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Bioactivity of eugenol, a major component of essential oil of Ocimum suave (Wild.) against four species of stored-product Coleoptera

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Bioactivity of eugenol, a major component of essential oil of Ocimum suave (Wild.) against four species of stored-product Coleoptera

(*Keywords:* Coleoptera, *Sitophilus granarius*, *Sitophilus zeamais*, *Tribolium castaneum*, *Prostephanus truncatus*, toxicity, repellency, *Ocimum suave*, eugenol essential oil)

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Abstract. Toxicity and protectant potential of eugenol against *Sitophilus granarius, Sitophilus zeamais, Tribolium castaneum* and *Prostephanus truncatus* was investigated in the laboratory using contact toxicity, grain treatment and repellency assays. Eugenol applied topically, impregnated on filter papers, whole grains or glass pebbles was highly toxic to all the four species. Beetle mortality was dosage-dependent. Eugenol was more effective on grain than on filter paper discs since the lowest dosage of 1 µl/kg of grain killed all the beetles within 24 h. The effectiveness of eugenol was significantly reduced by the length of storage after application. For grains bioassayed after 10 days of storage following treatment mortality decresed to less than 30% even with the highest dose of 10 µl/kg. Eugenol was also highly repellent to the four beetle species tested with overall repellency in the range of 80–100%. Development of eggs and immature stages inside grain kernels was completely inhibited by eugenol treatment.

1. Introduction

Sitophilus and *Tribolium* species are major pests of stored grains and grain products in the tropics. The recent accidental introduction of the larger grain borer, *Prostephanus truncatus* into African has added a new dimension to insect pest problems in storage, through its remarkable ability to damage well-dried maize, even when stored on the cob.

This beetle is currently a more serious pest in parts of sub-Saharan Africa than its native Central America (Dick, 1988).

The development of insecticide-based techniques for protecting grains in small traditional farm stores in Africa has only been partially successful because of the high cost of synthetic insecticides and erratic supply due to foreign exchange constraints. There are also health risks to farmers and other hazards to the environment as a result of misuse of insecticides. Many small-scale farmers in Africa mix stored foodstuffs with different kinds of plant materials for protection against pest damage (Hassanali *et al*., 1990; Poswal and Akpa, 1991; Talukder and Howse, 1995). The use of these traditional materials has recently stimulated active research to establish the scientific basis for their continued use regarding their efficacy, active constituents and effective application technology (Hassanali *et al*., 1990; Poswal and Akpa, 1991; Weaver *et al*., 1991; 1994a, 1994b; Regnault-Roger *et al*., 1993; Schmidt and Streloke 1994; Bekele 1994; Bekele *et al*., 1995).

The holy basil, *Ocimum suave* (Wild.) (Labiatae) is an aromatic perennial shrub native to Africa and India but widespread in many parts of the tropics (Kokwaro, 1976; Paton, 1991). Different parts of the plant have traditionally been used for the control of various ailments and as insect repellents, particularly against mosquitoes. Some local farmers in East Africa also mix foodstuffs with dry leaves of *Ocimum* plants for protection against pest damage (Kokwaro, 1976; Hassanali *et al*., 1990). More recently, ground leaves and essential oil extract of *O. suave* were shown in laboratory bioassays to be effective protectants of maize and sorghum against attack by *S. zeamais*, *Rhyzopertha dominica* and *Sitotroga cerealella* in storage (Bekele, 1994; Bekele *et al*., in press). Bekele (1994) identified eugenol as the major constituent of essential oil of *O. suave* comprising about 60% of the total collection (Table 1). This study was carried out to evaluate the toxicity and protectant potential of eugenol against grain weevils, *Sitophilus granarius* (Linnaeus), *S. zeamais* (Motschulsky) (Curculionidae), the red flour beetle, *Tribolium castaneum* (Herbst) (Tenebrionidae) and the larger grain borer, *Prostephanus truncatus* (Horn) (Bostrichidae).

2. Materials and methods

2.1. Rearing of insects

S. granarius, S. zeamais, T. castaneum and *P. truncatus* were cultured in a controlled environment room at 27± 1°C and 65–70% rh without light. Parent adults were obtained from laboratory stock culture maintained at the Federal Biological Research Centre for Agriculture and Foresty, Institute for Stored Product Protection, Berlin, Germany. The food substrates used

Table 1. Essential oil components of O. suave *in Kenya*

Common name	Formula	% Composition
eugenol	$C_{10}H_{12}O_2$	59·65
trans-β-ocimene	$C_{10}H_{16}$	14·52
β-cubebene	$C_{15}H_{24}$	5·26
trans-caryophllene	$C_{15}H_{24}$	3·27
trans-α-ocimene	$C_{10}H_{16}$	2·14
β-pinene	$C_{10}H_{16}$	1·66
linalool	$C_{10}H_{16}$	1·41

Bekele (1994).

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were whole wheat and maize grains for *Sitophilus* and *P. truncatus*, respectively, and wheat feed for *T. castaneum*.

2.2. Contact toxicity on filter paper

Eugenol (98% purity) used for the study was purchased from Aldrich Ltd., Berlin. A Whatman No. 1 filter paper (10.9 cm diameter) was placed in a glass Petri dish (11.0 cm diameter). An aliquot of 0, 1, 3, 5 or 10 μl eugenol dissolved in 1 ml of acetone was applied to the filter paper. The acetone was allowed to evaporate for 10 min prior to the introduction of 20 adults (three to seven days old of mixed sex) of each insect species separately into each dish and these were kept in the laboratory at 27± 2°C, 65–70% rh and L12:D12 photoregime. Each treatment was replicated five times. Insect mortalities were recorded after 24 h. Insects were presumed dead if they remained immobile and did not respond to three probings with a blunt dissecting probe after a five minute recovery period.

2.3. Contact toxicity by topical application

Tests for contact toxicity by topical treatment were carried out in the laboratory maintained at 27± 2°C, 65–70% rh and L12:D12 photoregime. The standard method described by McDonald *et al.* (1970) was used. Different solutions of eugenol (1, 3, 5 and 10 μl of eugenol in 1 ml acetone) were prepared. Three to seven day old insects of mixed sex were first transferred into Petri dishes lined with moist filter paper and chilled for three minutes to reduce their activity to enable topical treatment to be carried out. The immobilized insects were picked individually for treatment. 1 μl of eugenol solution was applied to the dorsal surface of the thorax of each insect with a micro-applicator. 50 beetles in five replicates of 10 insects each were treated with each dose. The same number of insects were treated with solvent only as control. After treatment, insects were transferred into 11·0 cm diameter glass Petri dishes (10 insects/Petri dish) containing food. Insects were examined daily for two days and those that did not move or respond to three probings with a blunt probe were considered dead. Insect mortalities were recorded at 24 and 48 h after treatment.

2.4. Beetle mortality on grain

The effect of eugenol-treated wheat and maize grains on adult mortality of the four beetle species was studied in the laboratory at 27± 2°C, 65–70% rh and L12:D12 photoregime. All *S. granarius*, *S. zeamais* and *T. castaneum* mortality assays were conducted using wheat and *P. truncatus* on maize. The grains were separately treated with eugenol solution made up of 1, 3, 5 or 10 μl eugenol in 10 ml acetone. Test solutions were mixed with 250 g samples of grain in one litre glass jars and stirred continuously for 30 min to ensure even spread of the material over the surface of the grains and kept for 3 h to allow the solvent to evaporate completely. The grains were then infested with three to seven day old adult beetles of mixed sex (20 beetles per jar) and each jar was covered with a nylon mesh held in place with rubber bands. Each treatment was replicated five times. Mortality counts were made after 24 h. In a similar experiment, beetles were exposed to glass pebbles treated with eugenol at 0, 1 and 5 μl/kg, and mortality was recorded after 24 h exposure.

To assess the persistence of the preparations, beetles in a similar experiment were exposed to treated grain which has been stored for 1, 10, 20 20 and 40 days. Mortality counts were made after a 24 h exposure.

2.5. Effect on hidden eggs and immature stages

The effect of eugenol on the development of eggs and immature stages of *S. granarius* and *S. zeamais* inside wheat kernels was bioassayed. Batches of 200 g of wheat in 300 ml glass jars were infested with 50 unsexed adults (three to seven days old) to allow egg laying. The parent adults were removed after seven days. One day after adult removal, four batches of the grain were treated with eugenol at a dose of 0 or 5 μl/kg. Thereafter, these treatments were repeated at one, two and three weeks after adult removal. Adults subsequently emerging were counted for a period of 6 weeks following the removal of adults.

2.6. Repellency bioassay

Two methods were used to evaluate the repellent action of eugenol against the four beetle species. The first method was based on an area preference test described by McDonald *et al.* (1970). Test arenas consisted of 11 cm Whatman No.1 filter papers cut in half. Different test solutions were prepared by dissolving 1, 3, 5 or 10 μl eugenol in 1 ml acetone. Each solution was applied to a half filter-paper disc as uniformly as possible with a pipette. The other filter paper halves were treated with acetone alone. The eugenol-treated and control half discs were air dried to evaporate the solvent completely. Full discs were then remade by attaching treated halves to untreated halves of the same dimensions with sellotape. Each filter paper was placed in a petri dish and 10 (three to seven days old) beetles of mixed sex for each species were released separately at the centre of each filter paper disc and then covered. Each treatment was replicated ten times. The number of insects present on control (N_C) and treated (N_T) strips were recorded after 30 min.

In the second method, repellency was assessed in a choice bioassay system consisting of two 1l glass jars connected together at their rims by means of a 30× 10 cm nylon mesh tube. A 5 cm diameter circular hole was cut at the middle of the mesh for the introduction of test insects. 250 g samples of maize were treated with different dosages of eugenol solution as before. One jar contained treated grains while the other jar had untreated maize and acted as the control. Twenty-five three to seven day old adults of mixed sex of each of the four beetle species were introduced into the nylon mesh tube through the circular hole by means of a 5 cm diameter funnel. Counts of beetles in the control and treated grains were made at hourly intervals for 3 h. After each test the glass jars were thoroughly cleaned and dried at 100°C. The assay for each dose of test material was replicated four times for each beetle species. Throughout the experiments, two blank controls were run periodically, and insect response to hexane-treated grain was compared with untreated grain.

All repellency assays were carried out in the laboratory at 27± 2°C and 65–70% rh. Per cent repellency (PR) values for both tests were computed as PR = $[(N_C - N_T/)(N_c + N_T)] \times 100$. PR data were analysed using ANOVA (analysis of variance) after transforming them into arcsin values. All negative PR values were treated as zero.

3. Results

3.1. Filter paper contact toxicity

Per cent mortality of each beetle species after 24 h exposure to increasing dosages of eugenol on filter paper discs are shown in Table 2. Beetle mortality was dose-dependent, with the highest dose of 10 μl/disc causing over 93% mortality in *S. granarius, S. zeamais* and *P. truncatus* but achieved only 45% kill in *T. castaneum*. All dosages of eugenol significantly ($P< 0.001$) killed more insects than the control.

3.2. Contact toxicity by topical application

Toxicity of eugenol applied topically to the beetles are summarized in Table 3. Toxicity increased with increasing dosage and time. Eugenol applied at the dosage of 7 μl/insect or more was more toxic to the beetles producing 100% mortality within 48 h of application.

3.3. Mortality in grain

Table 4 shows the per cent mortality of beetles in grain treated with different dosages of eugenol. All treatments caused significantly ($P< 0.001$) higher mortality than the untreated grain. Eugenol on grain was more effective against the beetles than on filter paper discs with the lowest dose of 1 μl/kg causing 95% mortality in *Sitophilus* and 100% mortality in *T. castaneum* and *P. truncatus*, 24 h after treatment. Similarly, glass pebbles treated with eugenol were equally toxic to the beetles (Table 5).

3.4. Persistence in grain

The effectiveness of eugenol was significantly ($P< 0.001$) reduced by the length of storage after application (Table 6). Mortality decreased with the time after treatment at which the grain was bioassayed. For grain bioassayed after 10 days of storage following application, mortality decreased to less than 30% even at the highest dosage of 10 μl/kg.

3.5. Effect on eggs and immature stages

Eugenol completely inhibited the development of eggs, larvae and pupae hidden inside wheat kernels. When grain containing eggs, first and second larval instars or pupae were treated with eugenol, no progeny emerged compared with the untreated grain (Table 7).

3.6 Repellency

Eugenol was highly repellent to the four beetle species bioassayed with overall repellency in the range of 80–100% (Table 8). Repellency was dosage-dependent.

Table 2. Toxicity of different dosages of eugenol-impregnated filter paper discs to the four beetle species

Dosage (μl/disc)	Mean % adult mortality after 24 h			
	S. granarius	*S. zeamais*	*T. castaneum*	*P. truncatus*
0	0 ± 0.0^{e}	0 ± 0.0^{e}	0 ± 0.0^{e}	0 ± 0.0^{e}
1	15 ± 0.9^{d}	12 ± 0.6^{d}	10 ± 0.6^{d}	47 ± 0.8^{c}
3	45 ± 0.7^{c}	41 ± 0.9^{c}	20 ± 0.5^{c}	85 ± 0.7^{b}
5	78 ± 0.9^{c}	77 ± 0.9^{b}	30 ± 0.9^{b}	100 ± 0.0^{a}
10	94 ± 0.8^{a}	95 ± 0.6^{a}	45 ± 0.7^{a}	100 ± 0.0^{a}

Mean of 5 replicates of 20 insects each. Column means for each species followed by different letter(s) are significantly different at the 0·05 level (Duncan's multiple range test).

Table 3. Toxicity of eugenol applied topically to the four beetle species

Dosage (μl/beetle)	Mean % mortality after 48 h			
	S. granarius	*S. zeamais*	*T. castaneum*	*P. truncatus*
0	0 ± 0.0^{d}	0 ± 0.0^{d}	0 ± 0.0^{d}	0 ± 0.0^{d}
1	40 ± 0.3^{c}	42 ± 0.4^{c}	42 ± 0.4^{c}	50 ± 0.6^{d}
3	86 ± 0.5^{b}	84 ± 0.5^{b}	82 ± 0.5^{b}	87 ± 0.5^{b}
5	90 ± 0.6^{ab}	92 ± 0.6^{ab}	89 ± 0.7^{ab}	93 ± 0.5^{ab}
7	100 ± 0.0^{a}	100 ± 0.0^{a}	100 ± 0.0^{a}	100 ± 0.0^{a}
10	100 ± 0.0^{a}	100 ± 0.0^{a}	100 ± 0.0^{a}	100 ± 0.0^{a}

Mean of 10 replicates of 10 insects each. Data transformed into arcsin percentage values before ANOVA and DMRT test. Column means for each species followed by different letter(s) are significantly different at the 0·05 level (Duncan's multiple range test).

Table 4. Toxicity of eugenol treated grain against the four beetle species after 24 h exposure

Dosage (μl/kg)	Mean % adult mortality after 24 h exposure			
	S. granarius	*S. zeamais*	*T. castaneum*	*P. truncatus*
0	0^{b}	0^{b}	0^{b}	0^{b}
1	95^{a}	95^{a}	100^{a}	100^{a}
3	100^{a}	100^{a}	100^{a}	100^{a}
5	100^{a}	100^{a}	100^{a}	100^{a}
10	100^{a}	100^{a}	100^{a}	100^{a}

Mean of 5 replicates of 20 insects each. Mortality recorded after 24 h. Column means followed by different letter(s) are significantly different at the 0·05 level (Duncan's multiple range test).

Table 5. Mortality of the four beetle species in glass pebbles treated with eugenol after 24 h exposure

Dosage (μl/kg)	Mean % adult mortality after 24 h exposure			
	S. granarius	*S. zeamais*	*T. castaneum*	*P. truncatus*
0	0^{b}	0^{b}	0^{b}	0^{b}
1	100^{a}	100^{a}	100^{a}	100^{a}
5	100^{a}	100^{a}	100^{a}	100^{a}

Mean of 5 replicates of 20 insects each. Mortality recorded after 24 h. Column means followed by different letter(s) are significantly different at the 0·05 level (Duncan's multiple range test).

Table 6. Mortality of the four beetle species in eugenol treated grain after different intervals of storage

Dosage (μl/kg)	Mean % adult mortality, days after treatment				
	1	10	20	30	40
(a) *S. granarius*					
0	0^{e}	0^{e}	0^{e}	0^{e}	0^{e}
1	13^{d}	5^{e}	0^{e}	0^{e}	0^{e}
3	25^{c}	11^{d}	2^{e}	0^{e}	0^{e}
5	36^{b}	20^{cd}	5^{e}	3^{e}	0^{e}
10	50^{a}	27^{cb}	14^{d}	9^{d}	2^{e}
(b) *S. zeamais*					
0	0^{e}	0^{e}	0^{e}	0^{e}	0^{e}
1	14^{cd}	3^{e}	0^{e}	0^{e}	0^{e}
3	23^{c}	10^{d}	2^{e}	0^{e}	0^{e}
5	36^{b}	19^{c}	4^{e}	3^{e}	0^{e}
10	48^{a}	23^{c}	9^{d}	8^{e}	2^{e}
(c) *T. castaneum*					
0	0^{c}	0^{c}	0^{c}	0^{c}	0^{c}
1	8^{b}	2^{c}	2^{c}	0^{c}	0^{c}
3	10^{b}	3^{c}	2^{c}	0^{c}	0^{c}
5	15^{a}	10^{b}	2^{c}	0^{c}	0^{c}
10	20^{a}	10^{b}	3^{c}	0^{c}	0^{c}
(d) *P. truncatus*					
0	0^{e}	0^{a}	0^{e}	0^{e}	0^{e}
1	27^{c}	8^{d}	2^{e}	0^{e}	0^{e}
3	30^{c}	14^{d}	3^{e}	0^{e}	0^{e}
5	42^{b}	27^{c}	9^{d}	4^{e}	1^{e}
10	57^{a}	29^{c}	14^{d}	9^{d}	2^{e}

Mean of 5 replicates of 20 insects each. Mortality recorded after 24 h exposure of treated grains stored for 1, 10, 20, 30 and 40 days. Means for each species followed by different letter(s) are significantly different at the 0·05 level (Duncan's multiple range test).

Table 7. Mean number of S. granarius *and* S. zeamais *adults produced in grain treated with eugenol at different times after oviposition period*

Dosage (μl/kg)	Time of treatment			
	24 h	1 week	2 weeks	3 weeks
S. granarius				
0	468^{a}	480^{a}	475^{a}	492^{a}
1	0^{b}	0^{b}	0^{b}	0^{b}
3	0^{b}	0^{b}	0^{b}	0^{b}
5	0^{b}	0^{b}	0^{b}	0^{b}
S. zeamais				
0	337^{a}	354^{a}	350^{a}	340^{a}
1	0^{b}	0^{b}	0^{b}	0^{b}
3	0^{b}	0^{b}	0^{b}	0^{b}
5	0^{b}	0^{b}	0^{b}	0^{b}

Data are average of 4 replicates. Means for each species followed by different letter are significantly different at the 0·05 level, *t*-test.

4. Discussion

Eugenol applied topically or impregnated on filter papers was toxic to all the four target species (Table 2 and 3). Maize or wheat grains treated with 3 μl/kg or more caused 100% mortality within 24 h (Table 4). Eugenol also caused complete inhibition of the development of eggs, larvae and pupae inside grain kernels (Table 7). This rapid and complete mortality is noteworthy since several alternate materials for pest control require much longer than 24 h to reach their maximum effect and few achieve 100% kill. Suitable eugenol preparations could thus be used in severely infested grain bulks for immediate control of these insect pests. Similarly, eugenol-impregnated glass pebbles caused 100% kill of all the four species (Table 5), suggesting that toxicity was not due to ingestion of treated grain. The rather significant loss of activity within 24 h of application may indicate that eugenol is also fumigative in action. The toxicity of eugenol may be attributed to its phenolic structure (Cremlyn, 1978). Phenols are generally known to be an important source of potent insecticids, fungicides, bactericides and herbicides for pest control.

Table 8. Mean % repellency (PR) values for different dosages of eugenol against the four beetle species in the choice arena

Dosage (μl/kg)	Mean % repellency (PR)			
	S. granarius	*S. zeamais*	*T. castaneum*	*P. truncatus*
0	$0 \pm 0{\cdot}0^{d}$	$0 \pm 0{\cdot}0^{d}$	$0 \pm 0{\cdot}0^{d}$	$0 \pm 0{\cdot}0^{d}$
1	$67 \pm 1{\cdot}4^{c}$	$70 \pm 1{\cdot}5^{c}$	$68 \pm 2{\cdot}3^{c}$	$64 \pm 1{\cdot}8^{c}$
3	$79 \pm 1{\cdot}6^{b}$	$82 \pm 2{\cdot}2^{b}$	$80 \pm 1{\cdot}8^{b}$	$80 \pm 2{\cdot}4^{b}$
5	$88 \pm 1{\cdot}5^{ab}$	$89 \pm 1{\cdot}4^{ab}$	$88 \pm 1{\cdot}6^{ab}$	$86 \pm 1{\cdot}6^{b}$
10	$95 \pm 1{\cdot}2^{a}$	$91 \pm 1{\cdot}8^{a}$	$92 \pm 1{\cdot}4^{a}$	$94 \pm 1{\cdot}5^{a}$
Overall PR	82	83	82	84

Mean of 5 replicates of 20 insects each. Column means for each species followed by different letter(s) are significantly different at the 0·05 level, Duncan's multiple range test.

Eugenol was also highly repellent to the beetles relative to the controls (Table 8). This confirms the findings of Hassanali *et al.* (1990) who demonstrated the highly repellent effect of eugenol against *S. zeamais* in a Y-shaped choice bioassay system. This repellent action increases the potential practical value of eugenol for grain protection against insect pest attack. Interestingly, eugenol is attractive to the Japanese beetle, *Popillia japanica* (Newman) (Ladd, 1980), the northern corn root worm, *Diabrotica barberi* (Smith and Lawrence) (Ladd *et al.*, 1983; Lance, 1988) and the scarab beetle, *Maladera matrida* (Argaman) (Ben-Yakir *et al.*, 1995).

Higher doses of eugenol on filter papers were required to achieve 100% kill (Table 2) compared to topical applications or grain treatment (Tables 3 and 4). For example, the highest dose of 10 μl on filter papers achieved only 45% kill in *T. castaneum* compared to 100% mortality in wheat treated with 1 μl. This phenomenon may be related to the physico-chemical behaviour of the compound on different surfaces. For example, the insects in treated grains are rapidly coated with test particles (due to their own movement) that adhere to them. Such insects, therefore, receive a topical chemical as well as physical treatment whereas filter paper trials provide little direct topical treatment initially until the insects become intoxicated and fall upon their dorsal surfaces and become coated with residual chemical from the surface of the filter paper. The use of filter paper as the sole method of determining toxicity of certain chemicals may give misleading results. *T. castaneum* was also less susceptible to the toxic effects of eugenol than the other three species. Insect species are known to have variable susceptibilities to insecticides related to behaviour and other physiological factors.

The results obtained suggest good potential for the use of eugenol preparations as repellent and toxicant agents against several stored product beetle pests. Toxicity and protectant potential of different terpenoids isolated from *Ocimum* species against major stored product insects had been reported. For example, Weaver *et al.* (1991) demonstrated the efficacy of linalool, a major component of freshly-milled *O. canum* (Sims) for protection against several stored product Coleoptera. Small-scale farmers in East Africa mix dried leaves of *O. suave* for protection against post-harvest damage. Bekele (1994) and Bekele *et al.* (in press) demonstrated the effectiveness of ground leaves and essential oil extract of *O. suave* in protecting maize and sorghum against attack by *S. zeamais, Rhyzopertha dominica* (Fab.) and *Sitotroga cerealella* (Olive). The bioactivity of *O. suave* may be attributed to the high concentration of eugenol in the leaves, although other minor toxic components such as linalool (1·4%) could be important. For example, some farmers in Rwanda protect farm-stored edible beans (*Phaseolus vulgaris* (L)) against insect damage by mixing them with the leaves of *O. cannum*. Linalool is the major component of the essential oil of this annual mint, representing 60 – 90% of the total volatiles collected (Weaver *et al.*, 1991) and is known to act as a reversible competitive inhibitor of acetylcholinesterase (Ryan and Byrne, 1988).

The rather significant loss of activity of eugenol within 24 h of application reduces its protectant potential in storage. It is possible to enhance its toxicity and persistence through suitable formulations such as combining it with plant oils in simple mixtures. This concept is currently being investigated. The low persistence of eugenol is, however, an advantage since the treated foodstuffs will pose less of a health hazard to humans. In the traditional post-harvest system in Africa, however, powdered dust formulations from *O. suave* leaves may be more economical to use since it can be produced locally by the farmers themselves.

The mode of action of eugenol is of special interest. Future work would focus on its penetration into insect cuticle and grain, metabolic target in the insect body as well as its effects on mammals fed on treated materials. Detailed toxicological studies are needed before eugenol could be recommended for use in stored product protection. The use of potentially toxic plant extracts on food commodities destined for human and animal consumption could also taint treated food in stores.

The use of plant materials in pest control could become important supplements or alternatives to imported synthetic pesticides. Therefore, it is important that appropriate technology is developed to promote a direct preparation of traditional pesticides at the farm level for those resource-poor farmers who have no access to commerical pesticides or cannot afford them.

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