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SHORT COMMUNICATION

Toxicological evaluation of native rodenticide formulations against *Mastomys natalensis*: implications for crop production and ecosystem safety

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ABSTRACT

This study evaluated the effectiveness of four rodenticides: Indomethacin, bromadiolone, cement, and a botanical product in controlling *Mastomys natalensis* (multimammate rats). A total of 120 rats were divided into groups of 15, each receiving bait treated with one rodenticide for nine consecutive days. Key parameters such as bait intake, mortality rate, and internal organ changes were monitored. Histopathological analysis showed severe damage in the liver, kidneys, heart, spleen, and lungs of rats treated with Indomethacin, bromadiolone, and cement, with evidence of hemorrhage, discoloration, and weight loss. Indomethacin was the most effective rodenticide, followed by bromadiolone and cement. The botanical rodenticide had no significant impact on mortality or organ pathology. Data analysis using one-way ANOVA and LSD post-hoc tests confirmed significant differences among treatments. The study recommends further research on field applications and ecological effects of these rodenticides.

Keywords: bait consumption; botanical rodenticide; bromadiolone**,** Indomethacin; *Mastomys natalensis*; mortality rate**;** organ toxicity

INTRODUCTION

The most destructive and economically significant vertebrate pests globally are rats. Rodentia, which includes 40% of mammalian species, is found on all continents except Antarctica, New Zealand, and a few islands

(Macdonald, 2001; Nowak, 1999). Rodents threaten food security, infrastructure, and public health with their diastema and increasing incisors for gnawing. The indigenous and abundant multimammate rat (Mastomys natalensis Smith, 1834) is a major rodent problem in sub-Saharan Africa. It is a major pest of pre-harvested and stored crops in eastern and southern Africa (Massawe et al., 2011; Mulungu, 2013; Leirs, 2003). These rodents cause crop damage, food pollution, and parasite and zoonotic disease transmission to humans and cattle. Multimammate rats (Mastomys natalensis) have a major economic impact. These rodents cause 5% to 15% grain crop losses, costing USD 45 million annually and contributing to global food insecurity, affecting over one billion people (Singleton et al., 2003; Makundi, 1991). Some places in Tanzania lose up to 15% of maize output to rats (Makundi et al., 1999; Leirs, 2003). Effective rodent population management is urgently needed, given these implications. These measures vary by location and depend on local rodent species, farming patterns, and farmers' socioeconomic capabilities to adopt control methods (Stenseth et al., 2003; Taylor, 2012). Rodenticides are still suggested by researchers and farmers (Makundi et al., 1999; Ngowo, 2005). Acute and chronic rodenticides have been used during outbreaks with mixed results.

Trapping, hunting, flooding, and fumigation are routinely utilized but seldom reduce rodent populations below economically detrimental levels (Smith, 1994; Thakur et al., 2013). Anticoagulant rodenticides (ARs) have been the main control strategy in Tanzania for decades. ARs were initially effective, but rodent resistance has increased, prompting the development and use of Second-Generation Anticoagulant Rodenticides (SGARs). SGARs are more potent and persistent but pose ecological hazards including secondary poisoning of non-target species and bioaccumulation (Eason et al., 2002; Shiel, 2013). Due to the dearth of effective alternatives and the need for rodent control in agriculture-dependent economies, their usage is warranted. However, the high expense and environmental dangers of commercial rodenticides emphasize the need for low-priced, locally available, and ecologically friendly alternatives. Large-scale investigations using locally manufactured rodenticides have been scarce, especially in smallholder agricultural systems where cost and accessibility are critical (Shiel et al., 2013; Swanepoel, 2017). Sustainable rodent management and food security require closing this gap.

MATERIALS AND METHODS

The study was conducted at the Sokoine University of Agriculture (SUA) Institute of Pest Management (IPM) Laboratory, situated at 06.084' S and 37.065' E. The institute studies pest epidemic prediction, management tactics, and dangers. This study used Sherman live traps to collect 100 adults Mastomys natalensis rats from agricultural fields. Minimum variability was achieved by selecting specimens of equal age and size. One kg of cement (used for desiccation), 200 g of bromadiolone (a potent anticoagulant), and a botanical rodenticide derived from locally used ethno-veterinary plants (pending phytochemical identification) were tested. Taste was improved by baiting with 3 kg of maize bran. The lab had bait crucibles, cages for monitoring, and Sherman traps for captures. To ensure animal welfare and data integrity, all procedures followed ethical and biosafety norms.

A total of 120 adult Mastomys natalensis were live-trapped in corn fields near Sokoine University of Agriculture (SUA). Sherman live traps were used to trap according to Khidr et al. (2018) and Abou-Hashem (2012). These traps capture small mammals without harming them, making them popular in rodent ecological and management studies. Peanut butter and coarse maize bait were employed to improve bait appeal and trapping. This combination attracts and captures M. natalensis due to its excellent palatability. To match the species' nocturnal activity patterns, the traps were deployed late afternoon and reviewed the next morning. After capture, rodents were caged for acclimatisation and experiments. Multimammate rats were humanely captured in the field and taken to SPMC for experimentation. Each rat was housed separately to reduce stress and aggression. For one week, they received 10% crushed maize adjusted to body weight to aid acclimatisation (Khidr et al., 2018). This acclimatisation phase reduced environmental stress and ensured laboratory adaptation (Abou-Hashem, 2012). All methods followed laboratory animal ethics. Cement, indomethacin, bromadiolone, and a plant extract were used to make standardised baits. To achieve uniform distribution and palatability, each bait formulation coated 1 kilogramme of maize bran with 10 g of the rodenticide. After mixing, the bait was divided into 10–20 g servings. These pieces were placed in crucibles for the test animals' ingestion. The laboratory tests used no-choice and free-choice feeding methods, according to Khidr et al. (2018). In the no-choice study, rats received just rodenticide-treated bait to directly assess toxicant ingestion and physiological consequences. The free-choice study gave rats a daily choice between treated and untreated bait, replicating normal feeding. These methods assessed rodenticide lethality and palatability. This dual method

allowed us a complete understanding of rodenticide efficacy under controlled but behaviourally relevant situations.

To avoid competition and for exact monitoring, 15 Mastomys natalensis rats were individually housed in a no-choice feeding experiment. One local rodenticide was mixed into 10 grammes of maize bran for each rat and given daily for nine days to each group. Weighing residual bait feed every 24 hours, measured bait consumption. Rats were weighed before and after the experiment (or at death) to examine the physiological effects of weight reduction. Daily mortality was documented, and dead rats were dissected to determine the cause of death. Post-mortem investigation determined each rodenticide's pathological effects and efficacy while ruling out other causes of mortality. The free-choice feeding experiment tested rodenticide efficacy when rats could select between treated and untreated bait. For nine days, 15 Mastomys natalensis were kept individually and fed 10 grammes of rodenticide-treated and untreated maize bran. To eliminate spatial bias, bait crucible positions were switched daily. After 24 hours, the leftover bait was weighed to determine overall intake and preference. Weight loss as a measure of physiological impact was recorded at the start and end of the experiment (or death) for each rat. Deaths were observed daily and examined post-mortem to confirm rodenticide-related death and identify internal signs. This design revealed toxicological and behavioural reactions under natural feeding settings.

Data collection for no-choice and free-choice feeding trials focused on mortality per dose, mortality over time, and median lethal dosage (LD_{50}). Lethality patterns and dose efficacy were tracked daily by recording rat deaths in each treatment group. Weighing residual bait 24 hours after feeding allowed a reliable assessment of bait intake and preference or aversion. To determine rodenticide-related physiological consequences, each rat was observed for poisoning. Behaviour and toxicology were thoroughly assessed using this methodical methodology. One-way Analysis of Variance (ANOVA) was used to compare treatment groups. If ANOVA showed significant variance, the LSD test at 5% significance level was used to compare group means. P-values below 0.05 showed a statistically significant difference, whereas those over 0.05 indicated no effect. All statistical procedures were performed using Genstat 16th Edition (Genstat, 2005), which supported ANOVA computations and post-hoc comparisons to identify group differences.

RESULTS AND DISCUSSION

The provided figure summarizes the comparative toxicological effects of four rodenticides tested against *Mastomys natalensis* under laboratory conditions. Parameters include average bait consumption, number of deaths, mean time to death, and LD_{50} values. Indomethacin demonstrated the highest potency, consistent with Victor et al. (2008), who reported rapid mortality and liver damage linked to NSAID toxicity. Bromadiolone also proved effective, causing anticoagulant-induced internal bleeding as noted by Mary et al. (2014). Cement showed delayed but complete lethality, aligning with Tommy (2009), who observed digestive obstruction due to cement ingestion. The botanical rodenticide, despite high consumption, exhibited no lethality, supporting findings by Akhtar et al. (2013) and Leirs (2003) regarding the limited acute toxicity of plant-based formulations.

Statistical analysis from the non-choice feeding experiment revealed that bait consumption significantly influenced mortality among the tested rodenticides ($p = 0.013$), while time to death was not statistically significant ($p = 0.051$). The $LSD_{0.05}$ values were 12.78 g for bait consumption and 3.586 days for time to death. As shown in Table 1, 100% mortality (n = 15) was recorded for rats exposed to Indomethacin, bromadiolone, and cement, with respective mean bait consumptions of 7.3 g, 8.5 g, and 16.4 g. Corresponding LD_{50} values were 0.073 g/kg for Indomethacin, 0.085 g/kg for bromadiolone, and 0.164 g/kg for cement, indicating highest potency for Indomethacin. These findings align with Victor et al. (2008), who also reported rapid toxicity and liver damage with Indomethacin exposure. Bromadiolone, known for causing internal hemorrhage by disrupting vitamin K-dependent clotting (Mary et al., 2014), also caused 100% mortality in the non-choice trial. The longer time to death observed for cement (7.33 days) corresponds with previous findings by Tommy (2009), who noted mortality from dehydration and intestinal damage due to gastrointestinal cement solidification. In contrast, the botanical rodenticide showed no mortality despite high consumption (29.5 g), indicating no acute toxic effect at the tested dose. This result is consistent with Akhtar et al. (2013) and Leirs (2003), who emphasized the need for further development and potency improvement of botanical rodenticides. Overall, these results confirm Indomethacin as the most effective rodenticide, followed by bromadiolone and cement, under controlled laboratory conditions.

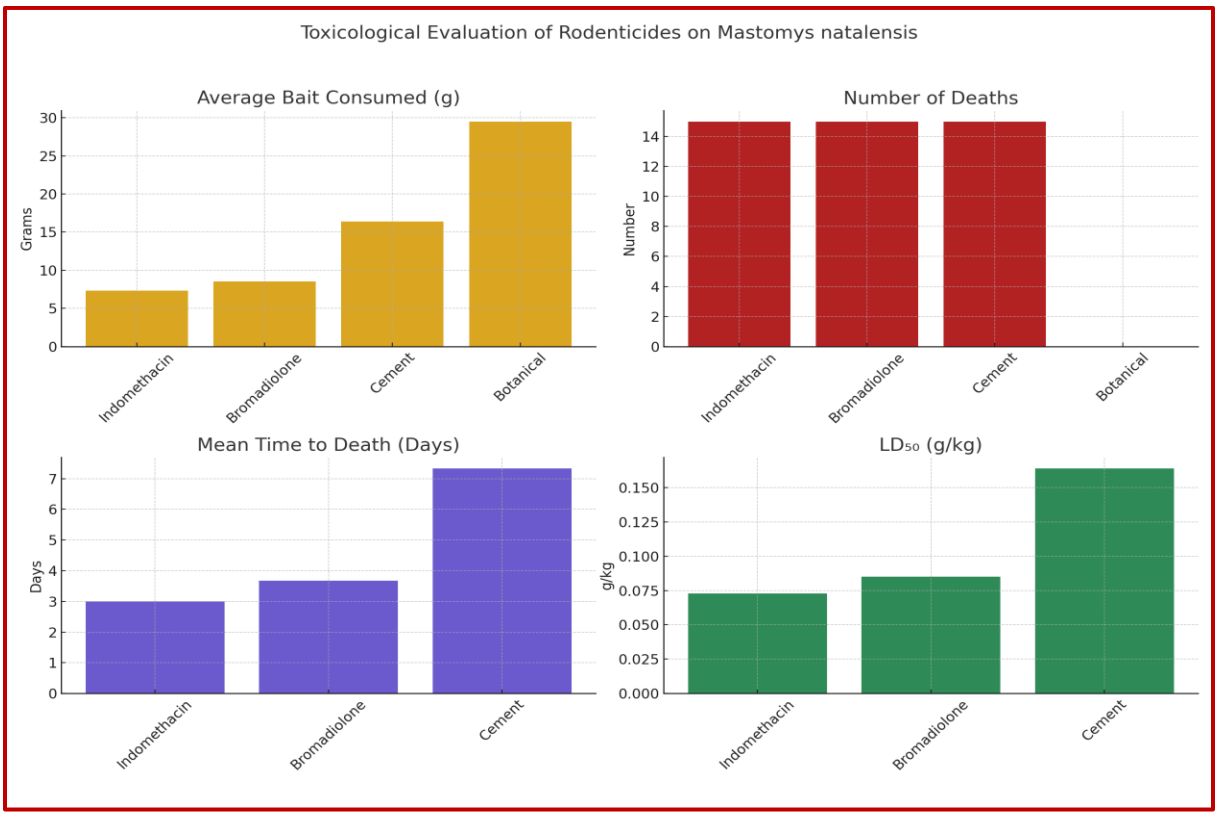

Figure 1. Toxicological effects of rodenticides on multimammate rat (*Mastomys natalensis*)

Table 1. No-choice feeding trial: toxicological effects of rodenticides on multimammate rat

Rodenticide	Average Bait Consumed (g)	Number of Deaths	% Mortality	Mean Time to Death (Days)	LD_{50} (g/kg)
Indomethacin	7.3	15	100%	3.00	0.073
Bromadiolone	8.5	15	100%	3.67	0.085
Cement	16.4	15	100%	7.33	0.164
Botanical	29.5	0	0%	–	–
$LSD_{0.05}$	12.78	–	–	3.586	0.1278

Under free-choice feeding conditions, *Mastomys natalensis* had simultaneous access to treated and untreated bait, allowing for behavioral assessment of bait preference and toxicological effectiveness. Each rodenticide was tested at a dosage of 10 g/kg, and results (Table 2) showed statistically significant differences in bait consumption among treatments ($p < 0.05$), with an $LSD_{0.05}$ of 4.418 g. Indomethacin again proved the most effective, achieving 100% mortality (15/15) with the lowest average bait consumption (3.48 g), confirming its high potency and palatability. This aligns with Victor et al. (2008), who noted rapid onset of toxicity and fatal liver damage from Indomethacin exposure. Bromadiolone caused 66.7% mortality (10/15), with higher bait consumption (10.63 g), suggesting partial avoidance or slower action. This supports findings by Aaron (2017), who reported reduced bromadiolone efficacy under free-choice conditions due to behavioral aversion, and by Mary et al. (2014), who associated bromadiolone toxicity with internal bleeding and liver necrosis. Cement achieved 33.3% mortality (5/15) with an average consumption of 7.53 g. The lower efficacy under free-choice conditions reflects similar findings by Tommy (2009), who observed diminished cement toxicity in the presence of alternative food sources.

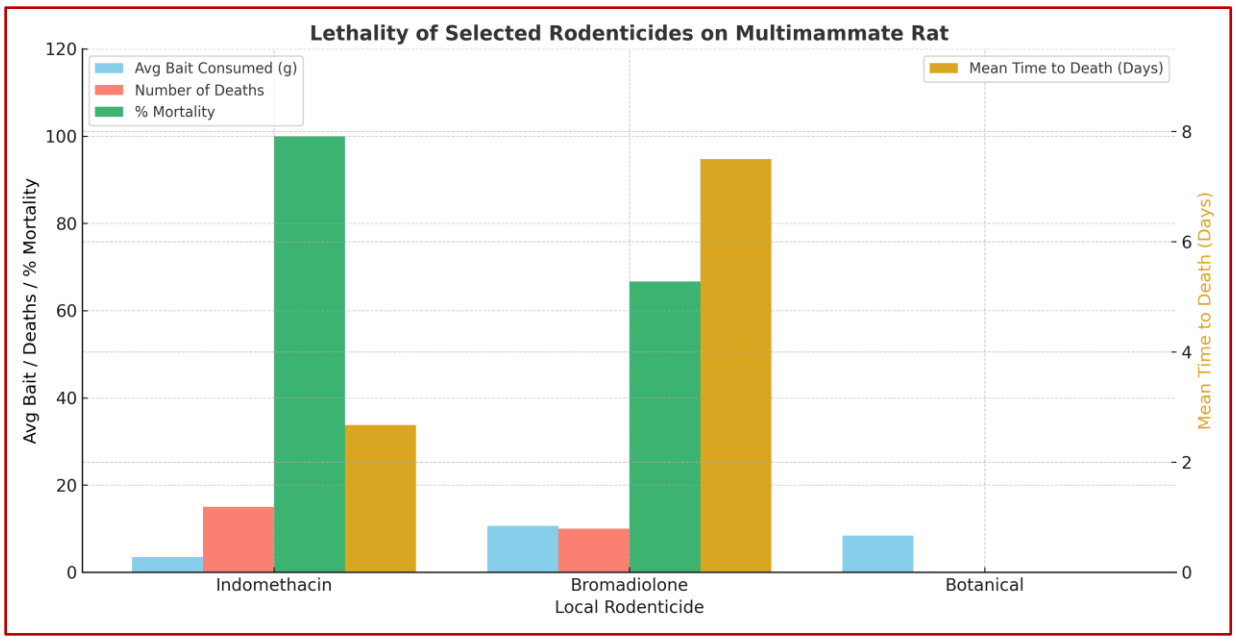

Figure 2. Lethality effects of rodenticides on multimammate rat (*Mastomys natalensis*)

The botanical rodenticide did not cause any deaths among the test rodents, even though the animals consumed a moderate amount of the bait (an average of 8.37 grams per individual). This indicates that the botanical formulation lacks the necessary toxicity to function as an effective acute rodenticide; it does not kill rodents quickly or reliably after ingestion. This result aligns with findings reported by Akhtar et al. (2013) and Leirs (2003), who highlighted similar challenges with plant-based rodenticides. These authors argued that while botanical compounds are attractive due to their natural origin and potentially lower environmental impact, many currently available formulations fail to deliver potent and rapid toxic effects, underscoring the need for further research and improvement in their chemical composition or mode of action.

Table 2. Free-choice feeding trial: lethality of selected rodenticides on *Mastomys natalensis*

Local Rodenticide	Average Bait Consumed (g)	Number of Deaths	% Mortality	Mean Time to Death (Days)
Indomethacin	3.48	15	100%	2.667
Bromadiolone	10.63	10	66.7%	7.5
Botanical	8.37	0	0%	–
$LSD_{0.05}$	4.418	–	–	3.837

In contrast, the mean time to death for rodents varied depending on the type of rodenticide used. Rodents fed Indomethacin-laced bait died on average in about 2.667 days, those exposed to cement-based bait died around 5 days, and those fed bromadiolone died after approximately 7.5 days. However, statistical analysis using the Least Significant Difference test at a 5% significance level ($LSD_{0.05}$ = 3.837 days) showed that these differences in mortality time were not statistically significant. This means that, although there were numerical differences in the time it took for the rodents to die after consuming each rodenticide, these variations could be due to random chance rather than a true effect of the different treatments. Overall, Indomethacin was the most effective rodenticide in terms of causing the highest mortality and doing so in the shortest time under the free-choice feeding conditions used in this study. It was followed by bromadiolone and cement in terms of effectiveness. The botanical rodenticide, despite being consumed, failed to cause any measurable toxic effect, confirming its ineffectiveness as an acute control agent for the multimammate rat in the tested conditions.

CONCLUSION

This study confirms that Indomethacin and bromadiolone are the most effective rodenticides for controlling *Mastomys natalensis*, each achieving high mortality rates within a short time frame, particularly under no-

choice feeding conditions. Cement demonstrated some effectiveness, but its reduced performance in the free-choice trial suggests limited reliability due to feeding behavior and bait selectivity. In contrast, the botanical rodenticide showed no mortality despite substantial consumption, indicating a lack of acute toxicity at the tested dosage. Its utility as an alternative rodent control agent remains inconclusive. Future research should prioritize improving botanical formulations or identifying more potent plant-derived compounds with proven efficacy against rodents.

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AUTHORS CONTRIBUTIONS

Patrick Cleophace Mpombeye: Led the study by designing the experiments, conducting field, laboratory work and drafting the manuscript. *Loth Sikwese Mulungu***:** supervised the research, advised on methodology, and contributed to data analysis and interpretation and manuscript revision. *Andrea Malima Kigeso***:** Assisted with experimental design, reviewed toxicological findings, and supported the interpretation of results. *Nicolaus Anania Mwakalinga*: contributed to histopathological analysis and helped interpret post-mortem observations. *Erasto Andreas Komba***:** Supported field trapping, animal care, data analysis, and manuscript preparation. All authors reviewed and approved the final version of the manuscript.

CONFLICT OF INTERESTS

The authors declare no conflict of interest.

ETHICAL APPROVAL

Permission to conduct the study was granted Institute of Pest Management of Sokoine University of Agriculture (SUA). The study adhered to strict ethical guidelines regarding the treatment of animals, ensuring that the research was conducted in a manner that minimized harm, followed humane protocols, and complied with legal and ethical standards. The ethical considerations taken during the design and execution of this study reflected a commitment to the responsible and respectful use of animals in research, to contribute valuable knowledge for pest control and public health, while safeguarding animal welfare.

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AVAILABILITY OF DATA AND MATERIALS

All datasets analyzed and described during the present study are available from the corresponding author upon reasonable request.

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