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Original scientific paper

The longevity of two types of cereal carriers for rodenticide baits under adverse environmental conditions

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SUMMARY

The protection of quality and safety of stored products requires adequate and regular measures of protection from harmful rodents. Poisonous baits in a variety of formulations, primarily those based on cereals, are the most widely applied method of rodent control. Providing rodenticide baits that are durable over extended periods of time under adverse environmental conditions is an evident challenge for successful rodent control.

The present study focused on examining the effects of particle size of maize- and wheat-based rodenticide bait carriers on bait longevity under unfavourable environmental conditions. Maize and wheat grain fractions with particle sizes <0.8 mm, 0.8-1.25 mm, 1.25-2 mm and >2 mm were kept in a climate chamber for 33 days at temperature varying from 30-35 C˚ and humidity from 90-95%. Baits containing different grain fractions, and supplemented with 1% sorbic acid, were tested for mold development. The same grain fractions without the preservative were used as control baits. Test and control baits were exposed to identical environmental conditions in the climate chamber over the same time period.

Mold development on preservative-free baits was considerably faster and more intensive, compared to baits that contained sorbic acid. Initial signs of mold development on control baits were observed as early as on the third day of testing. Carrier type and fraction size affected mold development significantly. Regarding maize-based baits, mold development was more intestive on grain fractions >1.25 mm, compared to wheat-based grain which enabled more intensive development of mold on fractions with particle size <1.25 mm.

Keywords: rodenticide, bait carrier, mold, wheat, maize, cereals

INTRODUCTION

Rodents account for more than 40% of all mammals, including a small number of harmful species that require active control (Tripathi, 2014). Damage caused by rodents concerns primarily the health and economic aspects, meaning that they may cause health hazard for humans and domestic animals or cause major economic losses by damaging infrastructure or causing harm during production, transport or storage of food and other products (Buckle, 1994).

A global food crisis is worsening and is expected to deepen further in the future, making the protection of food supplies increasingly critical. Rodents are present at every stage of production, distribution and storage, causing losses that cannot be afforded. It is crucial to conduct regular and adequate rodent control measures because effective measures of rodent control can result in at least a moderate 5% increase in food productivity. Generally, rodent control currently relies mostly on rodenticide applications, which is often considered a short-term solution to the problem (Tripathi, 2014). Successful rodent control involves the use of baits that are highly palatable to harmful rodent species. Food palatability for rodents depends on how tasty and attractive looking it is to animals (Young, 1946; Shahwar et al., 2024), and on the size of its fractions (Khan, 1974; Smythe, 1976; Kandhwal, 2009). Daily requirements of specific nutrients, such as proteins, fats or carbohydrates, may also modify animal inclination to one or another type of food (Tripathi, 2014). Depending on rodent behavior and preferences, baits based on single or mixed cereal grains, either whole or crushed, are most often used in preparation of rodenticide baits. Depending on climate, i.e. available cereals, wheat, corn, rice and sorghum are used most often (Jokić et al., 2012; Tripathi, 2014, Shahwar et al., 2015).

Mechanical processing of grain may significantly affect food palatability to rodents (Smythe, 1976; Kandhwal, 2009). Better acceptance of cracked grains over whole grains has been reported for various rodent species (Rao & Prakash, 1980; Leung & Clark, 2005). However, the longevity of treated grain is considerably shorter. In tropical regions, where bait decay is mainly due to mold development, rodent bait shyness is a significant concern. A similar aversion is observed when grain is treated with fungicides that act as repellents for rodents (Smythe, 1976). By supplementing bait with additives that postpone mold development it is possible to extend significantly the longevity of wheat- or maize-based baits (Blažić et al., 2024). A variety of bait formulations based on broken or ground grain, such as granules, pellets, ready-to-use or block baits, also allow attractants to be added to bait in order to raise its palatability to various harmful rodents.

The structure of bait can influence its acceptance by rodents and also significantly impact its rate of decay, particularly mold development. This study focused on examining how the particle size of rodenticide bait carriers, combined with sorbic acid, affects bait longevity under adverse environmental conditions.

MATERIALS AND METHODS

Test baits

Ground maize and wheat grains were used as bait carriers. Their different fractions, based on particle size, were made by sieving. Four grain fractions were made: <0.8 mm, 0.8-1.25 mm, 1.25-2 mm and >2 mm.

Control baits were made for each fraction of both maize and wheat grain. Test baits were made by mixing each fraction individually with 1% concentration of sorbic acid [E200] as a preservative. Control and test baits were prepared in four series (individually mixed), and each series included four replicates. The bait components were mixed on a rotary mixer for 1 h at 20 rpm.

Experimental design

Baits were measured out in portions of 40 g in plastic cups and kept in a climate chamber. Adverse environmental conditions were simulated in the chamber according to ECHA (2023) methodology, including 30-35°C ambient temperature and 90-95% humidity. Initial symptoms of mold development were visually checked at 3-day intervals. Each cup containing bait was kept in the chamber up to a moment when it is completely covered with mold. The monitoring period for mold development lasted 33 days, and all remaining cups were taken out from the chamber after that period.

Control and test baits were exposed to identical environmental conditions. Also, observation was done according to the same principle for both types of bait. The percentage of mold coverage on the bait surface was evaluated, and mold development was quantified on a scale from 0 to 100%.

Data analysis

Data collected on bait coverage with mold were transformed according to the equasion:

$V=\mathrm{sqrt}(X+1)$ (X-initial data representing the percentage of bait surface covered with mold; V-data after transformation). One-way factorial analysis of variance (one-way ANOVA) was used to determine the effect of grain fraction and carrier type (maize or wheat) on the longevity of rodenticide bait carriers supplemented with the preservative of choice under adverse environmental conditions. Further post hoc analyses of comparison were based on Tukey's HSD test. The degree of significance for all comparisons was P<0.05. Identical lettering in tables marked similarities in Tukey's test. The data were processed according to Sokal and Rohlf (1995), and Statistica for Windows 6.0 software (Stat Soft Italia, 1997) was used.

RESULTS AND DISCUSSION

Mold development on maize bait carrier

Mold development was not observed on test baits consisting of maize grain fractions of <0.8 mm and 0.8-1.25 mm. Mold developed after 18 days in 25% of the cups containing grain fraction 1.25-2 mm. After 27 days, the percentage of mold in the same cups rose to 100%. (Figure 1). Regarding the fraction exceeding 2 mm, initial signs of mold development were noticed as early as on the 6th day in 8.3% of the cups. Twelve days after test initiation, mold was found in a total of 41.7% of the cups. After a month, the same cups were 100% covered with mold.

Mold development of 5-10% was noticed during the first inspection in 66.7% of the cups containing control baits with particle size of <0.8 mm (Figure 2). During the second inspection, the cover percentage was 100% in all cups. Similar results were found for the particle fraction 0.8-1.25 mm. Mold coverage in cups containing the grain fraction 1.25-2 mm in the first inspection ranged from 15% to 20%, while the cover was 100% in all cups during the second inspection. Regarding the largest grain fraction, mold covered 20-80% of the surface during the first inspection, and 100% in all cups during the second inspection.

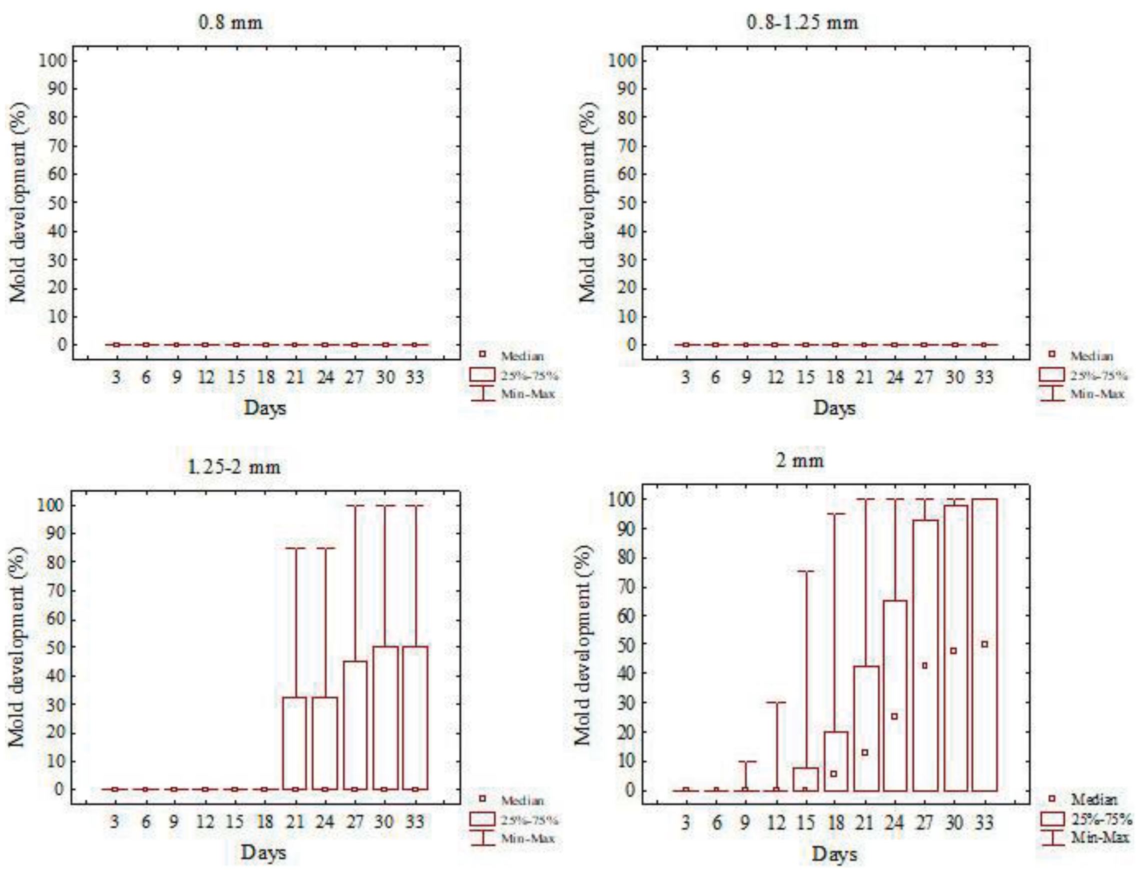

Figure 1. Mold development on test baits containing maize carrier of different particle sizes over the time period of testing

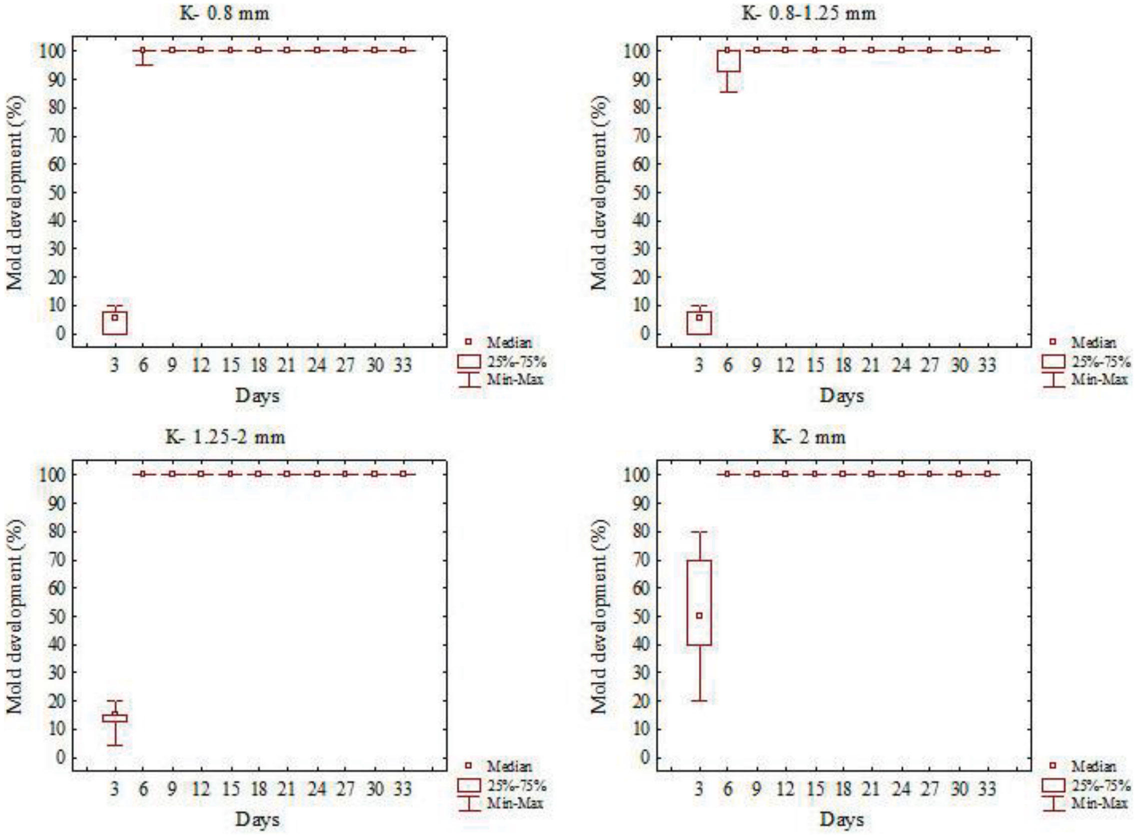

Figure 2. Mold development on control baits containing maize carrier of different particle sizes over the time period of testing

Table 1. Effects of particle size of maize bait on mold development over the test period

			Test baits				Control baits			
Days	F	P	8	8-1.25	1.25-2	2	8	8-1.25	1.25-2	2
3	103.85	0.00	1.00±0.00* **a**	1.00±0.00 **a**	1.00±0.00 **a**	1.00±0.00 **a**	2.18±0.27 **b**	2.18±0.27 **b**	3.91±0.16 **c**	7.17±0.43 **d**
6	20527.2	0.00	1.00±0.00 **a**	1.00±0.00 **a**	1.00±0.00 **a**	1.00±0.00 **a**	10.01±0.03 **c**	9.86±0.09 **b**	10.05±0.00 **c**	10.05±0.00 **c**
9	4970.37	0.00	1.00±0.00 **a**	1.00±0.00 **a**	1.00±0.00 **a**	1.19±0.19 **a**	10.05±0.00 **b**	10.05±0.00 **b**	10.05±0.00 **b**	10.05±0.00 **b**
12	1265.83	0.00	1.00±0.00 **a**	1.00±0.00 **a**	1.00±0.00 **a**	1.38±0.38 **a**	10.05±0.00 **b**	10.05±0.00 **b**	10.05±0.00 **b**	10.05±0.00 **b**
15	420.69	0.00	1.00±0.00 **a**	1.00±0.00 **a**	1.00±0.00 **a**	2.27±0.64 **b**	10.05±0.00 **c**	10.05±0.00 **c**	10.05±0.00 **c**	10.05±0.00 **c**
18	273.16	0.00	1.00±0.00 **a**	1.00±0.00 **a**	1.00±0.00 **a**	3.16±0.79 **b**	10.05±0.00 **c**	10.05±0.00 **c**	10.05±0.00 **c**	10.05±0.00 **c**
21	75.43	0.00	1.00±0.00 **a**	1.00±0.00 **a**	2.93±1.01 **ab**	3.96±0.97 **b**	10.05±0.00 **c**	10.05±0.00 **c**	10.05±0.00 **c**	10.05±0.00 **c**
24	62.21	0.00	1.00±0.00 **a**	1.00±0.00 **a**	2.93±1.01 **ab**	4.69±1.14 **b**	10.05±0.00 **c**	10.05±0.00 **c**	10.05±0.00 **c**	10.05±0.00 **c**
27	46.54	0.00	1.00±0.00 **a**	1.00±0.00 **a**	3.18±1.14 **ab**	5.35±1.31 **b**	10.05±0.00 **c**	10.05±0.00 **c**	10.05±0.00 **c**	10.05±0.00 **c**
30	43.59	0.00	1.00±0.00 **a**	1.00±0.00 **a**	3.26±1.18 **ab**	5.46±1.34 **b**	10.05±0.00 **c**	10.05±0.00 **c**	10.05±0.00 **c**	10.05±0.00 **c**
33	42.88	0.00	1.00±0.00 **a**	1.00±0.00 a	3.26±1.18 **ab**	5.52±1.36 **b**	10.05±0.00 c	10.05±0.00 **c**	10.05±0.00 **c**	10.05±0.00 **c**

* - Ms±Se

Data analysis revealed a significant statistical difference in mold development between test and control baits regarding maize grain fractions (Table 1). There was no statistically significant difference between test baits up to the 15th day, i.e. the size of maize grain fraction had no significant effect on the rate of mold development on test baits considering each inspection period separately. A difference in mold development was confirmed between test and control baits, as well as between control baits. After 15 days, baits containing larger maize fractions differed significantly from those with smaller fractions, considering the amount of mold that developed on each particular day of inspection.

Mold development on wheat bait carrier

Early mold development (5%) was detected on wheat grain consisting of <0.8 mm fraction in 8.3% of all cups (Figure 3). After 15 days, mold was found in a total of 16.7% of the cups. After a month, mold was found in 41.7% of the cups, while 100% cover was found only in 16.7% of the cups when the experiment was terminated. Regarding the particle size 0.8-1.25 mm, mold was initially found in only 16.7% of the cups but its cover rose to 100% by the end of the one-month test period. Mold was not detected on the grain fractions 1.25-2 mm. Regarding the largest fraction, mold was observed in 25% of the cups, and its cover reached 100% only in 8.3% of the cups by the end of the experiment.

In all cups containing the smallest fraction of control baits, 100% mold cover was observed as early as 3 days after the beginning of the experiment. Regarding the fraction 0.8-1.25 mm, 100% cover was found in 83.3% of the cups during the first inspection. In cups containing the fraction 1.25-2 mm, 100% cover was found on the 6th day of testing in 83.3% of the cups. The next inspection confirmed 100% cover in all cups. Similar results were also received for baits consisting of the largest particle size of grain.

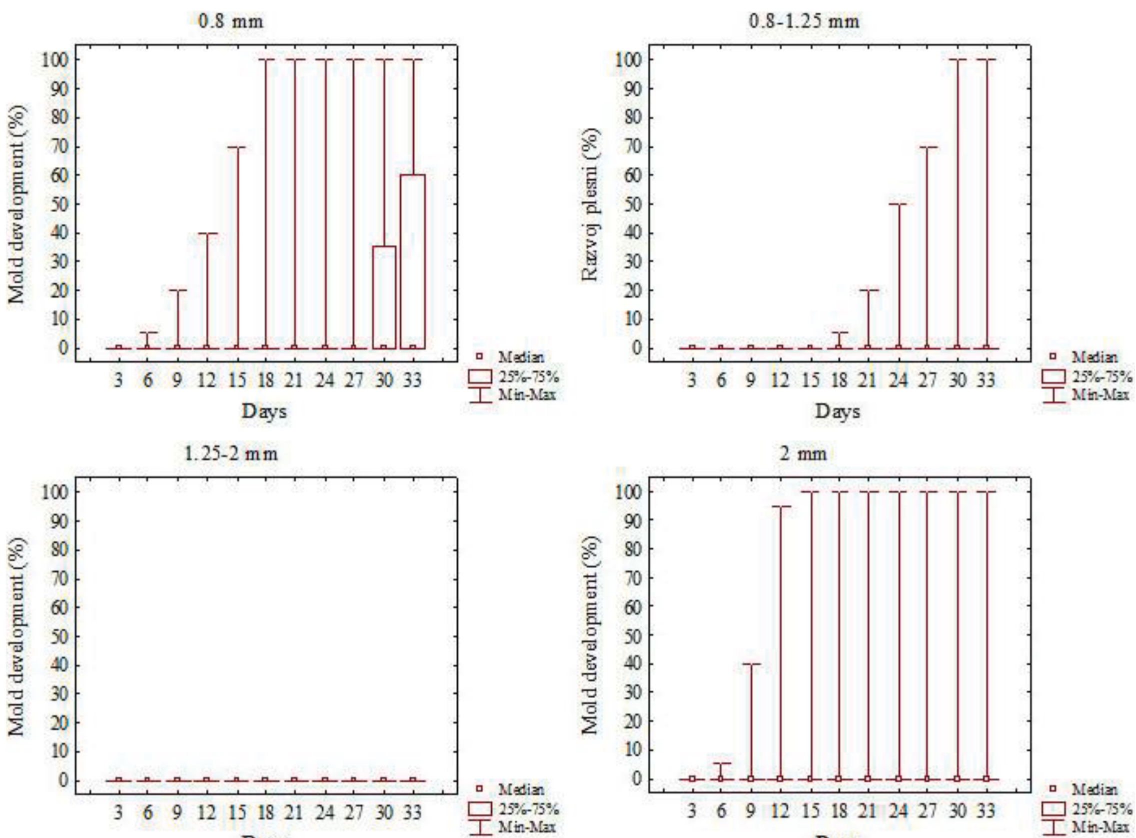

Figure 3. Mold development on test baits containing wheat carrier of different particle sizes over the test period

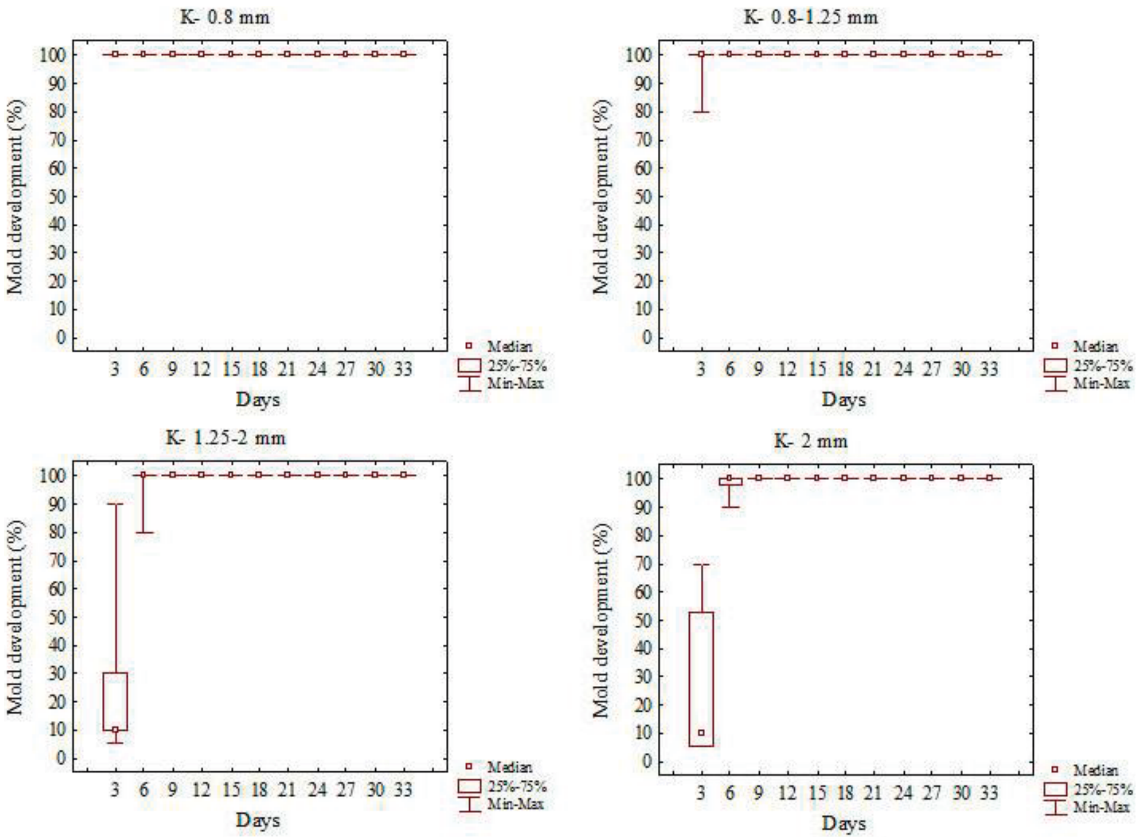

Figure 4. Mold development on control baits containing wheat carrier of different particle sizes over the test period

Table 2. Effects of particle size of wheat grain bait on mold development over the test period

			Test baits				Control baits			
Days	F	P	8	8-1.25	1.25-2	2	8	8-1.25	1.25-2	2
3	116.02	0.00	1.00±0.00* a	1.00±0.00 a	1.00±0.00 a	1.00±0.00 a	10.05±0.00 **c**	9.92±0.09 **c**	4.57±0.73 **b**	4.64±0.72 **b**
6	3910.95	0.00	1.12±0.12* a	1.00±0.00 a	1.00±0.00 a	1.12±0.12 a	10.05±0.00 **b**	10.05±0.00 **b**	9.87±0.12 **b**	9.94±0.06 **b**
9	615.73	0.00	1.29±0.29 a	1.00±0.00 a	1.00±0.00 a	1.45±0.45 a	10.05±0.00 **b**	10.05±0.00 **b**	10.05±0.00 **b**	10.05±0.00 **b**
12	237.22	0.00	1.45±0.45 a	1.00±0.00 a	1.00±0.00 a	1.73±0.73 a	10.05±0.00 **b**	10.05±0.00 **b**	10.05±0.00 **b**	10.05±0.00 **b**
15	182.64	0.00	1.62±0.62 a	1.00±0.00 a	1.00±0.00 a	1.75±0.75 a	10.05±0.00 **b**	10.05±0.00 **b**	10.05±0.00 **b**	10.05±0.00 **b**
18	147.99	0.00	1.87±0.75 a	1.12±0.12 a	1.00±0.00 a	1.75±0.75 a	10.05±0.00 **b**	10.05±0.00 **b**	10.05±0.00 **b**	10.05±0.00 **b**
21	135.54	0.00	1.95±0.76 a	1.31±0.30 a	1.00±0.00 a	1.75±0.75 a	10.05±0.00 **b**	10.05±0.00 **b**	10.05±0.00 **b**	10.05±0.00 **b**
24	105.07	0.00	2.20±0.84 a	1.63±1.51 a	1.00±0.00 a	1.75±0.75 a	10.05±0.00 **b**	10.05±0.00 **b**	10.05±0.00 **b**	10.05±0.00 **b**
27	70.85	0.00	2.51±1.02 a	2.13±0.77 a	1.00±0.00 a	1.75±0.75 a	10.05±0.00 **b**	10.05±0.00 **b**	10.05±0.00 **b**	10.05±0.00 **b**
30	48.11	0.00	3.51±1.04 a	2.51±1.02 a	1.00±0.00 a	2.45±0.86 a	10.05±0.00 **b**	10.05±0.00 **b**	10.05±0.00 **b**	10.05±0.00 **b**
33	42.01	0.00	3.99±1.13 **b**	2.51±1.02 **ab**	1.00±0.00 a	2.67±0.93 **ab**	10.05±0.00 **c**	10.05±0.00 **c**	10.05±0.00 **c**	10.05±0.00 **c**

* - Ms±Se

Data analysis confirmed a significant difference in mold development on wheat grain between the test and control baits over the period of inspections (Table 2). No significant difference was found between test baits until the last inspection, i.e. there was no demonstrated influence of grain particle size of wheat baits on the rate of mold development. Control baits showed no significant difference regarding mold development, except during the first inspection, i.e. the size of wheat bait particles had no effect on mold development.

Differences between two bait carriers

The acquired data show that particle size affects the development of mold on maize and wheat test baits (Figure 5). Wheat grain carrier was found to be more prone to mold development when its particles were small (0.8 mm and 0.8-1.25 mm), while the same tendency of fast mold development in maize grain was found for larger particles (1.25-2 mm and over 2 mm).

Comparing data for the 0.8 mm fraction, a statistically significant difference was found between the test baits of maize and wheat regarding the rate of mold development ($F_{1,262}$=20.92; p=0.00). A significant difference was also confirmed for the fraction size 0.8-1.25 mm ($F_{1,262}$=8.67; p=0.00). Accelerated mold development in fractions up to 1.25 mm was found on wheat baits. The fraction of grain particles sized 1.25-2 mm revealed a significant difference in the rate of mold development between maize and wheat baits ($F_{1,262}$=16.67; p=0.00). A significant difference was also found in the grain size fraction of >2 mm ($F_{1,262}$=15.38; p=0.00). Maize baits showed higher rates of mold development on grain size fractions exceeding 1.25 mm.

CONCLUSION

The results of the present study indicate that the intensity of mold development on rodenticide bait carriers based on maize and wheat free of preservative (control) was significantly greater than it was on maize- or wheat-based carriers supplemented with 1% sorbic acid. Particle size influenced the rate of mold

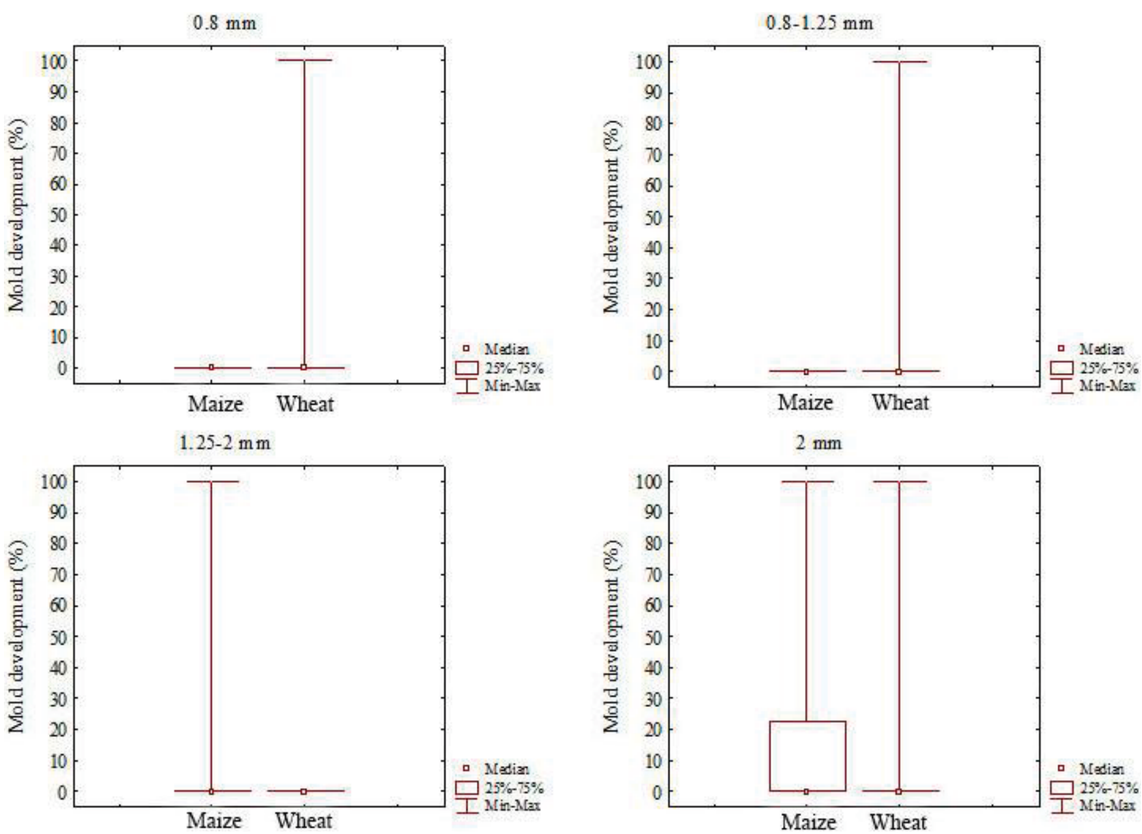

Figure 5. Mold development on maize and wheat test baits consisting of different particle sizes over 33 days of testing

development in both types of bait carriers. Mold development on the maize carrier was most intensive and considerably faster on larger fractions (>1.25 mm), compared to the smaller fractions in which mold failed to appear. In the experiment testing ground wheat grain as a rodenticide bait carrier, particle size affected mold growth but its intensity varied and was more prominent in smaller fractions (<1.25 mm). Comparing the results for test and control cups, it was found that the preservative added to maize or wheat bait carriers, sorbic acid in this instance, greatly contributed toward extending bait longevity.

The varying rates of mold development observed on the tested inert carriers of rodenticide baits highlight a need for further research. Specifically, a more detailed investigation is required to understand the effect of plant species on the binding and retention of preservatives on particle surfaces. Additionally, it is essential to examine how the homogenization process, including the duration and speed of mixer rotation, influences interactions between a preservative and inert bait carrier, affecting mold development under adverse environmental conditions.

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Održivost osnove rodenticidnih mamaka od dve vrste cerealija u nepovoljnim uslovima sredine

REZIME

Neophodno je pravilno i redovno sprovoditi mere zaštite od štetnih vrsta glodara sa ciljem obezbeđenja i očuvanja kvaliteta i zdravstvene ispravnosti čuvanih proizvoda. Primena otrovnih mamaka različitih formulacija, prvenstveno na bazi cerealija, predstavlja najzastupljeniju metodu suzbijanja glodara. Očuvanje rodenticidnih mamaka duži vremenski period u nepovoljnim uslovima sredine predstavlja izazov za uspešno izvođenje deratizacije.

Istraživanje je obuhvatilo ispitivanje uticaja veličine čestica nosača rodenticida na bazi kukuruza ili pšenice na održivost u nepovoljnim uslovima sredine. U inkubatoru, na temperaturi od 30 – 35°C i pri vlažnosti vazduha od 90 – 95%, frakcije kukuruza i pšenice veličina <0,8 mm, 0,8-1,25 mm, 1,25-2 mm i >2 mm su čuvane tokom 33 dana. Ispitivan je razvoj plesni na mamcima koji su sadržavali različite veličine frakcija sa dodatkom 1% sorbinske kiseline. Kao kontrola, korišćene su iste frakcije bez dodatka konzervansa. Test i kontrolni mamci izlagani su istim uslovima u inkubatoru tokom istog vremenskog perioda.

Razvoj plesni na mamcima koji nisu sadržali konzervans bio je dosta brži i intenzivniji u odnosu na mamke koji su sadržavali sorbinsku kiselinu. Prvi znaci razvoja plesni na kontrolnim mamcima uočeni su već trećeg dana testa. Vrsta osnove kao i veličina frakcija mamka značajno su uticali na razvoj plesni. Kod mamaka sa kukuruznom osnovom utvrđen je intenzivniji razvoj plesni kod krupnijih frakcija >1,25 mm za razliku od mamaka sa pšeničnom osnovom gde je razvoj plesni bio intenzivniji kod manjih čestica <1,25 mm.

Ključne reči: rodenticid, nosač rodenticida, plesni, pšenica, kukuruz, cerealije