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The Possible Effects of Bait Container Design on Mouse Feeding Activity in Real-World Structural Baiting Situations

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ABSTRACT: Tamper-resistant rodenticide bait containers are used extensively around the world for a multitude of rodent pest management efforts. A large portion of their use, however, is for protecting industrial food and pharmaceutical plants from commensal rodent invasions. Yet, no research exists as to the possible effects of bait container "architecture" on the feeding activity of the targeted rodents. This study compared two common, yet architecturally different, tamper-resistant bait containers for feeding and general activity as measured by deposited feces and feeding consumption on installed rodenticide bait blocks. The study, primarily involving house mice, was conducted over a 17-week period in a real-world baiting situation along the exterior perimeter of an industrial grain processing plant. The low-profile bait container, as represented by the Multiplex™ brand, exhibited a 17.8% greater amount of fecal pellets and a 15.4% heavier feeding index compared to a high-profile container, as represented by the Bell Laboratories Protecta container.

KEY WORDS: ant feeding activity, bait container design, exterior baiting, house mouse, *Mus musculus*, rodent feeding activity, tamper-resistant bait containers

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INTRODUCTION

Tamper-resistant rodenticide bait containers (also called "bait containers" and "bait boxes") used for exterior rodent baiting programs are designed to minimize non-target animals or humans from contacting the rodenticides, as well as reducing spillage and translocation of the pesticide by rodents. Bait containers are also designed to keep baits attractive and palatable for up to several weeks by protecting the bait from rain, snow, and wind-blown debris.

Tamper-resistant rodenticide containers must be used in those situations where children and/or non-target animals might otherwise contact or have access to the bait (Johnson 1983, NPCA 1985, Jacobs 1990). Commercially manufactured tamper-resistant bait boxes are made for mice and rats and vary in their degree of resistance to tampering depending upon the bait container's "architecture" (i.e., the design and the materials used in the container's construction). Some containers provide minimal levels of tamper resistance, while others are elaborately constructed, extremely durable, and are carefully designed to provide maximal protection to all non-target parties.

Regardless of how a tamper-resistant bait container is constructed, it cannot be considered "tamper-resistant" according to the Environmental Protection Agency (EPA) specifications unless it is secured in place either to the ground, a wall, or to some heavy object (Johnson 1983, USEPA 1995). Despite all the EPA tamper-resistant specifications, however, unless baits are secured within the containers, there is no preventing a rodent from carrying baits out of a container and dropping the bait on the ground or translocating the bait to an area where the bait could be encountered by people, pets and non-target wildlife. Thus, to a large degree, it is also the rodents that may determine "tamper-resistance" (Corrigan 1992 a,b; 1996). Nevertheless, securing baits within the containers is still not a criterion for tamper-resistant baiting.

Over just the past five years, manufacturers have produced several unique bait containers varying in "architectural designs". Changes have been made in the shape, materials, lids, lid positioning, locking mechanisms, access tools, and even the colors used for bait containers.

With changes in construction and design, questions are emerging as to whether or not differences in bait container architecture affect rodent-container behavior. For example, do exterior bait containers when used as perimeter defense programs for commercial buildings– regardless of design– merely serve as substitutes for natural cavities that rodents might investigate in their natural environments? Or might variations in bait container architecture affect the manner in which rodents interact with the containers and/or baits they encounter around commercial buildings and environments? Consider whether or not a container's architecture might cause a rodent to more readily enter (or avoid) a container, spend more (or less) time feeding on the baits contained within, accommodate other rodents to feed at the same time, and so forth.

Real-world studies of exterior bait stations and the behavior of commensal rodents in urban and industrial environments are lacking. Within laboratory settings, only limited studies have been conducted. Morris and Kaukeinen (1988) performed a study with wild-captured but laboratory acclimated house mice (*Mus musculus*) and their feeding activities within six different mouse-size tamper-resistant bait containers under laboratory conditions. They discovered that all of the containers were rapidly investigated by the mice, without any real preference for one container type over another.

Kaukeinen (1987) also, within controlled laboratory conditions, evaluated Norway rat (*Rattus norvegicus*) interactions with bait containers and posed several questions and challenges to container manufacturers. Kaukeinen stated, "Improvements in rodent utilization of bait containers might result from simple design modifications such as the drilling of holes to increase bait odor to the outside, the use of attractants, or the development of a regime of 'weathering' to establish rodent odor marking." Kaukeinen's study called for additional experiments using field ("real-world") conditions.

The purpose of this field study was to address Kaukeinen's insightful request of 17 years ago, and to investigate several aspects of bait container architecture as they might relate to commensal rodent feeding and interaction behaviors in real-world commercial environments. Both non-biological (servicing issues) and biological factors (rodent and non-rodent animal interactions) associated with conventional exterior rodent baiting programs were evaluated in this study. The on-the-job aspects of servicing bait containers as discovered during this study are presented by Collins and Corrigan (2004).

MATERIALS AND METHODS

Study Site and Existing Rodent Pressure

To investigate whether or not rodents might interact differently among bait containers of different design, two bait containers of similar function, yet substantially different design, were tested in a side-by-side comparison under actual use situations outside a large food plant located in west-central Ohio. The plant building measured 61 × 213 m (12,993 m^2).

The plant was bordered by asphalt parking /truck delivery areas on all four sides. Along one of the long sides of the plant, approximately 100 m away, was a large open and unmanaged field of several acres, containing many different species of weeds and field shrubs.

The rodent control records and logs at the plant maintained by the servicing pest professional showed years of heavy exterior mouse and occasional rat pressure. Thus, the bait containers were subject to normal (undisturbed) rodent activity, ambient wind currents, temperatures, direct sun, rain, and other natural climatic and operational factors.

Bait Container Models

The Protecta (Bell Laboratories) and the Multiplex™ (Syngenta Corporation) bait containers were compared in this study. Both of these container models represent high quality tamper-resistant exterior "rat-size" containers. The Protecta bait container is among the pest management industry's top-selling exterior bait containers and can be commonly found at many food plants throughout the United States and around the world. The Multiplex container made its appearance on the U.S. market in spring 2003.

A close comparison of the "architecture" of the two containers is striking (Figure 1). The Protecta container is designed with a high ceiling lid of 14.6 cm (interior floor to ceiling), a shallow (3.0-mm) lid-lip, an 8.0-mm entry step-over ("lip") through a circular portal, and a relatively narrow aisle (4.0 cm) leading to parallel bait "wells" containing 3.5-cm well-walls.

The Multiplex container is designed with a low, flat ceiling (7.62 cm interior floor to ceiling) a 13.0-mm overlapping lid-lip, an absence of any entryway step-over, an 8.0-mm recessed archway entry portal, and a relatively wide aisle (8.0 cm) leading into an "open" area, which instead of baiting wells, leads into "bait rooms" with walls varying between 7 - 8.0 cm. However, the option also exists for the bait to be installed outside of the bait room in the "front" of the Multiplex container. To keep the bait locations between the two different containers as similar as possible, baits were positioned in the Multiplex container in the front area of the station.

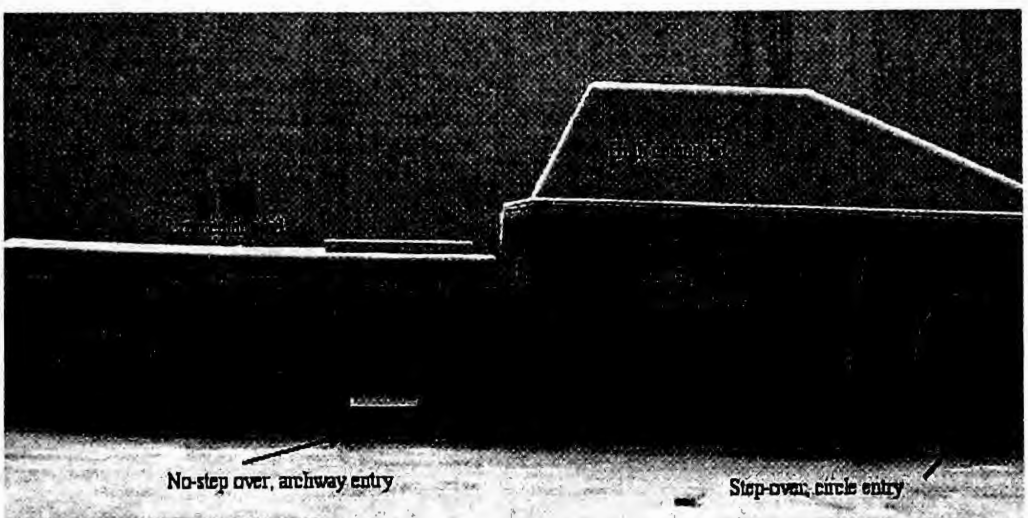

Figure 1. A side view comparison of the Syngenta Multiplex™ low profile bait container (left), and the Bell Laboratory Protecta high profile container. This perspective is certainly how a foraging rodent would encounter either one of the containers.

Figure 2. The positioning of the two paired bait containers along the outside wall of the grain processing plant. To meet tamper-resistant baiting criteria, the containers are secured to concrete patio stones. This securement technique is now among the most commonly employed in the pest management industry.

Bait Container Positioning

Already in place at the facility were 36 black Bell Labs Protecta containers spaced around the plant's foundation at 15.25-m (50-ft) spacing (as per conventional food plant rodent control programs). These containers were collected and removed from the site. In their place, 36 Multiplex bait containers (gray color) and 36 Protecta bait containers (gray color), mounted separately on 30 × 30 × 3.8-cm patio stones, were paired and placed at the same locations around the perimeter foundation of the food plant, for a total of 72 bait containers surrounding the plant. The container pairs were separated by 1-m spacings (Figure 2). Thus, with the exception of a second bait container being available at each "baiting spot", the baiting program remained representative of food plant rodent control.

It is also important to note that due to the dimensions of the plant in comparison to the typical home ranges and dispersal patterns of *M. musculus* (e.g., Crowcroft and Rowe 1963, Mackintosh 1981), it is likely that many, if not most, of the containers were being visited from mice of different family units, particularly for those containers located on the different sides of the plant. However, measurements of the pertinent behavior and population dynamics of the mice feeding on the plant's exterior along these lines were not conducted in this study.

The positions of the containers were staggered in design (A-B-A-B), and the pairs were reversed each service visit to overcome any bias due to geophysical factors, proximity to rodent populations, rodent or insect pheromonal trails and cues, or any other unknown influences. Any mouse leaving one bait container and traveling the 15.25 m along the wall to the next container in either direction would always encounter the alternative container model.

Installed Baits

Into each container, two bait blocks each containing 50 ppm of brodifacoum (one Talon WeatherBlok® XT; and one Final® block, Bell Laboratories, Madison, WI) were installed on the vertical bait holding rods as provided by each manufacturer, in the same locations within each of the containers. All baits were changed out at a maximum of four weeks or sooner due to total consumption, excessive dust, or wetness from rain. If bait was changed out in one station, the bait in the corresponding paired container was also changed out regardless of the bait's condition.

Data collected on rodent activity included dropping counts, rodent gnawing/feeding activity on the bait blocks, insect or other invertebrate feeding activity levels, bait integrity, and notations of any field anomalies. Container "visits" were accounted for via feeding on the bait blocks and via the counting and removal of the fecal pellets during each service. Of course, any new fecal pellets or gnawing evidence on a bait block since the previous visit counted as a new visit.

The number of *actual* mouse visits to the containers was likely to be significantly greater than what was recorded in this study because it is not known how many times mice may enter but not feed or defecate in a container, nor how many times a mouse might defecate or feed during only one visit. Feeding "consumption" by rodents was categorized as minor (<25% of block consumed), moderate (25 - 50%), or heavy (>50% consumption).

All 72 new bait containers were installed on 14 July 2003 and then checked at 24-hr, 72-hr, and then at 9- to 14-day intervals thereafter. Irregularities among servicing of the bait stations (and thus data collection points) were subjected to the needs of the food plant, but all stations were serviced and inspected during any particular visit. The servicing and data collection began on 15 July 2003 and continued through 12 November 2003. A total of 15 data points resulted in a total of 540 observations for each bait container type over a 17-week period.

RESULTS

Rodent Activity

House mice accounted for the majority (>95%) of rodent activity at the study site as determined through fecal pellet analysis and visual observations at the site. Live mice were repeatedly encountered within the bait containers during service visits, and more than 20 house mouse carcasses were removed from the building perimeter throughout the study period. This finding also was consistent with what the servicing pest professional had recorded for the past several years of servicing the plant.

Eastern chipmunks (*Tamias striatus*) were seen occasionally around some of the stations and chipmunk feces were collected on 15 occasions. Norway rat fecal pellets were collected only twice over the study period.

The data for general activity levels of rodent visitation for each type of bait container as evidenced by fecal pellets counts and bait block feeding activity are presented in Tables 1 and 2. As can be seen in Table 1, each type of bait container was *minimally* visited at approximately the same amounts. For example, a total of 24 (66.6%) of the Multiplex were visited over the study period as compared to 26 (72.2%) of the Protecta stations. However, twice as many days passed for the maximum number of Protecta stations to be visited as compared to the Multiplex containers. Overall, there was no difference in the total number of "visitations" to each container type (i.e., 241 total visits vs. 244 total visits).

Correspondingly, there was a 17.8% difference in the total number of mouse feces deposited within the two different containers, with a total of 5,631 feces being collected within the Multiplex as compared to 3,846 feces in the Protecta container (Table 1).

More bait was consumed by mice from inside the Multiplex container then from the Protecta (Table 2). Using the "heavy feeding" index alone, 50% or more of the blocks were consumed in 61 of the Multiplex containers compared to 40 of the Protecta containers over the 17-week period. Considering that house mice tend to leave numerous fecal pellets nearby areas where they feed, this result is not surprising relative to the amounts of feces collected between the two containers.

DISCUSSION

These data indicate that within this real world situation, mice (and ants, as discussed below) both fed and perhaps spent more time in the Multiplex container than in the Protecta container. It may be that if rodents spend more time in a bait container, the chances of the rodents consuming a lethal dose of bait, or perhaps interacting with a trap installed within a station, are increased.

But how can these differences be explained? How much does a bait container's architecture affect rodent behavior inside the containers? Although the complexity of rodent foraging behavior (e.g., Mackintosh 1981) prevents a complete answer to this question, some hypothesis can be drawn. Can the greater mouse activity in the Multiplex container be due to the mice having an aversion to stepping over the front entry lip in the Protecta? We hypothesize that this is not likely, as the mice already negotiate a much higher "step-up" when they climbed the 40-mm ledge of the anchoring patio stone to enter the containers.

It is possible that the recessed floor entry portal in the Multiplex container decreases any initial entrance-hesitation behavior by mice. For example, the head of a mouse is partially or completely inside the entry portal of the container before the rodent shifts its feet from the natural ground substrate to the plastic substrate of the, container. At this point the mouse might already be lured by a smell of bait. It may also be that foraging mice, upon initial approach, detect more food odors emanating

Table 1. Activity levels of Multiplex™ and Protecta exterior bait containers by mice over a 17-week period subject to heavy mouse pressure around a grain processing food plant

Container type	Total number of containers visited $n = 36$ (percent of total)	Number of days occurring for total number of stations to be visited	Total rodent fecal pellets collected (percent of total)	Grand mean value of fecal pellets $n = 15$*	Total number of visitations among brand container (mean percent)
Multiplex	24 (66.6)	41 days	5,631 (59.4)	15.6	241 (44.6)
Protecta	26 (72.2)	71 days	3,846 (41.6)	9.8	244 (45.1)

* mean of all 36 stations containers for the 15 data collection points

Table 2. Total number of bait blocks receiving minor, moderate or heavy feeding activity over a 17-week period for each brand of bait container. Minor (<25% consumption); Moderate (25 - 50%); and Heavy (>50%).

Container Type	Minor	Moderate	Heavy	Moderate and heavy feeding combined
Multiplex™	125	55	61	116
Protecta	159	45	40	85

from one container design than another. Maybe bait odors are more concentrated and escape less out of the Multiplex container's architecture, due to the low ceiling combined with a large overlapping lid and the more open bait room format. All of this may contribute towards channeling food odors out at lower levels, more so than the Protecta's architecture of high ceilings, bait wells, small lid overlaps, and narrower aisles.

If the above is true, then conceivably where the bait blocks are positioned within a container (i.e., outside or inside the Multiplex's "bait rooms", or at the front or back positions within the Protecta, or a vertical vs. horizontal bait securement) may affect rodent entry and subsequent time spent feeding. It may also be that the containers with low ceilings and larger overlapping lid lips, and "double walls", provide a greater "quieting effect" via the deadening of vibrations and sounds from outside the containers. If so, this may create more of a "burrow-like" environment (i.e., the natural protective environment) for a small rodent. Perhaps quieter environments allow small prey species (mice, rats) to perceive greater protection from predators.

If a "quieting effect" is at play, it might explain why the Protecta container exhibited a 15.4% greater amount of minor feeding occurrences on the blocks than the Multiplex (see Table 2). Why would there be more minor feeding occurrences on the blocks in one container type, while at the same time both containers exhibited approximately the same number of visits per container, and a similar overall number of containers received visits? It may be that the mice, although visiting each container type, are more "on edge" in a container where vibrations and noises are more readily picked up. Thus, the mice may not linger as long as they do in the quieter container (.i.e., more time to deposit more feces and feed more thoroughly).

Although it has never been formally researched or documented, pest professionals who service commercial buildings containing both low and high ceiling bait containers have periodically reported to the authors that they note more fecal pellets in the low-ceiling (i.e., low-profile) bait containers than in the high-ceiling containers. In fact, this observation repeatedly heard over the years from astute pest professionals was part of the impetus for this field study.

The implications of the differences in the numbers of fecal pellets between container types must also be considered. More feces result in more "natural weathering" to the containers. Pheromones present within the droppings (as well as within the urine) may play a significant role in causing a cycle of greater entry and activity (Bronson 1979, Hurst 1987, Laland and Plotkin 1991). In other words, more feces result in more "attractive pheromonal cueing", leading to more attraction, and consequently more feces, and so on).

The behavioral aspects of a rodent's initial approach to a "feeding box" and/or the physics involved in bait volatilization raises many questions involving rodent foraging behavior, air currents, heat dissipation, food odor channeling, and probably other factors unknown at this time. Also, some of this may be heavily influenced by daily climatic factors.

The role of possible repellent effects from plastics used in the construction of the containers also cannot be ruled out. In Kaukeinen's (1987) study, he noted "Besides design construction, there were some indications that some plastics may have repellent properties as may some metal container surfaces." We hypothesize, however, that if any repellent factors exist from the plastics, they are diminished if not neutralized after the initial few days or weeks, due to dust, dirt, blown debris, pheromonal markings, urine, feces, and possibly other ambient factors.

Ant Activity and Its Possible Significance to Rodent Activity

Although rodenticide bait containers are concerned primarily with rodent feeding, there is a trend in the structural pest management industry to also offer insect baiting operations within exterior rodenticide containers. With the advent of granular baits for various pest ant species, multi-utility bait containers makes sense.

Interestingly, it may be that foraging ants can provide some clues as to how certain aspects of bait container architecture may impact how mice and other small mammals also interact with containers. In this study, pavement ants (*Tetramorium caespitum*) were the only species of ant observed and collected in the containers. Over the 17 weeks, ants were found foraging in the Multiplex containers on 106 occasions (20% of all possible observations) compared to 19 times (3.5%) in the Protecta containers.

In both models, ants entered the containers through the main entry holes, trailed along the divider walls, and then entered the bait compartments. Although the Multiplex container was specifically designed with ant entry holes on the sides of the container, ants were never observed using these holes. Rather, they entered below the floor tray and emerged up through the rodent securement holes and proceeded along the vertical securement rods to gain access to the bait. On several occasions, ants were observed carrying rodenticide bait particles from the container.

The reasons pavement ants more readily enter and/or feed within the Multiplex container over the Protecta model are unknown. However, as was hypothesized for the mice, perhaps specific air currents are being channeled and are carrying food molecules out of the Multiplex container at greater intensity than in the Protecta container.

Possibly, the ants' antennae receive more stimulation due to the lack of a "step-over lip" in the Multiplex. Without this lip, food molecules are within the height to be detected by the pavement ant's maximal antennal reach. Some research (e.g., Holldobler and Wilson 1990, Helmy and Jander 2003) has suggested that foraging ants utilize their antennae in swinging motions and other movements to contact and navigate to various odor molecules in the air (pheromones, odors of plant juices, seeds, etc.). It is conceivable the ants are detecting volatilizing grain molecules escaping from one container's entry portal more so than the other. The 8.0-mm height of the entry lip on the Protecta container is at least 2.0 mm higher than the maximal extended head, body, and antennal length of *T. caespitum*. It may be that volatilizing food molecules are swept out and over the entry lip and beyond detection of the ants' antennal scoping with the antennae maximally extended upward.

It may also be possible that the plastics used in the construction of the Protecta container have properties more repellent to pavement ants than those of the Multiplex.

CONCLUSION

It should be noted these findings are representative of this particular site over a summer and early fall period. More research is continuing to determine if there is a seasonal effect or if rodents behave differently to the containers in other environments. For instance, will rats interact with the bait containers in the same manner as mice do? It is also not yet known whether or not other locations and environments may yield similar or different results.

Additionally, it is not known, among the dozen or so different bait containers on the market, how each compare when in use. Similarly, how other brands of low-profile bait containers (e.g., Bell's LP® station, the JT Eaton's metal container, the Aegis container, etc.) would compare in similar tests to the Multiplex container tested here, is unknown. In fact, it would require several dozen comparative tests in real-world situations to address the various architectural subtleties among the different models that might affect foraging rodents.

Nevertheless, bait container architecture may be highly significant in the investigation and feeding behavior of rodents as well as of several different invertebrates. And thus, it is the opinion of the authors that manufacturers of both rodent and insect bait containers should investigate the various materials and architectural design within real world environments to possibly maximize pest feeding and investigative behaviors within pesticidal bait containers.

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