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Bioefficacy of powdery formulations based on kaolin powder and cashew (*Anacardium occidentale* L.) balms to control *Callosobruchus maculatus* F. (Coleoptera, Chrysomelideae: Bruchidae) in stored cowpea (*Vigna unguiculata* L.)

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ABSTRACT

In this study, the bioefficacy of the powdery formulations were evaluated. Thus powdery insecticide Antouka®, kaolin powder and powdery formulations based on kaolin powder and various cashew balms were tested against, cowpea bruchid in storage. For each balm, it was formulated 10 g of powdery formulation, which were obtained with 10 g of kaolin and 1 mL of cashew balm. Antouka® insecticide was applied at recommended dose; powdery formulations were tested at 0.5 g; 1 g, for 50 g of cowpea seeds in jars. Twenty (20) cowpea weevils at 24 h old were introduced in each jar. The jars, covered with wire mesh, were kept outdoors during forty five (45) days using a randomized block design with four replicates. Therefore, parameters of mortality and F_1 progeny of *Callosobruchus maculatus*, weight losses, seeds damaged and germination rate were assessed. Results obtained indicated that Antouka® insecticide and the formulated powders caused a significant mortality rate and improved the germination rate of seeds. Nevertheless, the cold extracts had less seeds damaged than hot extracts. F_1 progeny decreased with increased dose, (25.50±7.96 insects to 44.50±7.67 insects for 0.5 g; and 11.25±4.62 insects to 29.50±3.22 insects for 1 g). According to calculated LD_{50} and their confidence intervals, formulated powders have significant toxicity on *C. maculatus*. These results revealed the bioefficacy of powdery formulations. They can be recommended as alternatives insecticides.

Keywords: *Callosobruchus maculatus,* cowpea, bioinsecticides, toxicity, Benin.

INTRODUCTION

Cowpea grains can be referred to "protein source for all" because it is affordable for both the rich and poor citizens and also a source of cash income especially in rural areas (Dugje et al., 2009 ; Akunne et al.,

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2013). In front of the huge damages caused by postharvest insects, the protection of grains during postharvest was achieved mainly with the use of synthetic insecticides. Several authors reported that farmers used excessively chemical synthetic insecticides in other to control many destructive insects (Akinkurolere, 2007; Akinneye and Ogungbite, 2013; Ileke, 2014). It have been reported that the use of chemical insecticides have a high purchasing cost, present potential risks to human health, the environment and lead to a new resistance of pests (Ofuya et al., 2008; Akunne and Okonkwo, 2006; Thiaw and Sembène, 2010). The intensive and not uncontrolled chemicals insecticides use for preservation of foodstuffs has direct effects on the environment and consumers Ngamo (2004). Thus, it is urgent to develop food grains storage processes that have limited side effects on human health and environment. Essentials oils of aromatics plants used currently are considered being effective against stored grains pest Ngamo et al. (2007).

However, these essentials oils of aromatic plants present a problem of volatility making their handling difficult Nguemtchouin (2012). Their volatile feature leads to their non-persistence on treated grains. The clay material endowed with adsorbent capacity was proposed as support for essential oil. And it results a powdery slowering from their insecticidal activity (Sékou et al., 2000; Nguemtchouin et al., 2009; Nguemtchouin et al., 2010).

In the present experiment, cashew (*A. occidentale*) balm was incorporated in kaolin powder. The main objective of this study was to evaluate the bioefficacy of the powdery formulations based on kaolin powder and cashew (*A. occidentale*) balm against *C. maculatus* on stored cowpea grains.

MATERIAL AND METHODS

Insect culture of the experiment

The insect rearing for obtaining adults of *C. maculatus* for the experiments were carried out using cowpea seeds in a room at temperature from 25 to 27 °C and relative humidity from 70 to 75%. The insects stock used was obtained at the Laboratory of Agricultural Entomology of the University of Abomey-Calavi (Benin). Indeed, one hundred (100) adults of *C. maculatus* of this stock is used to infest 200 g of cowpea (previously sterilized with the freezer at -20 °C, during 7 days) contained in jars. The jars openings were covered with wire mesh, (mesh of 1 mm diameter) to allow ventilation and prevent exit of insects and other external contamination. About 72 h after infestation, the previously one hundred 100 cowpea weevils introduced in jars were retired and the infested grains are left in incubation until emergence of new adult insects. At emergence, the jars contents were filtered in order to eliminate the emerged adults. After 24 h, the jars contents filtered the day before was filtered again in order to obtain adults of 24 h old used in experiment.

Preparation of the kaolin powder

Kaolin balls were bought at Abomey-Calavi markets. These balls are milled in powder and boiled with water in order to sterilize the powder. The pasty solution obtained is cooled at 30 °C, and then filtered with a sieve of mesh of 50 µm. The filtrate obtained was kept safe from contamination during 48 h. After decantation the floating liquid was separated and the remaining paste was collected, dried under sun and then was crushed in powder to keep in a desiccator safe from moisture.

Biological assay: contact toxicity of balms

Powdery insecticidal formulations based on kaolin powder and balm

The goal of this part of work was to study the insecticidal activity of the various formulations resulting from each balm. In order to evaluate the effect of the powdery insecticidal formulations against *Callosobruchus maculatus* on stored cowpea according to the method in Nguemtchouin (2012). Each powdery formulation contains active matter 10%. The active matter in this case consists of chemical compounds contained in various types of balms. Thus, the formulation must be obtained according to the ratio:

$$\frac{\text{Wbalm}}{\text{Wkaolin}} = 0.1$$

Where:

Wbalm : weight of cashew balm, and

Wkaolin: weight of powder of kaolin.

To formulate 10 g of powdery formulation, 10 mL of acetone were introduced into a bottle which 1 mL of cashew balm and 10 g of kaolin powder were added. After mixing during approximately 5 min, the mixture was left until complete evaporation of solvent. At the end of this evaporation, it resulted an aromatized powder of balm which was preserved in hermetically closed bottles. With these various treatments, it was associated a control treatment with seeds impregnated of kaolin powder previously treated with acetone (negative control); and another treatment with seeds impregnated of powdery chemical insecticide Antouka® (Permetrine 3 g/kg + Pirimiphos methyl 16 g/kg) (positive control).

For each test, 50 g of cowpea seeds were introduced into cylindrical jars (6 cm diameter and 12 cm height). The cowpea seeds were treated with each type of powdery formulation previously established. We used 0.5 and 1 g of aromatic powder which corresponded respectively to 1 and 2% of 50 g of the weight of cowpea seeds CISSOKHO et al. (2015). The contents were carefully mixed, then the tests were repeated 4 times for each powder quantity (0.5 and 1 g) and for each type of aromatized powdery formulation; for the control, the kaolin powder mere was applied at the same quantity (0.5 and 1 g). The unit was arranged in a randomized block design per quantity of application with 4 repetitions.

All jars were infested by 20 insects at 24 h old, randomly selected. The counting of dead insects was carried out each day from the beginning of the test to the death of total insects. The jars were covered with wire mesh, (mesh of 1 mm diameter) to allow a good ventilation, a good exchange with ambient conditions and prevent exit of insects and other external contamination.

For the data-collecting, the content of each jar was sieved at 45th day after infestation, the adults insects were collected from the jar and were counted. The collected data related not only to the biological parameters (the mortality of the insects, F_1 progeny production), but also on the agronomics parameters (the weight loss and seeds damaged in the various samples at the end of the storage period (formula), and the germination test);

Mortality percentages were corrected by the Abbot formula Abbott (1925), by taking account of the natural mortality observed in the control jars;

$$M_C = \frac{M_o - M_T}{100 - M_o} \text{ x } 100$$

Where:

Mc is the corrected mortality (%),

M_0 is the mortality of insects observed in jars treated (%) and,

M_T is the mortality of insects naturally observed in the control jars (%).

The percentages of weight loss were calculated as in Ileke (2015):

$$\%\ \text{weight loss} = \frac{\text{initial weight} - \text{final weight}}{\text{initial weight}} \times 100$$

The germination test

At the end of insect emergence, samples of 50 seeds without visible appearance of attack were collected from each treatment to evaluate their germination potentiality. Germination test was carried out on absorbing paper by using the method of paper disc described by Hanson (1995).

The following formula was used to determine the percentage of germination (%G):

$$\%\text{G} = \frac{\text{Number of grains that germinated}}{\text{Total number of grains planted}} \times 100$$

Percentage of cowpea seed damaged

At the end of experiment, the number of damaged cowpea seeds was evaluated by counting seeds with holes, those presenting the damage of attack and wholesome seeds. The percentage of grains damaged was calculated at the 45th day of experiment, using the following formula:

$$\%\ Seed\ damage = \frac{Nomber\ of\ seeds\ damaged}{total\ nomber\ of\ seeds} \times 100$$

Data analysis

Data were subjected to the one-way analysis of variance, using R computer Software package version 3.2.2. In the case of significant difference, Student Newman-Keuls (SNK) test was used to separate means. The mortality rates obtained according to the various quantities of powdery formulations were analyzed to the log-probit in order to determine the Lethal dose fifty (LD_{50}) using R computer Software package version 3.2.2. The mortality rates in the treated jars were corrected by the Abbot formula Abbott (1925) by taking account the mortality rate obtained in the control jars.

RESULTS

Effect of the powdery formulation on the mortality of *Callosobruchus maculatus*

Table 1 revealed the means of mortality rates obtained in the jars according to the quantity of powdery formulations and the exposure time. Statistical analyses indicated that, there was significant difference ($p<0.001$) between the means mortality rates observed in the control jars and those treated with the powdery formulations (Antouka® insecticide and those based on cashew balms). For the powdery formulations containing cashew balm, the quantities of 0.5 g and 1 g; the mortality rates rose up 19.01% and 26.25% of mortality respectively. This significant difference observed after 24 h of exposure between the control jar (treated merely with kaolin powder) and those treated with chemical powder and powdery formulation containing cashew balm with quantities of 0.5 g and 1 g, is also observed after 48 h and 72 h of exposure for the same quantities of the powders. After 48 h and 72 h exposure to the powdery formulations based on the various types of cashew balms; the mortality rates are respectively of: 32.36% and of 75.99% of mortality for the quantity of 0.5 g; and of 56.79% and 90.47% of mortality for the quantity of 1 g. In addition, after 96 h of exposure the chemical powdery formulation caused 100% of mortality; this mortality rate after 96 h of exposure was also observed with the powdery formulations containing cashew balms as well for the quantity of 0.5 g for 1 g. The mortality of the insects increased with quantity and duration of powdery formulation.

Effect of the powdery formulation: on percentage of weight loss, on the means number of emerged adult and on the percentage of seeds damage

The means numbers of F_1 progeny of *C. maculatus* of the jars treated with the powdery formulations (Antouka® insecticide and those based on cashew balms) were significantly lower (p<0.001) than the means numbers of F_1 progeny production of the control jars (only treated with the kaolin powder). The means numbers of emerged adults (Table 2) ranged between 25.50 ± 7.96 insects to 44.50 ± 7.67 insects for the quantity of 0.5 g; and from 11.25 ± 4.62 insects to 29.50 ± 3.22 insects for the quantity of 1 g of powder formulation. For the control jars (only treated with the kaolin powder), the means numbers of emerged adults (Table 2) rose to 358.25 ± 84.54 insects and 188.50 ± 46.94 insects for the quantities of 0.5 g and of 1 g respectively. The number of emerged adults decreased when the powder quantity used increased.

Table 2 shows the evolution of the means percentage of weight loss due to the *C. maculatus* damage on cowpea. There was a significant difference (p<0.001) between the means percentage of weight loss observed in the control jars and the jars treated with the powdery formulations. In jars treated with powdery formulations containing cashew balm, the smallest means percentages of weight loss were obtained with the balms cold extracted, with the means percentages of 7.59 ± 1.96% and 4.96 ± 0.84% and of 3.38 ± 1.2% and 2.97 ± 1.05%, for the quantities 0.5 g and 1 g of powdery formulations respectively. For all the powders used, the means percentages of weight loss decrease when the quantity increase. For the control treatments, the means percentage of weight loss rose to 38.50 ± 1.32% and 26.89 ± 4.03% for the quantities of 0.5 g and 1 g respectively.

The percentage of seeds damaged is presented in Table 2. There was a significant difference (p<0.001) between the means percentage of seeds damaged in the control jars compared to the treated jars. The powdery formulations containing balms strongly limited the seeds damaged. For powdery formulations containing balms, smallest percentage of seed damage were obtaining with the powdery formulations resulting from the cold extracts; with the means percentage of 6.02 ±2.12% and 10.42 ± 2.98% and of 2.28 ± 0.15% and 2.94 ± 1.14% for the quantities of 0.5 g and 1 g respectively. The means percentage of seeds damaged decrease when the quantities of powder increase. For the control jars, the means percentage of seeds damaged rose to 71.95 ± 13.67% and 49.09 ± 6.33% for the quantities of 0.5 g and 1 g of kaolin powder respectively.

Effect of the powdery formulation on percentage of seed germination

The means percentages germination of cowpea seed at 45th after treatment are as shown in Figure 1. The means percentage of seeds germinated obtained at the end of germination period, shows that there was a significant difference (p<0.001) between the means percentage of seeds germinated in the control jars compared to the treated jars. The smallest percentage of germinated seeds were obtained with control, with the means number of 18.25 ± 6.66% and 33.50 ± 4.78% for the quantities of 0.5 g and 1 g of kaolin powder respectively. For cowpea seeds from the jars treated with powdery formulations containing cashew balms, the means percentage of germinated seeds were: 86.50 ± 1.70% and

92.50 ± 2.50%, and of 88.50 ± 0.95% and 92.50 ± 1.50% respectively for the quantities of 0.5 and 1 g.

Lethal dose 50 (LD_{50}) of various powders applied on *C. maculatus* after 2 and 3 days of exposure

The lethal dose 50 (LD_{50}) of the various powders applied is presented in Table 3. The results indicated that to reach 50% of mortality rate of *C. maculatus* at 2 days after application of the powdery formulations containing cashew balms, all formulations resulting from the cashew balms should be applied approximately in the same proportions, as indicated it the confidence intervals: (0.46-0.80), (0.55-0.93), (0.49-0.88) and (0.52-0.82) for the powdery formulations BW-EH, BW-EC, BNW-EH and BNW-EC respectively. At 3 days after applications of the powdery formulations, the results indicated that to reach 50% of mortality, it needed approximately the same quantities of powdery formulations, but smaller quantities than in the case of 2 days after application. For the control jars, kaolin powder quantity to apply to reach 50% of mortality was greater than the case of various powdery formulations. However, the results indicated that to reach 50% of mortality, the various powdery formulations containing cashew balms can be applied to low dose compared to kaolin powder dose. These results also revealed that *C. maculatus* was more sensitive to powdery formulations containing cashew balm than mere kaolin powder.

Table 1: Means percentage (±SE) of corrected mortality of *C. maculatus* by type of powdery formulation.

Doses	Treatments	24 h	48 h	72 h	96 h
0.5 g	BW-EH	19.01 ± 1.36 b	32.36 ± 4.20 b	69.28 ± 3.78 b	100.00 ± 0.00 a
	BW-EC	13.94 ± 2.43 b	26.40 ± 6.13 b	75.99 ± 3.27 b	100.00 ± 0.00 a
	BNW-EC	13.94 ± 1.32 b	28.23 ± 3.98 b	75.01 ± 3.95 b	100.0 ± 0.00 a
	BNW-EH	11.38 ± 1.21 b	31.09 ± 5.49 b	69.76 ± 11.63 b	100.00 ± 0.00 a
	Control	1.25 ± 1.25 c	16.25 ± 3.14 b	33.50 ± 4.26 c	33.75 ± 4.26 b
	CT	87.50 ± 5.95 a	100.00 ± 0.00 a	100.00 ± 0.00 a	100.00 ± 0.00 a
1 g	BW-EH	25.00 ± 2.04 b	56.79 ± 5.79 b	88.70 ± 5.42 a	100.00 ± 0.00 a
	BW-EC	20.00 ± 4.56 b	50.74 ± 3.34 b	88.88 ± 5.23 a	100.00 ± 0.00 a
	BNW-EC	23.75 ± 2.39 b	56.71 ± 3.22 b	90.47 ± 5.58 a	100.00 ± 0.00 a
	BNW-EH	26.25 ± 2.39 b	52.59 ± 3.28 b	88.39 ± 6.74 a	100.00 ± 0.00 a
	Control	0.00 ± 0.00 c	18.75 ± 2.39 c	30.00 ± 5.40 b	32.50 ± 4.33 b
	CT	92.50 ± 3.22 a	100.00 ± 0.00 a	100.00 ± 0.00 a	100.00 ± 0.00 a

Each value is a mean ± standard error of four replicates. Means (±SE) in each column followed by the same letter are not significantly different (P>0.05) using the Student Newman-Keuls (SNK) test.
BW-EH = Balm from Weakened nut Extracts Hot;
BNW-EH = Balm from Not Weakened nut Extracts Hot;
BW-EC = Balm from Weakened nut Extracts Cold;
BNW-EC = Balm from Not Weakened nut Extracts Cold;
CT = Chemical Treatment.

Table 2: Weight loss, seeds damage of cowpea; and F_1 progeny of *callosobruchus maculatus.*

Doses	Treatments	% weight loss	means number of adult emerged (F_1)	% seeds damaged
0.5 g	BW-EH	13.64 ± 3.63 b	44.00 ± 5.44 b	20.16 ± 1.33 b
	BW-EC	7.59 ± 1.96 bc	30.75 ± 8.83 b	6.02 ± 2.12 b
	BNW-EH	12.55 ± 1.26 b	44.50 ± 7.67 b	15.36 ± 0.99 b
	BNW-EC	4.96 ± 0.84 c	25.50 ± 7.96 b	10.42 ± 2.98 b
	Control	38.50 ± 1.32 a	358.25 ± 84.54 a	71.95 ± 13.67 a
	CT	2.36 ± 0.58 c	2.75 ± 0.47 b	1.47 ± 0.21 b
1 g	BW-EH	6.12 ± 1.16 b	26.00 ± 3.93 b	12.30 ± 3.44 b
	BW-EC	3.38 ± 1.21 b	13.00 ± 3.13 b	2.28 ± 0.15 b
	BNW-EH	7.10 ± 0.91 b	29.50 ± 3.22 b	6.07 ± 2.79 b
	BNW-EC	2.97 ± 1.05 b	11.25 ± 4.62 b	2.94 ± 1.14 b
	Control	26.89 ± 4.03 a	188.50 ± 46.94 a	49.09 ± 6.33 a
	CT	3.79 ± 1.04 b	2.50 ± 0.50 b	1.29 ± 0.32 b

Each value is a mean ± standard error of four replicates. Means (±SE) in each column followed by the same letter are not significantly different (P>0.05) using the Student Newman-Keuls (SNK) test.
BW-EH = Balm from Weakened nut Extracts Hot;
BNW-EH = Balm from Not Weakened nut Extracts Hot;
BW-EC = Balm from Weakened nut Extracts Cold;
BNW-EC = Balm from Not Weakened nut Extracts Cold;
CT = Chemical Treatment.

Table 3: Determination of the lethal dose 50 (LD_{50}) of various powders necessary to reach 50% of mortality of *C. maculatus* 2 days and 3 days after application of the powders.

Treatments	LD_{50} (g)	
	2 DAA	3 DAA
BW-EH	0.61 (0.46-0.80)	0.21 (0.07-0.56)
BW-EC	0.72 (0.55-0.93)	0.13 (0.02-0.85)
BNW-EH	0.65 (0.49-0.88)	0.18 (0.05-0.61)
BNW-EC	0.65 (0.52-0.82)	0.17 (0.04-0.65)
Control (kaolin)	-	3.93 (3.84-1.83.10^5)

LD_{50} (confidences limits); (-): Nothing; DAA: Days After Application.
BW-EH = Balm from Weakened nut Extracts Hot;
BNW-EH = Balm from Not Weakened nut Extracts Hot;
BW-EC = Balm from Weakened nut Extracts Cold;
BNW-EC = Balm from Not Weakened nut Extracts Cold;
CT = Chemical Treatment.

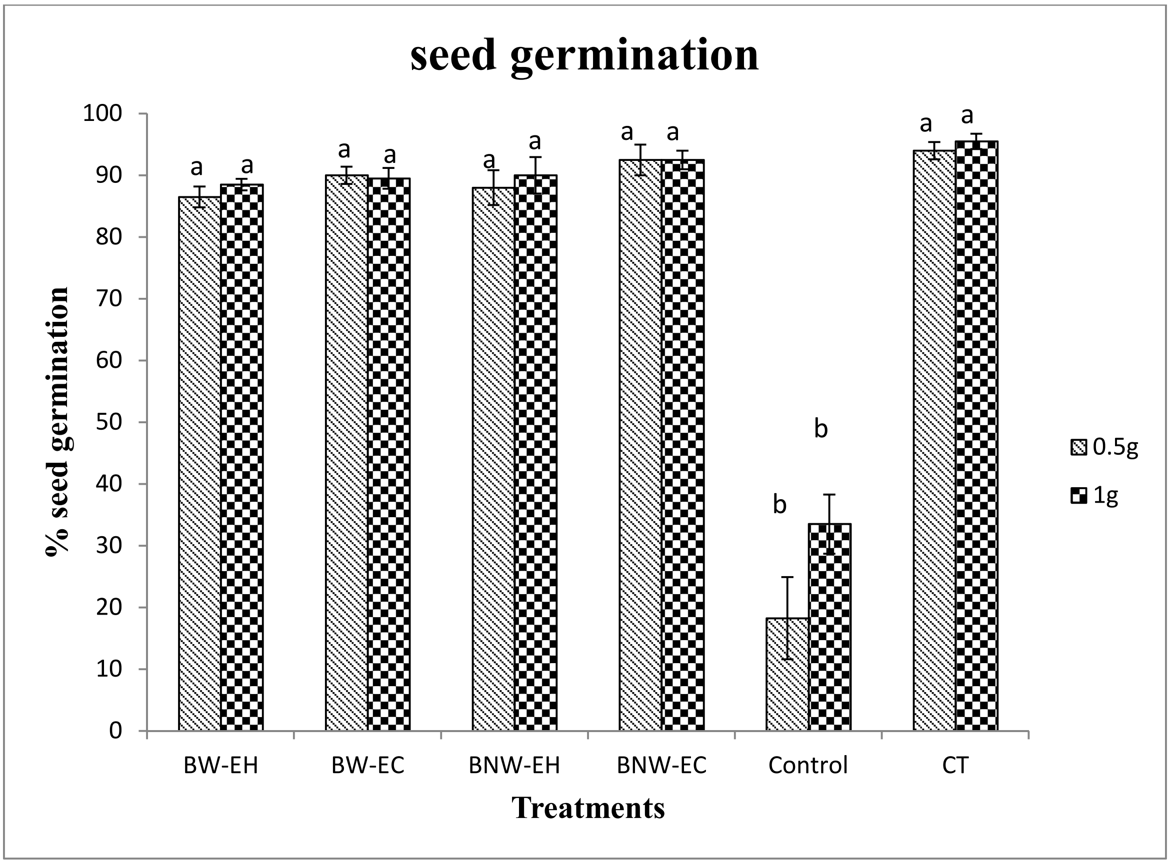

Figure 1: Percentage of cowpea seed germination. The bar segments with the same alphabetic letter are not significantly different (P>0.05) using the Student Newman-Keuls (SNK) test; BW-EH = Balm from Weakened nut Extracts Hot; BNW-EH = Balm from Not Weakened nut Extracts Hot; BW-EC = Balm from Weakened nut Extracts Cold; BNW-EC = Balm from Not Weakened nut Extracts Cold; CT = Chemical Treatment.

DISCUSSION

Results showed that powdery formulations containing cashew (*A. occidentale*) balms were toxic on cowpea weevils' *C. maculatus*. *C. maculatus*. The development of *C. maculatus* was reduced on cowpea treated compared to the control. The powdery Antouka® insecticide used caused 100% of mortality after 48 hours exposure. This mortality rate can be due to the active components contained in Antouka® powder (Permetrine 3 g/kg + Pirimiphos methyl 16 g/kg). The various cashew (*A. occidentale*) balms used to aromatize the kaolin powder for obtaining various powdery formulations used in this experiment caused 100% of mortality to *C. maculatus* after 96 hours of exposure, as well as for quantity of 0.5 g and 1 g of powdery formulations. The various cashew (*A. occidentale*) balms coated with the kaolin powder would have like mode of action to prevent any contact with the cowpea grains treated, thus causing the inanition. These results corroborate those reported by Kemabonta and Falodu (2013, Oparaeke and Bunmi (2006), and Ileke et al. (2014), in which they reported that oil and powder coming from cashew (*A. occidentale*) have caused 100% of mortality of maize weevil *Sitophilus oryzae* to 96 h after treatment of wheat grains. Forim et al. (2012) reported that the high rate of mortality observed with the use of plants extracts would be linked to secondary metabolites usually contained in the plants, which have high toxic effects on the insects. Other authors (Adedire et al., 2011; Ileke and Olotuah, 2012; Ileke et al., 2014) reported that the powder and oil of cashew could influence the movement and the mating of the adults insects, and could also cause the locomotion inhibition of the adults insects, thus reducing their lifespan.

Even without a significant difference between the toxic effects of the powdery formulations based on hot extracts and cold extracts of cashew balms, the numerical values indicated that powdery formulations based on cold extracts had a slightly higher effect than powdery formulations based on hot extracts. This could be due to the deterioration and the volatilization of some molecules such as anacardic acid, cardol, 2-Methyl-cardol and cardanol, during the hot extraction, thus reducing the toxic effect of cashew balms hot extract. This was also reported in the work of Rodrigues et al. (2011) and Taiwo (2015).

Except the powdery formulations (Antouka® insecticide and those based on cashew balms) which had significant effects on *C. maculatus,* the kaolin powder had a harmful but non-significant effect on cowpea bruchid *C. maculatus*. The beetles (*C. maculatus*) had stigma which are respiratory openings of the tracheas, and a hardened body. As soon as they were in contact with the kaolin powder, these respiratory openings were blocked thus causing the asphyxiation and the insects' mortality. Don-Pedro (1989), Ileke and Olotuah (2012), Ashamo et al. (2013), and AL-Naqib and AL-Dabbagh (1993) showed that the most significant characteristic of an inert dust was its great capacity for absorption of water and the lipids. Thus the kaolin powder applied absorbed water and the lipids coming from the insect hardened body, causing its death. Jassim and AL-Naqib (1989), and Nguemtchouin et al. (2009) had proved that kaolinite contained in majority: SiO_2, Al_2O_3, TiO_2, Fe_2O_3 and some fixers' ions (Ca^{2+}, Mg^{2+}, Na^+ and K^+). The kaolin powder applied at 1 g had better controlled the insects than with 0.5 g. This could be attributed to the major components of the kaolin which were abrasive agents of the cuticle of the insect and which would limit the insects' activities. These results corroborate those described by Riyad and Salem (2006), who remarked that kaolinite was an agent of exfoliation of the insect cuticle and thus made the insect very vulnerable.

The lethal dose 50 (LD_{50}) obtained, showed that for 50% of mortality the quantity of powdery formulation based on cashew balms was the same for the various balms. Indeed, to reach 50% of mortality of *C. maculatus* during a short time, it needed a quantity of powdery formulation relatively higher. This mortality during a short time, with some quantity of powdery formulation, could be due to the combine action, first of the chemical molecules (anacardic acid, cardol, 2-Methyl-cardol and cardanol) contained in the various cashews (*A. occidentale)* balms (Rodrigues et al., 2011; Adedire et al., 2011; Ileke et al., 2014), and of the components of the kaolin powder containing minerals salts only (SiO_2, Al_2O_3, TiO_2, Fe_2O_3) and some fixers' ions (Ca^{2+}, Mg^{2+}, Na^+ et K^+) (Jassim and AL-Naqib, 1989; Nguemtchouin et al., 2009), reducing insect's lifespan. Contrary to the powdery formulations based on kaolin and cashew (*A. occidentale*) balms, the lethal dose 50 (LD_{50}) obtained with kaolin powder only was higher than the quantity of powder necessary to reach 50% of *C. maculatus* mortality in the case of the powdery formulations containing cashew balms. This high quantity of kaolin powder necessary to reach 50% of *C. maculatus* mortality, could be related to the components of the kaolin powder containing minerals salts only (SiO_2, Al_2O_3, TiO_2, Fe_2O_3) and some fixers' ions (Ca^{2+}, Mg^{2+}, Na^+ et K^+) influencing insect's development (Jassim and AL-Naqib, 1989 ; Nguemtchouin et al., 2009).

The germination test showed that there was significant difference between the cowpea seeds treated with powdery formulations (Antouka® and those based on cashew balms) compared to those treated with kaolin powder. These results indicated that the powdery formulations especially those containing cashew balms had a positive effect on the germinative capacity of cowpea seeds. This positive effect of powdery formulations based on kaolin and cashew balms could be due to both effects of the kaolin powder and of the cashew (*A. occidentale*) balms. These results corroborate those described by Adedire et al. (2011), who reported that the extract of cashew (*A. occidentale*) had better controlled the influence of *C. maculatus* on cowpea seed and improve seed germination.

The high rate of *C. maculatus* emergence observed on the cowpea treated with kaolin merely could be related to its incapacity to protect the cowpea seeds in storage during a long time. This incapacity could be due to the insufficiency of the kaolin mineral components to completely prevent the insects (*C. maculatus*) activities and their development. Results obtained showed a significant reduction of: emergence rate; means percentage of damaged seeds and means percentage of cowpea seeds weight loss for those treated with powdery formulations (Antouka® and those based on cashew balms). Reduction of emergence rate observed could be certainly due: on the one hand to insecticidal activities performed by the insecticidal molecules (anacardic acid, cardol, 2-Methyl-cardol and cardanol) contained in cashew (*A. occidentale*) balms incorporated in the kaolin powder (Rodrigues et al., 2011; Taiwo, 2015; Adedire et al., 2011; Ileke et al., 2014), and on the other hand to the exfoliations effects of the insects cuticle caused by kaolin powder thus leading to the insect death. These results are in agreement with those described by Rehn and Espig (1991), where they found that insecticidal activity of the oil (*A. occidentale*) could be related to the presence of insecticidal molecules: anacardic acid, cardol, 2-Methyl-cardol and cardanol. These results are also in agreement with those reported by Riyad and Salem (2006), where the kaolin powder constituted an exfoliation agent of the beetles' cuticle in storage.

These combined effects of kaolin powder and the cashew balms would limit the insect's egg-laying and its development on the treated cowpea seeds. Then, that would lead to the reduction of weight loss and seeds damaged. These results corroborate those reported by Ileke et al. (2014) where it was noticed that the capacity of *Syzygium aromaticum* seeds powder and *Anacardium occidentale* nut powder to prevent the weight loss on treated seeds could be due to the insects' high mortality rate and the incapacity of the adults' emergence. These results are in agreement with those described by Adedire et al. (2011), where *A. occidentale* oil prevented the weight loss of cowpea (*Vigna unguiculata* L.), infested by *C. maculatus*.

Conclusion

In sum of this experiment, it appeared that powdery formulations based on kaolin powder and cashew (*A. occidentale*) balms had an insecticidal effect on *C. maculatus*. Thus, these powdery formulations significantly reduced emergence rate of adults of *C. maculatus*, weight loss and seeds damaged. These formulations allowed a high germination rate. These various results confirm bioefficacy of powdery formulations based on kaolin powder and cashew balms. In addition, both insecticidal activities exerted by powdery formulations based on kaolin powder and cashew balms on cowpea bruchid *C. maculatus* can be integrated into the strategic management of *C. maculatus.*

COMPETING INTERESTS

The authors declare that they have no competing interests.

AUTHORS' CONTRIBUTIONS

DAK was the principal investigator and drafted the manuscript. All the other co-authors (DCC, AHB-G, NVF-H and JD) contributed equally to the work and the manuscript writing.

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