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Research Article

Bioactivity and stability of spinetoram and spinosad on stored wheat as determined by adults of *Rhyzopertha dominica* (Coleoptera: Bostrichidae) bioassay

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Abstract: To examine the differences between spinetoram and spinosad in their insecticidal activity and stability on the stored wheat, bioassay tests were carried out for six consecutive months at 20 and 30 ± 1 °C by adults of *Rhyzopertha dominica* (F.) (Coleoptera: Bostrichidae). Samples were taken after zero, 2, 3, 5, 7, 15, 30, 60, 90 and 180 days of insecticides application. Results of median lethal concentrations (LC_{50}s) determined after three days of treatment indicated that spinosad was significantly more toxic than spinetoram against the adults. Results also revealed that mortality decline of *R. dominica* was correlated with temperature and the gradual degradation of the two insecticides over time during storage period. The half-life of spinosad and spinetoram on stored wheat were 99.02 and 69.32 days at 20 ± 1 °C, respectively. These were shortened at 30 ± 1 °C to 49.51 and 46.21 days, respectively. However spinosad displayed more bioactivity and stability than spinetoram. It can be concluded that spinosad and spinetoram do not remain persistent and even a slow degradation of these insecticides is likely to occur during wheat storage. Residues of spinosad and spinetoram persist on the wheat grains at levels well below the established tolerance levels.

Keywords: Insecticidal activity, median lethal concentrations, degradation, *Rhyzopertha dominica*

Introduction

The application of insecticides as grain protectants is a significant part of IPM program. These protectants must be safe with low mammalian toxicity and least residues in finished products (FAO, 2017). Many of the most commonly used grain protectants are being reconsidered for their effects on health and environmental safety. Therefore, the evaluation of newer and low-risk pesticides in stored-product protection is a must, for a wise IPM-based strategy. Spinosad has been proved to be one of the most important alternatives to traditional grain protectants and has been already registered in several countries (Subramanyam, 2006). This pesticide, which is based on fermentation products of the actinomycete bacterium, *Saccharopolyspora spinosa* (Thompson *et al.*, 1997), has been evaluated with success for direct application on the grains. These fermentation products are bacterial metabolites, which belong to a group known as ‘‘spinosyns.’’ While spinosad is based on spinosyns A and D (Hertlein *et al.*, 2011), more recently, a new member of the spinosyn group, spinetoram, which is based on two secondary

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metabolites, spinosyn J and L has been commercially introduced in various crops (Sparks *et al.*, 2008, 2012; Jones *et al.*, 2010). Spinetoram is often more effective than spinosad, (Sparks *et al.*, 2008; Jones *et al.*, 2010; Dripps *et al.*, 2011; Yee and Alston, 2012).

Their mechanism of action is to cause hyper excitation of the insect nervous system by activation of the nicotinic acetylcholine receptor (nAChR), specifically the subunit D *α*6, and altering the function of GABA-gated chloride channels, resulting in involuntary muscle contractions and tremors followed by paralysis and insect death (Salgado, 1998; Watson *et al.*, 2010; Morandin *et al.*, 2005). Spinetoram was introduced as a new spinosyn insecticide with greater potency and faster speed of action in comparison with spinosad (Dripps *et al.*, 2008; Sparks *et al.*, 2008). Recently, spinetoram has been tested and found to be effective for the control of several stored grain beetle species (Vassilakos *et al.*, 2012; Isikber *et al.*, 2013). Vassiliakos and Athanassiou (2012) reported that spinetoram is very effective against *R. dominica* and is considered more active and more persistent than spinosad (Dripps *et al.*, 2011). One of the most desired characteristics of a grain protectant is its capability for long-term protection which can range from 6 to12 months (Arthur, 1996; Athanassiou *et al.*, 2004). On the other hand, the lesser grain borer, *R. dominica*, a destructive pest of stored wheat worldwide, is highly susceptible to spinosad even at rates as low as 0.1 mg/kg and one tenth the recommended dose (Fang *et al.*, 2002a). In addition, temperature is one of the most important factors affecting biological processes in all living organisms and is also major factor affecting insecticide bioactivity and its degradation behavior (Athanassiou *et al.*, 2017; Arthur, 1994; Athanassiou *et al.*, 2008a, b). Pesticides residues in food are known as a major safety regard (Fishwick, 1988; Fields, 1999). Hence, it is necessary to leave minimum residue of protectant on food grains, and assuredly below the maximum residue level (MRL) imposed by each country. Consequently, the amount of protectants used and the length of storage should be managed to obtain maximum protection. Therefore, the present work was undertaken with the aim to compare the bioactivity as well as stability of spinetoram and spinosad on stored wheat grains as determined by adults of *R. dominica* bioassay for six months at 20 and 30 ºC.

Materials and Methods

Insecticides

Spinosad (a mixture of 50-95% of spinosyn A and 5-50-% spinosyn D) Spinosyn A: Spinosyn D.

Spinetoram (a mixture of 3'-O-ethyl-5,6-dihydro Spinosyn J and 3'-O-ethyl Spinosyn L) 3'-O-ethyl-5,6-dihydro Spinosyn J: 3'-O-ethyl Spinosyn L.

The insecticide formulations used were Radiant (12% SC) for spinetoram and Spintor (24% SC) for spinosad which produced by Dow Agro-Sciences.

Insecticide application

Six kilograms of wheat grains (variety Shandaweel1) were divided into six groups. The first two groups (spinetoram^A and spinetoram^B), each of them was mixed with 100 ml water solution of spinetoram to give a concentration of 10mg (a.i.) /kg, the second two groups (spinosad^A and spinosad^B), each of them was mixed with 100 ml water solution of spinosad to give a concentration of 1mg (a.i.) /kg, the third two groups (control ^{A} and control ^{B}), which served as controls, each of them was mixed with 100 ml distilled water. The groups of spinetoram^A, spinosad^A and control^A were stored in the incubator at 20 ± 1 °C. The others (spinetoram^B, spinosad^B and control^B) were stored at 30 ± 1 °C. Wheat grains were well treated by freezing at -18 °C for two weeks before pesticide and pest application to eliminate any possible infestation by any other species.

Sampling

Samples of wheat grains (from each insecticide treated or untreated groups) were taken randomly at intervals of 0 (2h after application), 2, 3, 5, 7, 15, 30, 60, 90 and 180 days.

Insects

Laboratory strain of *R. dominica* was used as an adult stage in these experiments. This strain was continuously reared free of insecticidal contamination for several years. These insects were reared in glass jars (approx. 250ml), each jar contained (about 200g) wheat grains and covered with muslin cloth and fixed with a rubber band. Insect cultures were kept under controlled conditions of 27 ± 2 °C and 65 ± 5% RH in the rearing room of the laboratory.

Bioassay tests

Spinetoram and spinosad were applied as solutions against *R. dominica* adults in wheat grains at six insecticidal concentrations. Water solution (2 ml of each insecticide) was added to (20g) wheat grains (in glass jars of approx. 250ml) to give 12, 10, 5, 2.5, 1.25 and 0.625mg (a.i.) of spinetoram/kg and 1.2, 1, 0.5, 0.25, 0.125 and 0.0625mg (a.i.) of spinosad/kg. In addition (20 g) wheat grains, which served as controls, were treated with (2 ml) distilled water. The glass jars of treated wheat grains were manually shaken for 10 min to achieve an equal distribution of the insecticide in the entire grain mass. Batches (20 adult) insects of *R. dominica* (1-2 week-old) were introduced to different treatments. Every treatment was conducted in three replicates. Glass jars were covered with muslin cloth and fixed with rubber bands. The bioassay tests were conducted for each tested insecticide at 20 ± 1 and 30 ± 1 ºC and 65 ± 5% RH. Mortality was recorded after 3 days from the initial treatment.

Determination of insecticide residual toxicity

Three replicates (each replicate was 20g of wheat grains) of each date of sampling after insecticide application were placed in glass jars of approx. 250ml. Batches (20 adult) insects of *R. dominica* (1-2 week-old) were introduced to wheat grains in each glass jar. The laboratory conditions and the exposure time of adults to treated and untreated wheat grains were the same as in the bioassay tests.

Half-life calculation

Half-life times ($t_{1/2}$) of spinetoram and spinosad were calculated mathematically according to Moye *et al.* (1987). The dissipation kinetics of pesticide residues were determined by plotting residue against elapsed time of application, and equation of best curve fit with maximum coefficients of determination (R^2) was determined. For dissipation of targeted pesticides in the samples, exponential relationship was found to be applicable corresponding to the general first-order kinetics equation:

$$C_t = C_0 e^{-kt}$$

Where C_t represents the concentration of the pesticide residue at time t, C_0 represents the initial deposits after application and k is the constant rate of pesticide disappearance per day. The dissipation half-life times of the investigated insecticides were calculated using the following equation:

$$t_{1/2} = ln\ (2)/k$$

Data analysis

Data were analyzed using probit analysis models (Finney, 1971) using a computer program of Noack and Reichmuth (1978). The lethal concentrations needed to kill 50, 90 and 99% of populations, their confidential limits (95%), slopes and insecticide persistence or residues were computed. A significant difference between LC_{50} values was based on overlap of 95% confidence intervals (Aydin and Gürkan, 2006). Mortality and residues data were subjected to analysis of variance (ANOVA) according to the GLM (General Linear Model). Significant differences in the means were separated by using LSD test (least significant difference). Data processing was conducted by SAS/STAT software 9.1.3 (2003).

Results

Bioactivity of spinetoram and spinosad

The results indicated that spinosad was significantly more toxic than spinetoram to the adults of *R. dominica*, LC_{50} values of spinosad and spinetoram were 1.24 and 5.80 mg (a.i.)

/kg, respectively, where mortality was recorded after 3 days of the treatment at 30 ± 1 °C and 65 ± 5%RH. While at 20 ± 1 °C, these values increased significantly for spinosad and spinetoram to 1.75 and 8.76mg (a.i.) /kg, respectively (Table 1).

Results also exhibited that, in spinetoram treatment, the taken samples of wheat grains stored at 30 ± 1 °C, gave the highest mortality percentages of *R. dominica* adults (the insect mortality was recorded after 3 days of the exposure), these decreased gradually from 62.22% after two hours (zero time) to 37.78% after 2 months of the insecticide treatment. While at 20 ± 1 °C, the mortality percentages of *R. dominica* adults decreased gradually from 53.33% after two hours (zero time) to 33.33% after 2 months of the insecticide application. Whereas, in spinosad experiment, the samples of wheat grains stored at 30 ± 1 °C, gave mortality percentages of *R. dominica* adults of 42.22% after two hours (zero time) which decreased to 20.00% after 2 months of the insecticide treatment. At 20 ± 1 °C, the mortality percentages of *R. dominica* adults decreased gradually from 34.44% after two hours (zero time) to 21.11% after 2 months of the insecticide application. The results also indicated that the samples of wheat grains stored for two months gave mortality of 20 to 37% in the insects depending on the type of pesticides and storage temperatures decreased as storage time increased (Table 2).

Table 1 Lethal concentrations of spinetoram and spinosad against the adults of *R. dominica* at 20 ± 1 and 30 ± 1 ºC.

Insecticide	Lethal concentrations (mg of ai /kg) and their 95% confidence limits[3]			Slope ± SD	R
	LC_{50}	LC_{90}	LC_{99}		
Spinetoram[1]	8.76[a] (5.27-14.54)	54.21[a] (32.64-90.03)	239.64[a] (144.29-398.01)	1.69 ± 0.59	0.928
Spinetoram[2]	5.80[a] (3.45-9.77)	44.47[a] (26.42-74.83)	233.93[a] (139.01-393.66)	1.57 ± 0.64	0.855
Spinosad[1]	1.75[b] (0.95-3.2)	11.87[b] (6.47-21.78)	56.55[b] (30.83-103.73)	1.54 ± 0.65	0.987
Spinosad[2]	1.24[b] (0.70-2.18)	8.68[b] (4.93-15.27)	42.44[b] (24.12-74.69)	1.56 ± 0.64	0.948

1: Treatment at 20 ± 1 ºC, 2: Treatment at 30 ± 1 ºC, 3: Mortality calculated after 3 days of the treatment, R: Correlation coefficient of regression line, SD: Standard deviation of mortality regression line.
Different lowercase letters within each column indicate significant differences ($p < 0.05$).

Table 2 Residual toxicity of spinetoram and spinosad against the adults of *R. dominica* on the wheat grains stored at 20 ± 1 and 30 ± 1 ºC.

Days after insecticide application	Mortality (Mean ± SD) (%)[1,2]			
	Spinetoram[3] (10 mg a.i./kg)	Spinetoram[4] (10 mg a.i./kg)	Spinosad[3] (1 mg a.i./kg)	Spinosad[4] (1 mg a.i./kg)
0[5]	53.33 ± 0.00a	62.22 ± 1.92a	34.44 ± 1.92a	42.22 ± 1.92a
2	51.11 ± 1.92ab	58.89 ± 1.92ab	33.33 ± 0.00ab	40.00 ± 1.00ab
3	48.89 ± 1.92bc	57.78 ± 1.92bc	31.11 ± 3.85abc	38.89 ± 1.92bc
5	45.56 ± 1.92cd	54.44 ± 1.92cd	28.89 ± 3.85bcde	36.67 ± 0.00cd
7	43.33 ± 0.00de	52.22 ± 1.92de	27.78 ± 1.92cde	35.56 ± 1.92d
15	41.11 ± 1.92ef	48.89 ± 1.92e	25.56 ± 1.92def	32.22 ± 1.92e
30	37.78 ± 1.92f	43.33 ± 0.00f	24.44 ± 1.92ef	27.78 ± 1.92f
60	33.33 ± 0.00g	37.78 ± 1.92g	21.11 ± 1.92fg	20.00 ± 1.92g
90	31.11 ± 1.92g	28.89 ± 1.92h	17.78 ± 1.92g	14.44 ± 1.92h
180	11.11 ± 1.92h	5.56 ± 1.92i	8.89 ± 1.92h	3.33 ± 0.00i
LSD	3.36	3.81	4.92	3.12

1: Mortality was zero in control treatments, and the mortality was calculated after 3 days of the treatment.
2: Means in each column for insecticide mortality followed by the same letters are not significantly different as determined by the LSD-test at ($P < 0.05$).
3: Treatment at 20 ± 1 ºC, 4: Treatment at 30 ± 1 ºC, 5: Two hours after the insecticide treatment (zero time).

Stability of spinetoram and spinosad

The half-life values, residues and loss rates of spinetoram and spinosad on wheat grains are shown in Table (3). The half-life values of spinetoram and spinosad were 69.32 and 99.02 days in the treatments at 20 ± 1 °C, respectively. These values were lessened at 30 ± 1 °C to 46.21 and 49.51 days, respectively.

Spinetoram residues decreased gradually after 0, 2, 3, 5, 7, 15, 30, 60, 90 and 180 days of the treatment at 20 ± 1 °C to 9.75, 9.07, 8.46, 7.52, 6.81, 6.34, 5.68, 4.68, 3.24 and 1.53 mg (a.i.) /kg which indicated loss rates of 0, 6.77, 13.23, 22.87, 30.15, 34.97, 41.74, 52.00, 66.70 and 84.31%, respectively. While at 30 ± 1 °C, these residues were 9.45, 8.35, 8.01, 6.92, 6.29, 6.34, 5.58, 4.38, 3.57, 2.41 and 0.47 mg (a.i.) /kg, indicating loss rates of 0, 11.64, 15.24, 26.77, 33.44, 40.95, 53.65, 62.22, 74.50 and 95.03% after the aforementioned period of days, respectively. In case of spinosad treatment at 20 ± 1 °C, its residues were 0.96, 0.91, 0.84, 0.77, 0.73, 0.66, 0.62, 0.53, 0.45 and 0.24 mg (a.i.) /kg, which showed loss rates of 0, 5.21, 12.50, 19.79, 23.96, 31.25, 35.42, 44.79, 53.13 and 75.00% after 0, 2, 3, 5, 7, 15, 30, 60, 90 and 180 days of the treatment, respectively. Whereas in spinosad treatment at 30 ± 1 °C, the residues were 0.91, 0.84, 0.81, 0.75, 0.71, 0.61, 0.51, 0.35, 0.24 and 0.07 mg (a.i.) /kg, which revealed loss rates of 0, 7.69, 10.99, 17.58, 21.98, 32.97, 43.96, 61.54, 73.63 and 92.31% after the above mentioned indicated days, respectively. The data of insecticide residues revealed also that the variation in the degradation of the tested insecticides was significantly affected by the increase in the time after the treatments.

Table 3 Stability of the insecticides tested on stored wheat grains.

Days after insecticide application	Spinetoram[1]		Spinetoram[2]		Spinosad[1]		Spinosad[2]	
	Stability[3]	Loss (%)	Stability[3]	Loss (%)	Stability[3]	Loss (%)	Stability[3]	Loss (%)
0[4]	9.75 ± 0.00a	0	9.45 ± 0.66a	0	0.96 ± 0.09a	0	0.91 ± 0.06a	0
2	9.09 ± 0.57ab	6.77	8.35 ± 0.58b	11.64	0.91 ± 0.00ab	5.21	0.84 ± 0.00ab	7.69
3	8.46 ± 0.51bc	13.23	8.01 ± 0.58b	15.24	0.84 ± 0.12abc	12.50	0.81 ± 0.05bc	10.99
5	7.52 ± 0.61cd	22.87	6.92 ± 0.66c	26.77	0.77 ± 0.12bcd	19.79	0.75 ± 0.00cd	17.58
7	6.81 ± 0.00de	30.15	6.29 ± 0.34cd	33.44	0.73 ± 0.06cd	23.96	0.71 ± 0.06d	21.98
15	6.34 ± 0.40ef	34.97	5.58 ± 0.38d	40.95	0.66 ± 0.07de	31.25	0.61 ± 0.05e	32.97
30	5.68 ± 0.38fg	41.74	4.38 ± 0.00e	53.65	0.62 ± 0.07de	35.42	0.51 ± 0.04f	43.96
60	4.68 ± 0.00g	52.00	3.57 ± 0.27e	62.22	0.53 ± 0.05ef	44.79	0.35 ± 0.00g	61.54
90	3.24 ± 1.25h	66.70	2.41 ± 0.19f	74.50	0.45 ± 0.05f	53.13	0.24 ± 0.04h	73.63
180	1.53 ± 0.20i	84.31	0.47 ± 0.16g	95.03	0.24 ± 0.04g	75	0.07 ± 0.00i	92.31
LSD	1.12		0.94		0.16		0.08	
Half-life (Day)	69.32	-	46.21	-	99.02	-	49.51	

1: Treatment at 20 ± 1 ºC, 2: Treatment at 30 ± 1 ºC.
3: Insecticide stability on the stored wheat grains (mg of ai /kg) (mean ±SD). Means in each column for insecticide residues followed by the same letters are not significantly different as determined by the LSD-test at $P < 0.05$.
4: Two hours after the insecticide treatment (zero time).

Discussion

It is desirable and an important advantage when the residual bioactivity of low-toxicity insecticides are highly effective (such as some biopesticides) for use in stored-grain protection. Persistence of some protectants, such as organophosphorus compounds is not a suitable quality because it is related with high amounts of toxic residues in food, which could have serious hazards for human health. Spinosad is registered by the US Environmental Protection Agency for use in stored products in the USA and its active ingredient is registered for use on more than 250 different crops (Subramanyam *et al.*, 2003), as an alternative to traditional grain protectants. Based on the obtained results of the lethal concentration values, spinosad is more toxic than spinetoram against the adults of *R. dominica*. Also, there are some studies published about efficacy of spinetoram against several stored grain insects. It was effective only in the high doses of 5 and 10 mg of a.i./kg of grain and ineffective at 2 mg of a.i./kg of grain after 21 days of exposure in treated wheat, it was less effective than spinosad (Vassilakos *et al.*, 2012; Azab, 2015). On the contrary, Vassilakos and Athanassiou (2012a, b, 2013) reported that spinetoram was equally and in some cases more effective than spinosad against major stored-product beetle species. In several investigations spinetoram was very effective against a wide range of pests, in several crops, often more effective than spinosad (Sparks *et al.*, 2008; Jones *et al.*, 2010; Dripps *et al.*, 2011; Yee and Alston, 2012).

Regarding the effectiveness of the residues of the tested insecticides, although the activity of both insecticides was clearly high and continued for more than three months (with the consideration that the insect mortality was determined only after three days of the insect-wheat sample exposure) the activity was affected by the interaction between the temperature and time of the experiment. Although temperature affected efficacy of spinosad and spinetoram on *R. dominica* adults positively it affected toxicants remains on wheat negatively. These results are in agreement with the published results of Athanassiou *et al.* (2017) who found that the spinosad was more effective at high temperatures and the efficacy of spinosad decreased with time at high temperature against *Ostrinia nubilalis* (Hübner) (Lepidoptera: Crambidae) (Musser and Shelton, 2005). The results of this study showed that spinetoram and spinosad may cause mortality of 20 to 37% one month after treatment against *R. dominica*. In Kenya, Mutambuki *et al.*, (2002) revealed also that spinosad at 0.35, 0.70, and 1.44 mg/kg applied to stored corn gave effective control of larger grain borer and maize weevils for a period of 24 weeks. Fang et al. (2002a) and Fang and Subramanyam (2003) reported that spinosad gave a good residual activity, which makes it an ideal protectant for stored grains. On the other hand, some studies demonstrated that the long term effectiveness of spinosad on wheat was highly affected by several factors, biotic or abiotic such as insect species, the type of grain, the concentration and the registered rate of 1 mg of a.i./kg of grain of spinosad was not high enough to control all investigated insects species, immediately after grain treatment and 180 days after the grain treatment, as well (Fang *et al.*, 2002a; Subramanyam *et al.*, 2003; Toews and Subramanyam, 2003; Chintzoglou *et al.*, 2008; Athanassiou *et al.*, 2008a, b; Bonjour and Opit, 2010). Based on the obtained results of the residues and half-life values of spinetoram and spinosad, it can be assumed that they do not remain stable and a gradual and slow degradation of the toxicants does occur during the storage period. These results are in agreement with the previous studies of Fang *et al.* 2002b and Daglish and Nayak 2006, who in laboratory investigation observed that a loss of more than 25% of spinosad residues occurred in treated wheat soon after application. However, the significant decrease in mortality of *R. dominica* that was recorded during storage time can be attributed to a gradual breakdown of the toxicants over time. Moreover, at the application rate of 1 mg/kg, there was about 25-30% loss of spinosad through grain storage, leaving 0.70-0.75 mg/kg spinosad remains on grain (Subramanyam, 2006; Daglish and Nayak, 2006). Various types of protectants lose activity at different rates depending on the temperature of storage. Higher temperatures generally result in greater rates of decay of protectant activity (Arthur 1994; Athanassiou *et al.*, 2008a, b). Pesticides residues in food are known as a major safety concern (Fishwick, 1988; Fields, 1999), therefore it would be necessary to leave a minimum residue of protectant on the grain that should be below the maximum residue level (MRL). Hence, the use of a pesticide of very low mammalian toxicity, such as spinetoram (Rat oral LD_{50} > 5000 mg/kg of body weight) can be considered as a safe solution in this regard. Also, the maximum residue limits for spinosad on grain were approved by the CODEX Committee on Pesticide Residues in 2005. The CODEX tolerance is 1 mg/kg.

Conclusion

The current laboratory study indicated that spinetoram and spinosad residues slowly broke down and their activity was affected by the wheat storage periods and the tested temperatures. Also, spinosad showed higher activity and stability than spinetoram.

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اثرات حشره‌کشی و پایداری سموم اسپینتورام و اسپینوزاد روی حشرات کامل سوسک کشیش *Rhyzopertha dominica* (Coleoptera: Bostrichidae) در انبار گندم

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چکیده: برای سنجش اثرات حشره‌کشی و پایداری سموم اسپینتورام و اسپینوزاد روی حشرات کامل سوسک کشیش *Rhyzopertha dominica* (F.) (Coleoptera: Bostrichidae) آزمایش‌های زیست‌سنجی در مدت شش ماه در دمای ۲۰ و ۳۰ درجه سلسیوس انجام گرفت. نمونه‌برداری‌ها از زمان صفر، ۲، ۳، ۵، ۷، ۱۵، ۳۰، ۶۰، ۹۰ و ۱۸۰ روز پس از تیمار انجام شد. نتایج LC_{50} سه روز پس از تیمار نشان داد که اسپینوزاد برای حشرات کامل به‌طور معنی‌دار سمی‌تر از اسپینوزاد بود. هم‌چنین نتایج نشان داد که میزان مرگ‌ومیر حشرات کامل با افزایش دما و کاهش تدریجی اثرات حشره‌کش‌ها همبستگی دارد. نیم عمر سموم اسپینوزاد و اسپنتورام در دمای ۲۰ درجه سلسیوس به‌ترتیب ۹۹/۰۲ و ۶۹/۳۲ روز بود. اما در دمای ۳۰ درجه سلسیوس به‌ترتیب ۴۹/۵۱ و ۴۶/۲۱ روز بود. بنابراین سم اسپینوزاد نسبت به اسپینتورام سمیت و دوام بیش‌تری داشت. لذا می‌توان نتیجه گرفت که اسپینوزاد و اسپینتورام به‌تدریج در انبار گندم تجزیه می‌شوند. هم‌چنین باقی‌مانده اسپینوزاد و اسپینتورام در دانه‌های گندم در زیر آستانه تحمل باقی می‌ماند.

واژگان کلیدی: اثرات حشره‌کشی، میانه غلظت کشنده، تجزیه، سوسک کشیش