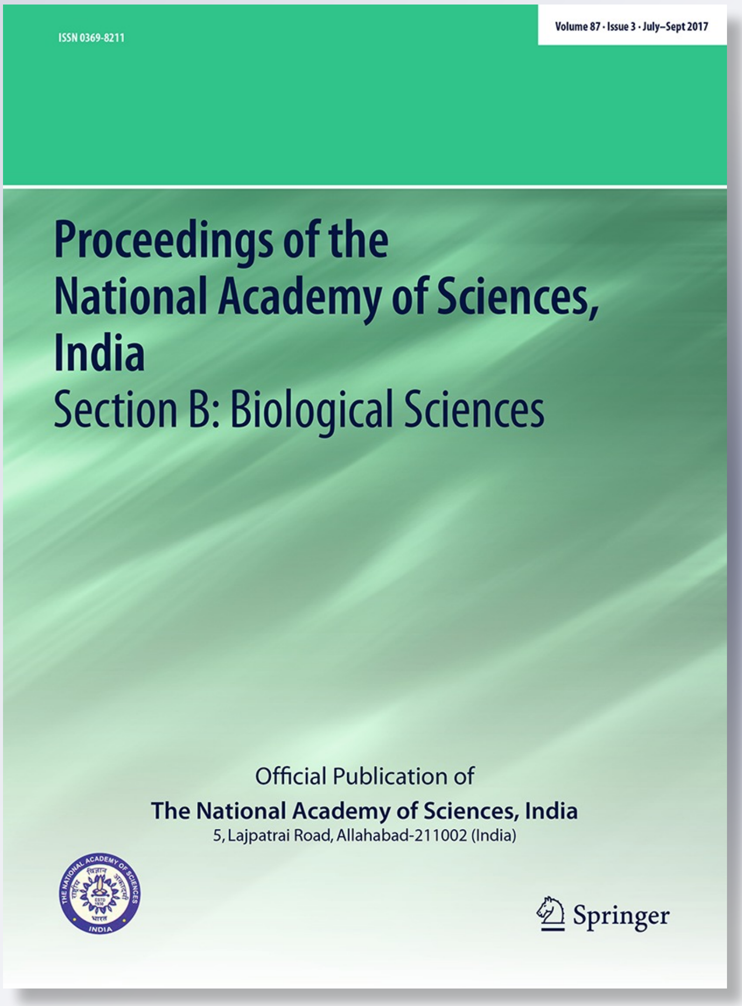

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RESEARCH ARTICLE

Feeding Deterrence Effects of Defatted Jojoba (*Simmondisa chinensis*) Meal Against Indian Gerbil, *Tatera indica* (Hardwicke)

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Abstract In search for safe and eco-friendly management of rodent pests a number of phyto-chemicals have been evaluated as repellent, antifertility agent, antifeedant and toxicant etc. Protein rich residue of seed of Jojoba (*Simmondisa chinensis*) known as defatted jojoba meal is reported to possess marked suppressive effect on food intake in a variety of animal species. In present study the defatted jojoba meal at a concentration of 5, 10, 15, 20, 25 and 30 % in pearl millet bait (w/w basis) was evaluated for its anti-rodent properties against *Tatera indica*, a predominant rodent pest of Indian subcontinent. Under no-choice condition the bait consumption during treatment period of 7 days was significantly reduced (3.01 ± 0.40–4.76 ± 0.14 g/100 g bwt/day) in comparison to pre-treatment plain bait consumption (9.33 ± 0.73–10.37 ± 0.29 g/100 g bwt/day). At higher dosages 50 % gerbils died. Besides, weight reduction in the range of 10.63–16.67 % was also observed. In choice test mean consumption of treated food was also significantly reduced (0.64 ± 0.28–1.44 ± 0.20 g/100 g bwt/day) in comparison to plain bait (5.80 ± 0.18–8.80 ± 0.29 g/100 g bwt/day) during 7 days of treatment period. Jojoba treated pearl millet bait when offered with plain sorghum bait, after an exposure period of 5 days left an imprinting effect on Indian gerbil which led to aversion towards plain pearl millet bait for 10–11 days. The findings showed that jojoba defatted meal exert strong dose dependant deterrence in Indian gerbils and also induces condition aversion learning behavior in the gerbils.

Keywords Jojoba (*Simmondisa chinensis*) · Indian gerbil (*Tatera indica*) · Deterrence · Choice and no-choice · Conditioned taste aversion

Introduction

Rodents inflict serious loss to food production at pre and post-harvest stages worldwide. Some estimates from India indicate 2-15 % damage to standing crops due to rodent depredations, which may reach to nearly 100 % during outbreaks [1–4]. Over a dozen species are regarded as problem species in agriculture and storage. Of these a complex of 2–5 rodent species inhabit any agro-ecosystems [5] and the Indian gerbil, *Tatera indica* is one of the important species of this pest complex in most of the agro-ecological regions of the country [1]. Besides, this species is also regarded as reservoir of plague bacteria. Thus *T. indica* is an important pest as well as vector species impacting food and health security [1, 2].

Present day rodent management technology mostly rely on use of toxic chemicals (acute and chronic rodenticides), which provide immediate respite from the problem but are not considered as sustainable strategy. Besides, rodenticide associated problems, like toxicity to non-targets, induction of bait shyness and poison aversion, development of resistance etc. further limit their repeated applications. Therefore there is a dire need to develop safe and eco-friendly means for management of rodent pests [6]. A number of plant products have been evaluated against rodents as repellent [7–9], antifertility agent [10–12], antifeedant [6, 13] and toxicant [14–17] that may be exploited as an important tool in this direction. It is well known that the secondary metabolites produced by such plants play an important role in defense of plants against

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variety of herbivores and pathogenic microorganism [18]. Phyto-chemicals have advantages over broad spectrum pesticides, as they affect only target pest and closely related organism, decompose quickly and provide the residue-free food and a safe environment [9].

The jojoba plant (*Simmondsia chinensis*) is a shrub cultivated in arid and semiarid regions of the world for its oil which is used as lubricant and in cosmetics. The protein-rich residue of seed left after oil extraction (cake), known as defatted jojoba meal, has a markedly suppressive effect on food intake in a variety of species [19]. The defatted jojoba meal contains several cyanide containing glucosides, such as simmondsin and its derivatives which are reported to induce food intake inhibition, emaciation and occasionally mortality (at higher dosages) in albino rats [20–23] probably by stimulation of the cholecystokinin (CCK) system.

The present study is therefore attempted to evaluate the deterrence or toxic effect of defatted jojoba meal against Indian gerbil, *T. indica* a predominant rodent pest species of Indian agriculture.

Besides possibility of induced conditioned taste aversion (CTA) due to defatted jojoba meal has also been explored.

Material and Methods

Collection and Maintenance of Test Animals

The test gerbils, *T. indica*, were live trapped with the help of single catch Sherman traps from Central Research Farm, Central Arid Zone Research Institute (CAZRI), Jodhpur, India (Lat. 26°14′54.5″N Long.72°59′34.03″E). The field collections were housed in iron mesh cages (5 × 2.5 × 2.5ft) and acclimatized for 15 days for the laboratory conditions before starting the experiment. During acclimatization they were provided with grounded pearl millet and tap water ad libitum. Hygienic conditions were maintained by regular cleaning of cages and replenishment with fresh food and water on daily basis. After acclimatization injured and sick animals and pregnant females were discarded and only healthy adults were selected for the study as per the guidelines of European Plant Protection Organization [24].

Feeding Trials

Defatted remainants of jojoba seeds after oil extraction (jojoba meal) was used for trials against Indian gerbil in laboratory. The meal mixed with preferred food (grounded pearl millet) at different concentration was used for evaluation of deterrent effect against Indian gerbils. Prior to exposure of jojoba meal treated food, the test gerbils were offered known quantity of grounded pearl millet (20 g) daily for 3 days and their consumption was recorded as pre-treatment consumption. This provided a base line consumption data and accordingly jojoba meal treated food (20 g/day) at different test concentrations was provided to the test rodents. Three experiments were laid to understand anti-rodent (deterrent) effects of defatted jojoba meal against *T. indica*.

Experiment 1

No-choice feeding trials: Six test gerbils (three males and three females) of known body weight were used for different test concentrations. Defatted jojoba meals at a concentration of 5, 10, 15, 20, 25 and 30 % each was mixed with the grounded pearl millet (w/w basis). Based on the pretreatment daily mean consumption (9.33 ± 0.73–10.37 ± 0.29 g/100 g), the treated food (20 g each) was offered to test gerbils of different test concentration simultaneously for 7 days. Tap water was available to the gerbils ad libitum. No alternate plain food was offered to the animals during the seven day trial. The consumption for each test concentration was recorded after 24 h and the treated food was replenished with fresh treated food daily. After treatment period the surviving rodents of each test concentration were offered plain food (grounded pearl millet) only for 7 days and their daily food intake was recorded as post treatment consumption. In addition, the mortality percentage for each concentration, time to death and final weight were also recorded.

Experiment 2

Choice feeding trials: Six test gerbils (three males and three females) of known body weight were used for each of the six test concentration. Defatted jojoba meal at 5, 10, 15, 20, 25 and 30 % was mixed with grounded pearl millet on w/w basis. Being a choice feeding trial, the plain food (grounded pearl millet) as well as jojoba meal treated food was offered to test gerbils in separate bowls for each concentration. Tap water was available to the gerbils ad libitum. The trial was run for 7 days. The position of both the food bowls was altered daily to avoid site preference on feeding. The consumption of treated and untreated food was recorded daily for seven successive days and then treated food was removed and surviving individuals were provided with plain food only. Daily plain food consumption was recorded as post treatment intake. Based on intake of plain and treated food during treatment period, extent of deterrence/avoidance was calculated. Final body weight of the gerbils was also recorded after 7 days of exposure period.

Experiment 3

Conditioned taste aversion: Rodents are known to possess strong conditioned learning behavior. Induction of bait shyness is a perfect example of such a behavioural manifestation in rodents. Therefore this experiment was conducted to understand if exposure of defatted jojoba meal induces any taste aversion learned behaviour in Indian gerbils. On the basis of earlier two experiments two intermediate concentrations (10 and 20 %) of defatted jojoba meal was further evaluated for this purpose. Experiments were laid under choice conditions, where a set of laboratory acclimatized six gerbils (3 males and 3 females) for each test concentration were exposed to two different types of plain food viz. crushed pearl millet and sorghum for 3 days. Afterwards 10 and 20 % defatted jojoba meal were mixed in pearl millet and offered to the test gerbils along with plain bait of sorghum for five consecutive days. After treatment period gerbils of both the sets were offered plain crushed grains of pearl millet and sorghum for another 2 weeks. Consumption of both the foods pre, during and post treatment periods were recorded.

Data-Analysis

For statistical analysis, the absolute consumption data (g) were converted to relative data (g/100 g body weight) for each concentration. The variation in body weight during treatment was calculated according to following formula proposed by Guidobono et al. [25].

$$\text{Loss in weight } (\%) = [(\text{Initial body weight} - \text{final body weight})/\text{initial body weight}] \times 100$$

The level of significance was assessed with one sample *t* test.

The effect of defatted jojoba meals on deterrence was calculated by following formula:

$$\text{Percent deterrence } (\%) = [(\text{Consumption of untreated bait} - \text{consumption of treated bait}) / \text{Consumption of untreated bait}] \times 100$$

The pre and treatment intake (in experiment 1) and consumption of treated and untreated food during treatment period (in experiment 2 and 3) at different concentrations were subjected to paired t- test for analyzing the level of significance and drawing further inferences.

Results and Discussion

No-Choice Feeding Trials

The results obtained revealed that mean daily consumption of plain bait (at pre-treatment stage) was at par ranging from 9.33 ± 0.73–10.37 ± 0.29 g/100 g bwt/day which was drastically reduced to 3.01 ± 0.40–4.76 ± 0.14 g/100 g bwt/day in baits treated with different concentrations of defatted jojoba meal during 7 days exposure period. Further probe into the data did not show any significant variation in day wise intake of baits treated with different concentrations of jojoba however, daily intake showed a non-significant decreasing trend from day 1 to day 7. Maximum variation was observed at highest test concentration (30 %) where the intake was reduced from 4.14 (on day 01) to 3.01 g/100 g bwt on day seven. The results further revealed that the intake of food treated with defatted jojoba meal was significantly lower than the pretreatment intake reflecting strong anti-rodent properties in the defatted jojoba powder (Table 1). Secondly the consumption of treated bait was inversely proportional to the concentration because the intake of treated food was the least (3.01 g/100 g bwt) at 30 % concentration (in 5–6 days), which increased to 3.89, 4.03, 4.05, 4.16 and 4.76 g/100 g bwt at 25, 20, 15, 10 and 5 %, respectively in 7 day exposure period revealing a greater deterrent effect at higher concentrations (Table 1). Intake of jojoba treated food affected the health of animals as their body weight was reduced in the range of 10.63–16.67 %, which was at par irrespective of treatments (Table 1). Even mortality of test gerbils was also noticed in some cases i.e. 50 % kill at higher dosages (25 and 30 %) within 5–6 days, and 33.33 and 16.67 % at subsequent lower dosages (20, 15 and 10 % treatments), however the lowest test concentration (5 %) did not register any mortality (Table 1). Poor intake (starvation) and presence of secondary metabolites in the treated food might have led to mortality of gerbils.

Choice feeding trials: After ascertaining that jojoba meal has anti- rodent properties through forced feeding (no choice trials) this experiment was carried out to understand its efficacy under choice conditions where the test gerbils had a choice between treated and untreated food during 7-day long experimental period. The pretreatment mean intake of plain food in this experiment (9.50 ± 0.68–10.40 ± 0.32 g/100 g bwt/day) was similar to that in no-choice trials (9.33 ± 0.73–10.37 ± 0.29 g/100 g bwt/day).

Impact of treatments was evident from the first day of exposure, as the mean intake was highest (2.21 g/100 g bwt) at lowest concentration (5 %) and minimum (0.75 g/100 g bwt) at 25 % concentration which was subsequently reduced on following days and reached to least

Table 1 Laboratory evaluation of Jojoba meal (defatted seed powder) against *T. indica* (no-choice test)

Percent concen-tration	Pretreatment consumption (g/100 g body wt.)/day	Feeding period (days)	Mean consumption treated bait (g/100 g body wt.)/day	Paired t test between 2 and 4	Trends in body wt.				Percent mortality	Time to death	
					Initial wt (g)	Final wt (g)	Paired t test between 6 and 7	Percent wt reduction		Mean (days)	Range (days)
1	2	3	4	5	6	7	8	9	10	11	12
05	10.25 ± 0.53	07	4.76 ± 0.14	10.12*	117.33 ± 13.85	105.17 ± 14.35	4.37*	10.63	–	–	–
10	9.58 ± 0.30	07	4.16 ± 0.15	20.20*	119.16 ± 15.51	105.50 ± 14.15	4.71*	11.46	16.67	6.5	6–7
15	9.61 ± 0.54	07	4.05 ± 0.12	13.53*	114.00 ± 13.0	100.00 ± 13.20	3.34*	12.26	16.67	6.5	6–7
20	9.33 ± 0.73	07	4.03 ± 0.04	9.04*	130.83 ± 6.97	113.25 ± 6.87	3.78*	13.44	33.33	6.5	6–7
25	9.92 ± 0.79	07	3.89 ± 0.08	8.36*	139.67 ± 8.24	119.33 ± 8.37	4.19*	14.56	50	5.5	5–6
30	10.37 ± 0.29	07	3.01 ± 0.40	15.72*	137.67 ± 6.35	114.67 ± 3.27	3.60*	16.67	50	5.5	5–6

* Significant Critical t value at 5 %: 2.44 and 1 %: 3.70

i.e., 0.87 and 0.20 g/100 g bwt at lowest and highest concentration, respectively on 7th day of exposure. Overall mean consumption (7-day) of treated food was least i.e., 0.64–0.90 g/100 g bwt/day at higher test concentrations (20, 25 and 30 %) and was maximum (1.44 g/100 g bwt/day) at lowest test concentration (5 %). On the other hand mean consumption of plain/untreated food showed altogether a reverse trend i.e., maximum intake (8.80 g/100 g bwt/day) at highest concentrations and least (5.80 g/100 g bwt/day) at lowest test concentration (Table 2). However, in comparison to pretreatment intake, plain bait consumption during treatment period was also reduced indicating adverse effects on rodent's appetite due to intake of jojoba treated bait. As a result, weight reduction in test gerbils was least (1.94 %) at 30 % concentration and highest (5.95 %) at lowest (5 %) treatment (Table 2). The reason for this trend was obvious because the less intake of treated food at different concentrations was accordingly compensated by the gerbils with more intake of plain food. The intake of jojoba meal treated food in general was significantly lower ($P > 0.05$) than the plain food for all the test concentrations during 7 day long choice trials (Table 2). This clearly revealed that the treated food was neither acceptable nor palatable to the gerbils irrespective of the test concentrations.

Pattern of the intake of plain and treated bait indicated that the baits with higher concentration of defatted jojoba meal showed relatively higher deterrence (Table 2). Percent deterrence was over 90 % (at 20 and 30 %), between 80 and 90 % at moderate dosages (10–20 %) and 77.22 % at lowest concentration (5 %). Higher values (>80 %) may be considered as an effective indicator of deterrent properties of defatted jojoba meal against Indian gerbils. There was no mortality of test animals, probably due to availability of an alternate food (choice test).The results of the present investigation reflect presence of strong anti-rodent properties which deterred the Indian gerbils from taking defatted jojoba meal at various test concentrations in choice tests. Even in no choice tests the gerbils lost 11–17 % weight and up to 50 % mortality at different treatments. It is well known that the secondary metabolites present in the plants play defensive role against a number of potential enemies [18]. Secondary compounds may be bitter, toxic, offensively odorant or have anti-nutritional effect [26]. Herbivores may avoid ingesting these compounds using several mechanisms, including an innate ability to taste or smell and learning aversion conditioning [27, 28]. Either of these mechanisms might have influenced the consumption of baits treated with defatted jojoba meal by Indian gerbils. Most plant toxins show a dose dependent effect [26] as has been observed in the present investigation also where mortality and deterrence was high at higher concentration. Curtis et al. [9]

Table 2 Laboratory evaluation of Jojoba meal (defatted seed powder) against *T. indica* (choice test)

Percent concen-tration	Pretreatment consumption (g/100 g body wt.)/day	Feeding period (days)	Mean daily bait intake (g/100 g body weight)/day			Percent avoidance (%)	Trends in body wt.			
			Plain bait	Treated bait	Paired t test between 4 and 5		Initial wt (g)	Final wt (g)	Paired t test between 8 and 9	Percent wt reduction
1	2	3	4	5	6	7	8	9	10	11
5	10.37 ± 0.82	07	5.80 ± 0.18	1.44 ± 0.20	16.55*	77.22	112.00 ± 3.31	105.33 ± 3.23	3.38*	5.95
10	10.32 ± 0.31	07	6.83 ± 0.20	1.25 ± 0.21	17.44*	83.85	117.17 ± 3.40	110.50 ± 3.67	4.70*	5.69
15	09.50 ± 0.68	07	7.84 ± 0.42	1.12 ± 0.19	11.94*	85.71	120.67 ± 3.97	114.33 ± 3.59	4.61*	5.25
20	10.18 ± 0.48	07	8.17 ± 0.19	0.90 ± 0.06	42.21*	88.98	123.33 ± 4.56	118.50 ± 3.97	4.82*	3.9
25	09.90 ± 0.72	07	8.50 ± 0.29	0.70 ± 0.13	20.68*	91.76	129.33 ± 4.45	126.33 ± 4.76	5.17*	2.32
30	10.40 ± 0.32	07	8.80 ± 0.12	0.64 ± 0.28	23.21*	92.73	128.67 ± 3.91	126.17 ± 3.40	4.67*	1.94

* Significant Critical t value at 5 %: 2.44 and 1 %: 3.70

also recorded higher repellency against voles at higher dosages of most of the candidate species tested. Simmondsin, a glucoside present in jojoba and defatted jojoba meal has been reported to cause food intake inhibition in rats by several researchers.

Cokelaere et al. [22] reported that food intake inhibition by albino rats increased with increase in dose of simmondsin concentration, at 0.1–1.0 % and defatted jojoba meal. Similarly, Lievens et al. [29], observed that meal pattern in rats were dose-dependent and it was most severe at highest concentration. Mortality at higher dose as observed in the present study under no-choice test may be attributed to the toxic effect of simmondsin [30]. However mortality after fifth day of exposure to the defatted jojoba meal and no mortality in choice test (in the presence of alternative food) may be due to starvation as root cause of death. In the present study the consumption of treated bait was significantly ($P > 0.05$) lower than untreated bait with less consumption at higher dose and vice versa (Table 2). Earlier Cokelaere et al. [31, 32] had reported that simmondsin, inhibits food intake by increasing satiety through an indirect interaction with peripheral CCK4 system. Lievens et al. [29] also recorded significantly reduced consumption of treated bait than untreated one by albino rats. A significant reduction in body weight among different concentrations of defatted jojoba meal in no-choice test was observed (Table 1), whereas it was dose dependent in choice test. These observations are also in line with the reports of Boozer and Herron [19] who recorded reduced food intake and reduced body weight with simmondsin treated baits at 0.15 and 0.25 %, which was more pronounced at higher dosages. Likewise, the authors [19] also reported non-significant reduction in body weights of albino rats at 0.015 and 0.05 % simmondsin in baits but increasing the concentration to 0.15 % led to small but persistent weight loss and a rapid weight loss of about 6 % at highest dose (0.50 %). The deterrence for treated food was noticed at all the test concentrations in choice tests, however it was more at higher dosages. Similar observations of higher anti-feedant effect were recorded by Singla and Parshad [6] with neem based botanical bird repellent against *Rattus rattus*.

Conditioned taste aversion: Two cereal baits (crushed pearl millet and sorghum) were simultaneously offered to the gerbils for two selected test concentrations (10 and 20 %) of jojoba meal. Prior to treatments mean consumption of pearl millet was slightly higher (5.09 and 5.23 g/100 g bwt/day) than that of sorghum (4.36 and 4.95 g/100 g bwt/day) for respective test concentration (pre- treatment phase). Thereafter, treatments with defatted jojoba meal prepared in crushed pearl millet at 10 and 20 % concentration were offered to test rodents on fourth day.

Presence of jojoba meal (10 %) in pearl millet bait led to sudden drop in its intake (during treatment phase) from first day itself (3.42 g/100 g bwt) and subsequently continued to decline recording 0.66, 0.56, 0.87 and 0.84 g/100 g bwt only on day 2, 3, 4, and 5, respectively. The trend was reverse in case of sorghum which increased significantly to 5.49, 6.58, 7.09, 8.04 g/100 g bwt on respective days and remained higher even after withdrawal of treated food (Table 3; Fig. 1). Mean consumption of treated pearl millet during 5 days of treatment period was significantly lower i.e., 1.27 g/100 g bwt as against 7.06 g/100 g bwt for untreated sorghum. Similar trends were also noticed with intake of pearl millet treated at 20 % treatments vis a vis untreated sorghum with relatively more pronounced effects. The treatment phase registered immediate decline in consumption of treated pearl millet bait from day 1 (0.25 g/100 g bwt) which reduced to zero levels on day 4 and 5, whereas the intake of untreated sorghum increased to 9.29, 9.04, 10.3, 7.9 and 7.57 g/100 g bwt on day 1 to day 5. Overall mean intake of treated pearl millet during 5-day treatment phase was significantly reduced (0.31 g/100 g bwt) over untreated sorghum (8.82 g/100 g bwt) (Table 3; Fig. 2). These results further confirmed that defatted jojoba meal powder possesses dose dependent deterrence effects on Indian gerbils. During post treatment phase, when plain pearl millet and sorghum was offered to the same set of test rodents (after the withdrawal of jojoba meal treatments), the intake of pearl millet (in the sets with 10 % treatments) although showed increasing trend (2.35 g/100 g bwt on first day to 3.64 g/100 g bwt on ninth day) against that of sorghum which showed decreasing trend (6.6 g/100 g bwt on first day to 4.75 g/100 g bwt)

Table 3 Condition taste aversion by *Tatera indica* after feeding on jojoba (10% & 20 %) in preferred food (crushed bajra) in choice test

Concent-ration (%)	Mean Consumption (g/100 g bwt)/day							
	Pre treatment consumption (mean ± SE of 03 days)		Treatment consumption (mean ± SE of 05 days)			Post treatment consumption (mean ± SE of 14 days)		
	Pearl millet	Sorghum	Jojoba meal treated pearl millet bait	Sorghum (plain)	Paired t test between 4 & 5	Pearl millet	Sorghum	Paired t test between 7 & 8
1	2	3	4	5	6	7	8	9
10	5.09 ± 1.09	4.36 ± 0.55	1.27 ± 0.54	7.06 ± 0.48*	6.03	3.64 ± 0.23	5.06 ± 0.17*	3.93
20	5.23 ± 0.79	4.95 ± 0.75	0.31 ± 0.14	8.82 ± 0.49*	22.55 (*P* = 0.05)	3.18 ± 0.26	5.34 ± 0.11*	6.98 (*P* = 0.05)

* Significant between col. 4 and 5 and col. 7 and 8

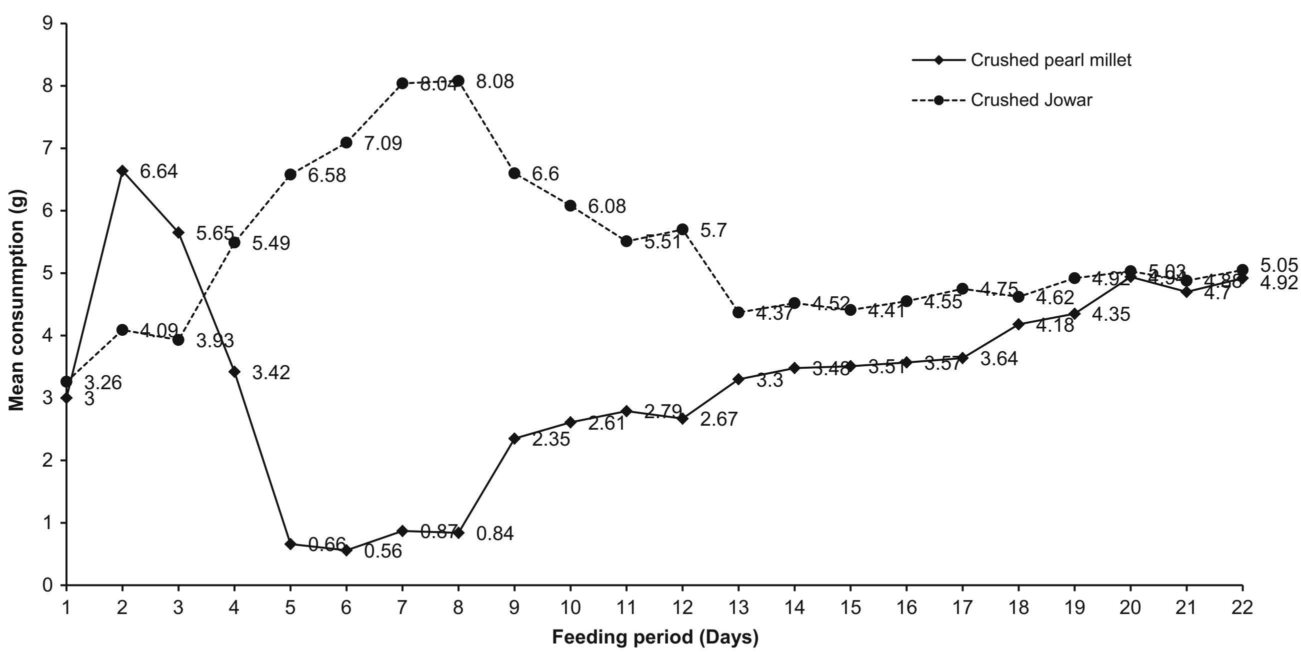

Fig. 1 Conditioned taste aversion by *Tatera indica* after feeding on Jojoba defatted meal (10 %) mixed in crushed pearl millet in choice test

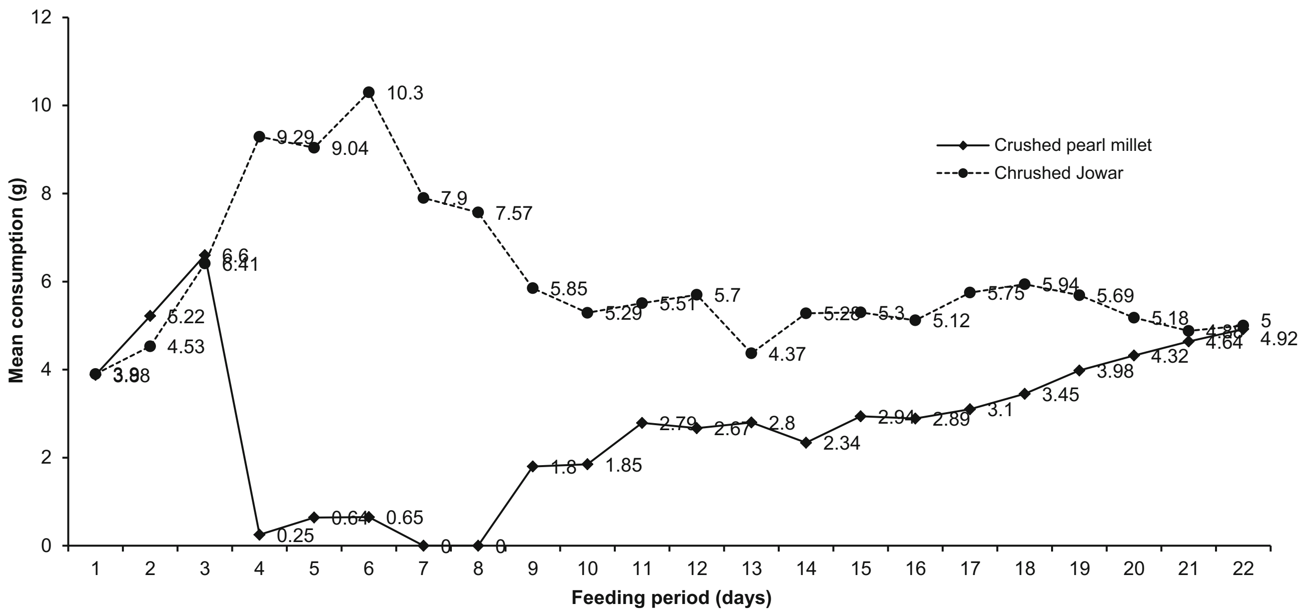

Fig. 2 Conditioned taste aversion by *Tatera indica* after feeding on Jojoba defatted meal (20 %) mixed in crushed pearl millet in choice test

during the same period, the intake of pearl millet continued to be significantly less up to 9 days after withdrawing the treatment. Similar trend was also noticed in case of 20 % treatments, but the intake of pearl millet was significantly lower up to 11 days after withdrawal of treatment. The consumption of both the baits reached at par after 10 days (4.18 g for pearl millet and 4.62 g for sorghum) and 12 days (4.32 g for pearl millet and 5.69 g for sorghum) with 10 and 20 % jojoba meal treatments, respectively (Figs. 1, 2).

The experiment was run for 14 days after withdrawal of treatments and the overall mean consumption of pearl millet (3.64 and 3.18 g/100 g bwt/day at 10 and 20 % conc., respectively) was significantly lower than sorghum (5.06 and 5.34 g/100 g bwt/day at 10 and 20 % conc., respectively) during post treatment (Table 3).

The significant reduction in post treatment consumption of pearl millet over sorghum may be due to learned taste aversion produced by simmomdsin containing defatted jojoba meal mixed in pearl millet during treatment period. Indian gerbils associate the taste of pearl millet to negative feeling produced by simmondsin which lasted for 9–11 days. With albino rats, Lievens et al. [29] also noticed conditioned taste aversion after receiving simmondsin at 0.15, 0.25 or 0.5 % conc. prepared in saccharine solution. The authors noted significant increase (>70 %) in preference for saccharine solution as compared to simmondsin treated saccharine. Singla and Parshad [6] also recorded less consumption of neem treated bait by rats exposed after 10 days of first feeding than those exposed after 50 days of first feeding.

The findings therefore indicated that the unpleasant experience with treated pearl millet bait for 5 days had an imprinting effect on Indian gerbils, leading to acquired learning through conditioned taste aversion which lasted for at least 9 and 11 days at 10 and 20 % concentrations of jojoba meal powder, respectively.

Conclusion

It may therefore be concluded that jojoba defatted meal exert a strong, but dose dependant deterrence in Indian gerbils when offered in different concentration in bait. Mortality was observed at higher dose (in no-choice) may be due to starvation. The gerbils treated with defatted jojoba meal mixed in pearl millet showed conditioned aversion learning behavior also lasting for 9 and 12 days at 10 and 20 % concentration, respectively.

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References

1. Parshad VR (1999) Rodent control in India. Integr Pest Manag Rev 4:97–126
2. Tripathi RS (2009) Rodent management under current scenario of changing land use pattern. In: Ramamurthy VV, Gupta GP, Puri SN (eds) IPM strategies to combat emerging pests in the current

scenario of climate change. Entomological Society of India, New Delhi, pp 367–386
3. Rajendran TP, Tripathi RS, Dutta BC, Bora DK, Rao AMKM (2006) Rodent pest management in northeast India. AINP on Rodent Control (ICAR). Central arid Zone Research Institute, Jodhpur
4. Sridhara S, Rajendran TP (2009) Bamboo flowering and rodent outbreaks. Scientific Publishers, Jodhpur **157p**
5. Tripathi RS, Chaudhary V (2005) Principles and practices of rodent pest management. In: Prasad D, Singh A (eds) Advances in plant protection sciences. Akansha Publishing House, New Delhi, pp 245–259
6. Singla N, Parshad V (2007) Antifeeding effect of neem (*Azadirachta indica*)-based formulation botanical bird repellent against the house rat (*Rattus rattus*). Indian J Agric Sci 77(8):502–504
7. Barnett JP, Waldrop TA (1998) Oleoresin capsicum has potential as a rodent repellent in direct seedling longleaf pine. In: Proceedings of the ninth biennial southern silvicultural research conference, Clemson, pp 326–328. (General Technical Report-Southern-Research Station, USDA-Forest Service)
8. Curtis PD, Rowland ED, Good GL (2002) Developing a plant-based vole repellent: screening of ten candidate species. Crop Prot 21:299–306
9. Singla N, Thind RK, Mahal AK (2014) Potential of *Eucalyptus* oil as repellent against house rat, *Ratus rattus*. Sci World J 2014:1–7
10. Dehghani F, Panjehshahin MR, Mirzaee Z, Mehrabani D (2005) Effect of Foeniculum vulgare organic extract on blood sex hormones and reproductive tissues of male rats. J Appl Anim Res 27(1):17–20
11. Deng W, Wang GY, Zhao SD (2011) Antifertility effects of crude ethanol extracts of *Tripterygium hypoglaucum* (Levl.) Hutch in male Mongolian gerbils (*Meriones unguiculatus*). J Appl Anim Res 39(1):44–48
12. Singla N, Garg M (2013) Effect of crude cottonseed oil containing gossypol on fertility of male and estrous cycle of female *Bandicoota bengalensis* Gray and Hardwicke. J Appl Anim Res 41(2):156–165
13. Curtis PD, Rowland ED, Harribal MM, Curtis GB, Renwick JA, Martin-Rehrmann MD, Good GL (2003) Plant compound in *Pachysandra terminalis* that act as feeding deterrents to Prairie Voles. Hort Sci 38(3):390–394
14. Oji O, Madubuik FN, Ojimelukwa PC, Ibeed CM (1994) Rodenticidal potential of the *Thevetia peruviana*. J Herb Spice Med Plants 2(3):3–10
15. Zhan SC, Yan YS, Lin T (1997) Isolation of toxin of Rhododendron molle and its toxicity and killing efficiency against rodents. Chin J Vector Biol Control 8(2):89–91
16. Abou-Hashem AAM (2012) Evaluation of rodenticidal effects of some plant extracts under laboratory and field conditions. J Basic Appl Zool 65:282–288
17. Abou-Hashem AAM (2013) Rodenticidal effect of Argel (*Gomphocarpus sinaicus* Boiss) leaves on the Norway rat (Albino), *Rattus norvegicus*, Berkenhout under laboratory condition. J Appl Sci Res 9(3):1690–1695
18. Mazid M, Khan TA, Mohammad F (2011) Role of secondary metabolites in defense mechanism of plants. Biol Med 3(2):232–249
19. Boozer CN, Herron AJ (2006) Simmondsin for weight loss in rats. Intern J Obes 30:1143–1148
20. Booth AN, Elliger CA, WaissJr AC (1974) Isolation of toxic factor from jojoba meal. Life Sci 15:1115–1120
21. Verbiscar AJ, Banigan TF, Weber CW, Reid BL, Trei JE, Nelson EA (1980) Detoxifaction of jojoba meal. J Agric Food Chem 28:571–578
22. Cokelaere MM, Flo G, Curtis PD, Decuypere E, Van Boven M, Vermaut S (1996) Food intake activity of Simmondsin and defatted jojoba meal: dose–response curves in rats. In: Janic J (ed) Progress in new crops. ASHA Press, Arlington, pp 377–382
23. Flo G, Vermaut S, Darras V, Van Boven M, Decuypere E, Daenens P, Kuhn E, Cokelaere M (1998) Jojoba meal and simmondsin: role in food intake regulation. Recent Research Development in Agricultural and Food Chemistry-II, pp 653–671
24. Mathys G (1975) Guidelines for the development and biological evaluation of rodenticides. EPPO Bull 5(1):50
25. Guidobono JS, Leon V, Gomez VIE, Busch M (2010) Bromodiolone susceptibility in wild and laboratory *Mus musculus* (house mice) in Buenos Aires, Argentina. Pest Manag Sci 66(2):162–167
26. Harborne JB (1991) The chemical basis of Plant defense. In: Polo RT, Robbins CT (eds) Plants defense against herbivory. CRC Press, Boca Raton, pp 45–60
27. Provenzo FD (1995) Post ingestive feedback as an elementary determinant of food preference and intake in ruminants. J Range Manag 48:2–17
28. Provenzo FD (1996) Acquired aversions as the basis for varied diets of ruminants foraging on rangelands. J Anim Sci 74:2010–2020
29. Lievens S, Flo G, Decuypere E, Van Boven M, Cokelaere M (2003) Simmondsin: effects on meal patterns and choice behavior in rats. Physiol Behav 78:669–677
30. York DA, Singer L, Oliver J, Abbott TP, Bray GA (2000) The detrimental effect of simmondsin on food intake and body weight of rats. Indian Crops Prod 12:183–192
31. Cokelaere MM, Dangreau HD, Daenens P, Arnouts S, Kuhn ER, Decuypere EM-P (1992) Influnce of pure simmondsin on food intake in rats. J Agric Food Chem 40:1839–1842
32. Cokelaere MM, Flo G, Decuyper EM-P, Vermaut S, Daenens P, Van Boven M (1995) Evidences for satiating effect of defatted jojoba meal. Indian Crops Prodct 40:91–96