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Evaluation of the efficacy of plant powders in the control of *Tribolium castaneum* (Coleoptera: Tenebrionidae) on stored foods

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Abstract
The evaluation of the efficacy of plant powders on red flour beetle *Tribolium castaneum* (Herbst) (Coleoptera: Tenebrionidae) was carried out in Mubi. The plant products were the powders of *Khaya ivorensis* and *Annona senegalensis*. Permethrin 0.60% was used as positive control. 1.0g, 2.0g and 3.0g were constituted into four replicates for each of the treatment on 20.0g of sorghum, maize and millet flours. Thereafter, 10 newly emerged adult *Tribolium castaneum* were added. The effects were noted for their toxicity and suppression of development. The results revealed that the plant products tested were effective when compared with the control, since they significantly recorded higher mortality and also suppressed larval and F1 progeny emergence on different grain flours. *Khaya ivorensis* performed significantly (P>0.05) better than *Annona senegalensis*. Therefore, sustainable use of these plant products in the control of weevils on stored foods is recommended especially *Khaya ivorensis* on *Tribolium castaneum*.

Keywords: *Annona senegalensis*, *Khaya ivorensis*, *Tribolium castaneum*, Maize, Millet, Sorghum

Introduction
The risk of the invasion of stored grains as well as the processed commodities is enormous [1]. A continuous deterioration in terms of quality and quantity due to insects' infestation is on the increase [2], and this will in turn affect the germination capacity of the grains [3].
The red flour beetle *Tribolium castaneum* (Coleoptera: Tenebrionidae) is a major insect pest of flour, rice, millet and other milled and processed commodities of cereals [4, 5], and show more preference to millet than any other cereal [6]. *T. castaneum* can cause serious damages to food grains in terms of quality and quantity [7]. *T. castaneum* are also reported to cause serious risk to human health by the contamination of stored commodities through the secretion of toxic quinones which are known to be carcinogenic nature [8, 9].
And so the control of *T. castaneum* is necessary not only for food security but also for human health protection. Over the years, chemical insecticides have been used extensively and have been effective [10]. However, the problems with the use of chemical insecticides against these stored product pests, which include their effects on non-target organisms, resistance by the insect pests to the insecticides, environmental pollution and also their persistency in the environment have made farmers and researchers to look for an alternative control measures that are safe for human health, readily available, effective and biodegradable [11]. Biopesticides in various forms and in different formulations is one of the many possible avenues explored with regard to control [12].
In this study, the efficacy of *A. senegalalensis* and *K. ivorensis* powder in the control of *T. castaneum* on stored foods was evaluated.

Materials and methods
Study area
This study was carried out in Parasitology and Entomology Laboratory, Department of Zoology, Adamawa State University, Mubi. Mubi is located in the north eastern part of Nigeria between latitude 10^{0}14'N and 10^{0}18'N of the equator of longitude 13^0 14'E and 13^0 19'E of the Greenwich meridian. The area has a tropical climate with an average temperature of 32 ^{0}C and lies within the Sudan savannah vegetation zone in Nigeria.

The area has an average relative humidity from 28%-45% and annual rainfall of about 1056mm [13].

Collection and preparation of plant products

Fresh leaves of mahogany (*Khaya ivorensis*) and wild custard apple (*Annona senegalensis)* were collected from a plantation in Mubi town, and were identified in a herbarium of Plant Biology Department, Adamawa State University, Mubi. The leaves were dried in a cupboard under room temperature for about two weeks. Thereafter, they were separately ground into fine powder using electric blender, and were sieved through 60mm mesh size sieve. The powders were kept in a container with screw cap top at room temperature to prevent quality loss. [14].

Collection and preparation of grains flour

Clean millet, maize and sorghum grains were purchased from Mubi main Market. Thereafter, they were washed with clean water, and oven dried at 40^0 to free them from foreign infestations. The grains were ground into fine powder using a grinding mill, sieved and kept in a separate container with a cover.

Source of insects *(Tribolium castaneum)*

The parent stock of red flour beetle (*T. castaneum*) was obtained from infested semovita grids. They were subsequently transferred to clean uninfested semovita grids and were allowed to stand for about three days. Thereafter the adult *T. castaneum* were removed and the exposed semovita grids were monitored for *T. castaneum* adult overtime under laboratory conditions. This was done to raise adult *T. castaneum* of uniform size and age for the experiment.

Experimental procedures

- The powdered sample obtained from sorghum, maize and millet were weighed into 20g each, put in 350cm^3 experimental jars.
- Three different doses of plant treatments and the chemical insecticide used (permethrin 0.06%) were constituted at 1.0g, 2.0g and 3.0g. Each treatment dose on every grain sample was replicated four times, and was added accordingly on the 20g of the powdered grain in the experimental jars. The content of the jars was thoroughly mixed using a sterilized stick to ensure proper mixing of the powdered grains and the treatment samples.
- Thereafter, ten (10) newly emerged unsexed adult *T. castaneum* were introduced into each of the rearing jar, and the whole content was covered with muslin cloth with the aid of a rubber band in order to ensure that the insects do not escape, and to also provide ventilation during the experiment.
- A control jars were setup for each of the grain powders which contained ten (10) unsexed adult *T. castaneum* and were replicated four times, but no treatment was added.

Data collection

Data was collected on the following parameters:

Mortality

Mortality count was carried out between 24 hrs and 168 hrs of exposure. The death *T. castaneum*) was noted by the inability of the adult insect to respond to a touch using a broom stick. Thereafter, the death insects were subsequently removed.

Number of larvae

The number of larvae developed in the various treatment jars were observed two weeks after the mortality counts was conducted. This was done by sieving out the content of the treatment jar using 60mm mesh. All the larvae noted were counted and recorded. Thereafter, the larvae as well as the remaining experimental jars' contents were subsequently put back.

F1 progeny emergence

The F1progeny emergence was observed one week after the larval count was conducted. The entire jar content was sieved out using the same 60mm mesh sieve, and the number of newly emerged adult *T. castaneum* were counted and recorded

Data analysis

Data collected was analyzed using Analysis of Variance (ANOVA) with the aid of SPSS version 16.0. The means were separated using the Duncan Range Multiple Test (DRMT) at 5% (P>0.05) level of significance.

Results

Mortality of *T. castaneum* reared on sorghum, maize and millet flours

Table 1 shows the average mortality of *T. castaneum* reared on three different grain flours. The results revealed that there was a significant difference (P>0.05) in mortality of *T. castaneum* after 7 days (168 hrs) of exposure to treatments on sorghum, maize and millet flour. The synthetic chemical (permethrin 0.60%) at 3.0g significantly (P>0.05) recorded higher mean mortality of *T. castaneum*, ranging from 7.50±0.45 in maize flour to 8.50±0.57 in sorghum flour.

Among the plant treatments, *Khaya ivorensis* at 3.0g dose recorded a significant higher (4.00±0.58) average mortality in sorghum flour, followed by 3.75±0.64 in maize flour more than *A. senegalensis*. Generally, all treatments significantly (P>0.05) recoded higher mortality of *T. castaneum* than the control experiment (untreated).

There was a significant difference (P>0.05) in the mean total of mortality across the treatments. *K. ivorensis* recorded significant higher mean mortalities more than *A. senegalensis* at all doses, but control experiment (untreated) had the least mean mortality.

Larval developments of *T. castaneum* on sorghum, maize and millet grains flour

In Table 2, the effect of plant treatments (*K. ivorensis* and *A. senegalensis*) on the development of larvae of *T. castaneum* on three different grain flours (sorghum, maize and millet) is shown. The result revealed that, there was a significant difference (P>0.05) in the number of larvae developed overtime on the three grain flours. Millet flour treated with *A. senegalensis* at 1.0g dose recorded a significant (P>0.05) higher (148.25) number of larvae, when compared to the ones developed on the entire grain flour treated. The mean total values showed a significant difference (P>0.05) in terms of larval development. The highest occurrence of larvae (115.75±34.24) was recorded in grain flours treated with *A. senegalensis* at 1.0g treatment dose, while the least (72.58±1.04) was recorded in grain flours treated with *K. ivorensis* at 3.0g treatment dose. The absolute total further revealed the highest larval development on millet grain (696.50), followed by sorghum (624.50), while the least (580.50) was recorded in maize flour (Table 2).

F1 generation emergence of *T. castaneum* on sorghum, maize and millet grains flour

Table 5 shows the effect of plant treatments on the F1 progeny emergence of *T. castaneum* reared on sorghum, maize and millet. The results followed a similar trend with larval development recorded, as millet recorded higher (344.75) number of the adult emergence of *T. castaneum*. *K. ivorensis* significantly (*P*>0.05) suppressed adult emergence of *T. castaneum* to the minimum (16.00±5.88) at 3.0g treatment dose more than *A. senegalensis* which was able to reduce emergence by only 31.33±9.93 at 3.0g treatment dose. Compare to the control (untreated) experiment the treatment plants significantly reduced the number of adult *T. castaneum* emergence (Table 3).

Table 1: Effect of treatments on the mortality of *T. castaneum* reared on different grain powders.

Treatment	Dose (g)	Sorghum	Maize	Millet	Mean Total
Control	0.0	0.50±0.19^{a}	0.00±0.00^{a}	0.25±0.09^{a}	0.25±0.25^{a}
Khaya ivorensis	1.0	3.75±0.47^{b}	2.25±0.35^{bc}	2.75±0.43^{b}	2.92±0.76^{ab}
	2.0	3.00±3.37^{b}	1.50±0.23^{ab}	1.75±0.46^{ab}	2.08±0.80^{b}
	3.0	4.00±0.58^{b}	3.75±0.64^{c}	3.50±0.59^{b}	3.75±0.25^{ab}
Annona senegalensis	1.0	1.75±0.29^{b}	1.00±0.13^{ab}	2.25±0.24^{b}	1.67±0.63^{a}
	2.0	2.00±0.34^{b}	1.75±0.29^{b}	1.75±0.14^{ab}	1.83±0.14^{a}
	3.0	1.00±0.17^{ab}	1.75±0.00^{b}	1.75±0.20^{ab}	1.50±0.43^{a}
Permethrin 0.60%	1.0	5.00±0.67^{a}	5.00±0.42^{a}	3.75±0.39^{a}	4.58±0.72^{bc}
	2.0	5.75±0.52^{a}	6.50±0.35^{ab}	7.00±0.64^{b}	6.42±0.63^{c}
	3.0	8.50±0.57^{a}	7.50±0.45^{b}	8.00±0.48^{b}	8.00±0.50^{c}

Values are means of four replicates. Means carrying the same super-script alphab*et al*ong the column are not significantly different (*P*>0.05).

Table 2: Effect of plant treatments on larval development on different grain flour.

Treatments	Dose (g)	Sorghum	Maize	Millet	Mean Total
Control	0.00	80.50^{a}	82.25^{a}	87.25^{a}	83.3±3.50^{a}
Khaya ivorensis	1.00	107.00^{a}	65.50^{a}	105.00^{a}	92.5±23.40^{ab}
	2.00	87.75^{a}	78.25^{a}	84.00^{a}	83.3±4.79^{a}
	3.00	73.75^{a}	71.75^{a}	72.25^{a}	72.58±1.04^{a}
Annona senegalensis	1.00	80.00^{a}	119.00^{b}	148.25^{b}	115.75±34.24^{c}
	2.00	80.75^{a}	82.50^{a}	119.75^{ab}	94.33±22.03^{ab}
	3.00	114.75^{a}	81.25^{a}	79.50^{a}	91.83±19.87^{ab}
Absolute Total		624.50	580.50	696.50	

Values are means of four replicates. Means carrying the same superscript alphab*et al*ong the column per treatment are not significantly different (*P*>0.05).

Table 3: Effect of plant treatments on F1 emergence of *T. castaneum* reared on different grain flours

		Grain powder			
Treatment	**Dose (g)**	**Sorghum**	**Maize**	**Millet**	**Mean Total**
Control	0.00	130.25^{b}	150.75^{b}	126.50^{b}	135.83±13.05^{c}
Khaya ivorensis	1.00	22.50^{a}	34.00^{a}	56.75^{ab}	37.75±17.43^{b}
	2.00	14.75^{a}	11.50^{a}	35.25^{a}	20.50±12.88^{ab}
	3.00	12.00^{a}	13.25^{a}	22.75^{a}	16.00±5.88^{a}
Annona senegalensis	1.00	63.75^{b}	43.00^{a}	43.00^{a}	49.92±11.98^{b}
	2.00	38.25^{ab}	35.75^{a}	35.75^{a}	36.58±1.44^{b}
	3.00	26.50^{a}	24.75^{a}	42.75^{a}	31.33±9.93^{b}
Absolute Total		308.00	313.00	344.75	

Values are means of four replicates. Means carrying the same superscript alphab*et al*ong the column per treatment are not significantly different (*P*>0.05)

Discussion

It has been reported that post-harvest loss of grain in terms of quality and quantity due to insect pests has become a serious concern all over the world, such that demand for good and quality products that are free from chemical residue is on the increase [15]. The significant number of *T. castaneum* larvae and F1 adults found in sorghum, maize and millet flour treated with *K. ivorensis* and *A. senegalensis* when compared with the control (untreated) experiment, suggested that *K. ivorensis* as well as *A. senegalensis* can serve as protectants against *T. castaneum*.

The toxicological effects of the powder treatments in terms of mortality as revealed in this study indicates that the treatments have properties that can be used as fumigants in the control of stored product pests. Although *K. ivorensis* appeared to be more effective in terms of toxicity than A. senegalensis, the efficacy of the two plant treatments was significant (*P*>0.05), since *T. castaneum* reared on treated sorghum, maize and millet flours all recorded a significant (*P*>0.05) higher mortality when compared with the control (untreated) experiment. This agrees with the work of Ishaya *et al*. [16], Bamaiyi *et al.* [17] and Wahedi *et al.* [18] who reported the toxicological properties of *Khaya ivorensis* on stored product pests. The study also agrees with the work of Vanichpakom *et al*. [19], Khalequzzaman and Sultan [20] and Ishuwa *et al*. [21], who reported a contact toxicity of *A. reticulata* against *Callosobruchus maculatus, A. squamosa* against *T. castaneum* and *A. muricata* and *A. senegalensis* against cowpea bruchids *C. maculatus* respectively.

The treatments were able to reduce the number of larvae and F1progeny emergence of *T. castaneum* when compared with the control (untreated). This also revealed that the treatments also can reduce the development of insects as reported by other authors like Ishuwa [21] who recently reported a significant reduction of F1 progeny emergence of *C. maculatus* treated with *Annona muricata* and *Annona senegalensis*. The number of larvae and the F1 adults of *T. castaneum* recorded in this study revealed that millet flour favours the development of *T. castaneum* more than the maize and sorghum flours.

The overall results therefore confirmed the effectiveness of the treatments (*K. ivorensis* and *A. senegalensis*) against adult *T. castaneum* and its development.

Conclusion

In conclusion, *K. ivorensis* and *A. senegalensis* have been revealed in this study because of their efficacy on *T. castaneum* to have a good potential that can serve as an alternative to chemical insecticides which have been causing serious problems in the biosphere in terms of pollution and effect on non-target organisms. The biopesticides if used sustainably will provide a safe method of controlling insect pests on stored foods without any harm to the ecosystem.

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