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Perforation index assessment of Maize seeds treated with some Agro wastes Powder against maize weevil, *Sitophilus zeamais* (Motschulsky) [Coleoptera: Curculionidae]

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Abstract
This research evaluated the toxicity of five agro wastes (cowpea seed coats, melon shells, plantain, banana and cassava peels,) on maize weevil (*Sitophilus zeamais*). Powders were tested at dose 0.2, 0.4, 0.6, 0.8, 1.0, 1.5 and 2.0g/ 20g of maize seeds. Parameters that were evaluated include adult mortality, numbers of adult emergence, seed damage, weight loss and weevil perforation index. Proximate composition and phytochemicals were also investigated. Results showed that all the tested agro wastes powders and extracts significantly ($P<0.05$) reduced the population of adult *S. zeamais* on treated maize seeds. Melon shell powder at dosage 2.0 g caused 53.33% mortality of adult *S. zeamais* after 24 hours of treatment. This followed by Cassava peel powder that evoked 40.0% weevil mortality. The least toxic was cowpea seed coat powder that caused 20.0% mortality of adult weevil. The lethal dosage of Banana peel, Cassava peel, Cowpea seed coat, Melon shell, and Plantain peel powder at which 50% (LD50) population of maize weevil response after the first day of exposure were 3.46 g, 2.74 g, 4.88 g, 1.89 g, and 4.38 g, respectively. All the concentrations of Cassava peel and Melon shell extracts gave maximum seed protection against maize weevil. The phytochemical and antinutrient compositions of all the agro-waste used in this study showed that the waste contains Tannin, Alkaloid, Saponin, Flavonoid, Oxalate, Phytate and Cyanide with different levels of composition in percentage and milligram per gram. The melon shell of all the examined agro waste had the lowest lethal dosage and concentration to the adult *S. zeamais.* The use of Melon shell and cassava peel as bioinsecticides in the control of maize weevil in stored maize seeds among poor resource farmers should be advocated. The utilization of these wastes will also help reduce the problems associated with their management.

Keywords: Toxicity, Perforation index, *Sitophilus zeamis*, Agro waste, Bioinsecticide

Introduction
Stored product pests are a serious concern globally because they reduce both the quality and quantity of grains. The effects of pest infestation most especially insects are significant because they account for about 18% losses out of the total crop production worldwide (Oerke, 2006). Also, it is estimated that about 7% to 50% of all grain produced worldwide are destroyed by pests annually (Pimentel, 2009; Sallam, 2013; Culliney, 2014; Oliveira *et al*., 2014). The largest insect order with over 360,000 species described worldwide is the Coleoptera (Adedire, 2001; Gressit, 2020). This insect order contains the most common and significant stored product pests (Adedire, 2001; Sallam, 2013; Culliney, 2014; Ileke *et al*., 2020a). Maize weevil (*Sitophilus zeamais*) is a major primary pests that have a nearly cosmopolitan in the tropical region of the world as they cause significant damages through their feeding activities (Adedire, 2001; Nwaubani and Fasoranti, 2008; Soujanya *et al*., 2016a; Bhattacharjee *et al*., 2019). This often leads to shortages to the farmers which could threaten food security. It is essential to protect stored products from insect pests in order to guarantee the global food supply (Soujanya *et al*., 2016b). Efforts geared towards minimizing these losses have led to the use of pesticides running into billions of liters yearly (Pimentel, 2005; Alavanja, 2009; Ileke *et al*., 2020b). The primary method of grain protection is the use of synthetic chemicals to avoid or control insect infestations (Bhattacharjee *et al*., 2019). Indiscriminate use of synthetic insecticides on stored product may make those products unsafe for man's consumption and in the insect, it results in the development of resistance (Mohan *et al*., 2010; Correa et al., 2011; Soujanya *et al*., 2016a). Studies have shown that the use of synthetic insecticides has a cognate effect on non-targeted and also lead to other environmental hazards (Aktar *et al*., 2009; Abdel-Tawab, 2016; Ileke *et al*., 2020a; b). The hazardous nature of chemical insecticides necessitated a search for alternative, eco-friendly methods of controlling insect pests of storage such as the use of botanicals which are basically plant products (Midega *et al*., 2016; Suleiman *et al*., 2018; Ileke *et al*., 2020a).

Plant products possess the potential to be of value in pest management because they could be non-phytotoxicity, systemic, easily biodegradable and have stimulatory nature of host metabolism (Soujanya *et al*., 2016a). It is important to note that natural (plant) products constitute a very low percentage of current insecticides used (Yu, 2008). Hence, due to their natural origin, low mammalian toxicity, fast biodegradability and little to no residues, interest in the use of plant products has grown over the last few decades (Soujanya *et al*. 2016b; Ileke *et al*., 2020a). Some of these naturally occurring chemicals are known as 'secondary metabolites' found in botanicals have been shown to be very active biologically (Ileke *et al*., 2020b). They are phytochemicals which includes; saponins, tannins, flavonoids, alkaloids, phenols, tarpenes, cardiac glycosides and coumarins. Many of these secondary metabolites induces very deleterious biological reactions, while some of them are commonly used for food and drugs (Soetan, 2008). Extract, ash and powders of plants such as *Azadirachta indica, Zanthoxylum zanthoxyloides*, *Anacardium occidentale*, *Moringa oleifera*, *Alstonia boonei*, *Garcina kola*, *Nicotiana tabacum*, *Lantana camera*, *Annona squamosa*, *Justicia adhatoda*, *Ocimum tenuiflorum*, *Acanthus montanus* and *Acanthospermum hispidum* have been studied as potential alternatives to control *Sitophilus* species (Ileke and Oni, 2011; Ileke and Ogungbite, 2014; Karunakaran and Arulnandhy, 2018; Obembeet *et al*., 2020; Ileke *et al*., 2020a; b; 2021).

Agricultural wastes can be regarded as residues from the cultivation and processing of raw agricultural products such as fruits, vegetables, meat, poultry, dairy products, and crops (Obi *et al*., 2016). They are sometimes seen as a nuisance in the society when they are not properly managed. A way that these agricultural wastes could be managed is utilizing them in insect pest managements. Despite the fact that this practice is not common, some researchers have described the use of agricultural wastes such as rice husk and melon shell in ash or powder form to manage stored product pests (Olorunmota *et al*., 2017; Otitodun *et al*., 2017; Ashamo *et al*., 2021a; b). Nevertheless, more work is needed to harness the pesticidal efficacies that may be present in some of these agricultural wastes.

Therefore, there is a need to discover more of these wastes with insecticidal potentials. With this, the issue associated with the disposal of such waste will be minimized. The specific objectives of this research study are to evaluate toxicity of powders from cowpea seed coats, cassava peel, melon shell, banana and plantain peels on maize seeds and perforation index of the seeds during storage. The phytochemical and proximate compositions of five agro wastes were also investigated.

Materials and Methods

Insect rearing

Adult maize weevils, *Sitophilus zeamais* used for this study were supplied by Storage Entomology Research Laboratory, Department of Biology, Federal University of Technology, Akure (FUTA), Nigeria. One hundred (100) pairs of the weevils were introduced into 1 litre glass kilner jar containing 1000 g of maize grains collected from Agricultural Development Programme, Ado Ekiti, Ekiti State, Nigeria. The weevil culture was maintained under a constant insectarium condition of 28$\pm$2ºC and 75$\pm$5% relative humidity.

Collection and preparation of Agro waste powders

Cowpea seed coats, cassava peel, melon shell, banana and plantain peels in their fresh form and of insecticide free state collected from Ago Aduloju farm, Ado Ekiti, Ekiti State, Nigeria. The agro wastes were taken to Crop, Soil and Pest Management Department, Federal University of Technology, Akure (FUTA), Ondo State for authentication by plant taxonomist. They were thoroughly cleaned with distilled water, air-dried in the laboratory for 30 days before pulverized into coarse powder and finally ground in an electric blender, JTC Omni Blender V (Model TM-800). The resulting powders were sieved with a nylon mesh of 1mm^2 dimension in other to get fine powder for further use.

Collection of maize grains

Experimental maize seeds were sourced from newly stock maize seeds free of insecticides at the Agricultural Development Programme, Ado Ekiti, Ekiti State, Nigeria. The cleaned seeds were first remove before disinfested by putting them in a deep freezer at -5ºC for 7 days to ensure that all existing insect developmental stages are killed (Adedire *et al*., 2011). The disinfested maize seeds were later air dried naturally in the laboratory to safeguard against mould development (Adedire *et al*., 2011).

Preparation of ethanolic extracts

Extraction of cowpea seed coats, cassava peel, melon shell, banana and plantain peels were carried out by soaking 300 g of cowpea seed coats, cassava peel, melon shell, banana and plantain peels powders separately in an extraction bottle containing 6000 ml of absolute ethanol. The mixture was stirred occasionally at an interval of 6 hours with a glass rod. Extraction was terminated after 3 days. The mixture was filtered and the solvent regained by redistilling in a rotary evaporator at 30 to 40°C with rotary speed of 3 to 6 rpm for 8 hours (Udo *et al*., 2011). The resulting extracts were air dried to remove traces of ethanol. Crude extracts were bottled and labeled separately before been kept in a refrigerator.

Determination of Proximate composition

The composition of moisture, ash, protein, fat, crude fibre and carbohydrates in the agro wastes used in this study were determined by the procedures for proximate analysis described by AOAC (1990).

Phytochemical screening of the Agro wastes

Chemical tests were carried out on the ethanolic extracts of the cowpea seed coats, cassava peel, melon shell, banana and plantain peels for the qualitative and quantitative determination of phytochemical constituents using standard procedures as described by Harborn (1973); Trease and Evans (1985); Sofowora (1993), Ejikeme *et al*. (2014), Ileke *et al*. (2020a).

Weevil Bioassay

Entomotoxicity of five agro waste powders on adult mortality of *S. zeamais*

Twenty grammes (20 g) of disinfested maize seeds was put inside plastic cups (250 ml) before 0. 2, 0.4, 0.6, 0.8. 1.0, 1.5 and 2.0 g dosages of the cowpea seed coats, cassava peel, melon shell, banana and plantain peels were carefully measured in three replicates. Ten pairs of newly emerged adult *S. zeamais* (10 males: 10 females) were introduced into each of the plastic cups containing the treated maize seeds and covered with lid. The control experiment was also set up without any of the agro waste powders. Insect mortality was evaluated daily for 7 days. At the end of 7 days post treatment, data on percentage adult mortality was corrected using Abbott (1925) formula thus:

$$P_T = \frac{P_o - P_c}{100 - P_o} \times 100$$

Where P_T = corrected mortality (%)

P_O = observed mortality (%)

P_C = control mortality (%)

Daily observations were made on the insect bioassay set up until first filial generation adult emerged.

The numbers of damaged maize seeds were expressed in percentage as follows:

$$\%\ \text{Seed damage} = \frac{\text{Number of seeds damaged}}{\text{Total number of seeds}} \times 100$$

Weight loss of the maize seeds was expressed as % loss in weight as follows:

$$\%\ \text{Weight loss} = \frac{\text{Change in weight}}{\text{Initial weight}} \times 100$$

Weevil Perforation Index (WPI) was expressed according to Fatope *et al*. (1995) as follows:

$$\text{WPI} = \frac{\%\ \text{treated maize grains perforated}}{\%\ \text{control maize grains perforated}} \times 100$$

Entomotoxicity of five agro waste extracts on adult mortality of *S. zeamais*

Twenty grammes (20 g) of disinfested maize seeds was put inside plastic cups (250 ml) before 0. 2, 0.4, 0.6, 0.8. 1.0, 1.5 and 2.0 ml concentrations of the cowpea seed coats, cassava peel, melon shell, banana and plantain peels were carefully measured in three replicates. Ten pairs of newly emerged adult *S. zeamais* (10 males: 10 females) were introduced into each of the plastic cups containing the treated maize seeds and covered with lid. The control experiment and solvent treated (positive control) were also set up without any of the agro waste powders in three replicates. Insect mortality was evaluated daily for 7 days. At the end of 7 days post treatment, data on percentage adult mortality was corrected using Abbott (1925) formula as described above. The weevil bioassay experimental set up was kept inside the insect rearing cage for further 35 days to allow first filial generation adult to emerged. Total number of adult emergence, weight loss, seeds damage and Weevil Perforation Index were calculated as described above.

Data Analysis

Data collected from the laboratory tests were subjected to analysis of variance (ANOVA) at 5% significance level and treatment means were separated using New Duncan's Multiple Range Test. Probit analysis was carried out on percentage mortality of the adult *S. zeamais* to determine the 50% lethal dose/concentration (LD_{50}/LC_{50}) and 90% lethal dose/concentration (LD_{90}/LC_{90}).

Results

Proximate Composition of Five Agro – waste

The proximate compositions of five different agricultural wastes are presented in Table 1. The highest percentage moisture content was found in plantain peel (10.31%); this was not significantly different (P>0.05) from what was recorded in cowpea seed coat (10.08%), cassava peel (9.70%), and banana peel (9.65%). The lowest moisture content was recorded from melon shell waste with a 7.11% composition. The percentage composition of ash content of the five agro-waste was significantly different (P<0.05). The highest ash content was found in plantain peel waste (16.74%), followed by cassava peel (13.74%). The lowest ash content was recorded in the waste of banana peel (10.50%). The crude fibre was higher in melon shell (21.03%) waste compare to other agro-waste screened (P<0.05), while the lowest was recorded in plantain peel waste (4.48%). The percentage composition of crude protein detected from all the agro-waste was significantly different (P<0.05). The highest composition of crude protein was found in cowpea pod waste (10.16%), followed by banana peel waste (8.67%). The lowest composition of crude protein was recorded in cassava peel (6.86%). The fat content composition was higher in melon shell waste (6.56%), with a significant difference compared to other agro-waste screened (P<0.05). The fat content was found in the cowpea seed coat (0.96%). The silica composition was higher in cowpea seed coat waste with 48.16%, while the least composition of silica was recorded from the waste of cassava peel with 29.26%. A significantly different (P<0.05) composition of silica was recorded in all the screened agricultural waste.

Table 1: Proximate Composition of Five Agro wastes Tested

Agro – waste	Proximate Composition (%)					
	Moisture Content	Ash Content	Crude Fibre	Crude Protein	Fat Content	Silica
Banana Peel	9.65±0.18b	10.50±0.09a	10.12±0.28c	8.67±0.15c	2.87±0.16c	35.05±0.33c
Cassava Peel	9.70±0.12b	13.74±0.06d	8.11±0.19b	6.86±0.06a	2.07±0.08b	29.26±0.06a
Cowpea seed coat	10.08±0.23b	12.30±0.10b	18.90±0.27d	10.16±0.04d	0.96±0.03a	48.16±0.15d
Melon Shell	7.11±0.11a	13.35±0.08c	21.03±0.10e	8.55±0.09c	6.56±0.08e	52.35±0.27e
Plantain Peel	10.31±0.32b	16.74±0.03e	4.48±0.07a	8.14±0.09b	3.83±0.24d	30.56±0.12b

Each value is the mean ± standard error, n = 3 replicates. Letters as in Table 1, mean followed by the same letters within the same column are not significantly different (p>0.05) using New Duncan's Multiple Range Test.

Phytochemical Composition of Five Different Agro-waste

The composition of phytochemicals constituent of agricultural waste (banana peel, cassava peel, cowpea seed coat, melon shell, and plantain peel) used in this study is presented in Table 2. The highest percentage of tannin and flavonoid was found in melon shell waste with 0.13 mg/g and 4.81mg/g, respectively. The rate of the quantity of tannin and flavonoid found in melon shell waste was significantly different (P<0.05) from the amount of tannin found in other agricultural waste used in this study. The lowest percentage of tannin and flavonoid was found in banana peel. The highest rate of alkaloid and saponin was found in the dried waste of cassava peel with 9.59 mg/g and 12.42 mg/g, respectively. The composition of alkaloid and saponin found in cassava peel was significantly different (P<0.05) from the composition found in banana peel waste (4.69 and 9.40 mg/g was detected, respectively), cowpea seed coat waste (5.27 and 0.98 mg/g was detected, respectively), melon shell waste (8.53 and 7.16 mg/g was detected respectively), and waste of plantain peel 7.3.7 mg/g of alkaloid and 9.36 mg/g of Saponin. The lowest percentage composition of alkaloid was recorded in banana peel waste (4.69 mg/g), while the lowest percentage of saponin was found in Cowpea seed coat (0.98 mg/g).

Table 2: Quantitative Analysis of Phytochemical Constituent of Five Agro – waste

Agro waste	Phytochemical Composition (mg/g)			
	Tannin	Alkaloid	Saponin	Flavonoid
Banana Peel	0.04±0.00a	4.69±0.07a	9.40±0.12c	0.92±0.05a
Cassava Peel	0.08±0.00c	9.59±0.11e	12.42±0.03 d	1.84±0.15b
Cowpea seed coat	0.07±0.00b	5.27±0.07b	0.98±0.91a	3.25±0.04d
Melon Shell	0.13±0.00e	8.53±0.15d	7.16±0.12b	4.81±0.06e
Plantain Peel	0.10±0.00d	7.37±0.15c	9.36±0.06c	2.45±0.03c

Each value is the mean ± standard error, n = 3 replicates. Letters as in Table 2, mean followed by the same letters within the same column are not significantly different (p>0.05) using New Duncan's Multiple Range Test.

Antinutrient Composition of Five Agro – waste

Table 3 showed the percentage composition of some selected antinutrients found in five screened agricultural waste. The highest percentage composition of oxalate was recorded in banana peel waste (2.09 mg/g), the percentage composition was significantly different (P<0.05) from the composition recorded from plantain peel (1.89 mg/g), cassava peel (1.35 mg/g), cowpea seed coat (1.15 mg/g), and melon shell (0.84 mg/g). The percentage composition of phytate was higher in cassava peel waste with 47.85 mg/g composition, followed by 35.03 mg/g recorded from the waste of banana peel. The lowest percentage composition of phytate was recorded in cowpea seed coat waste (11.99 mg/g). There is a significant difference in the percentage composition of phytate recorded from all the five agro-waste screened in this study (P<0.05). The highest percentage composition of cyanide was found in cassava peel waste with 64.42 mg/kg, the composition of cyanide in cassava peel was significantly different (P<0.05) compare to other agro-waste screened. The composition of cyanide in banana peel (20.64 mg/kg), cowpea seed coat (25.92 mg/kg), melon shell (27.13 mg/kg), and plantain peel (23.93 mg/kg) are not significantly different (P>0.05).

Table 3: Antinutrient Composition of Five Agro – waste

Agro-waste	Antinutrient Composition		
	Oxalate (mg/g)	Phytate (mg/g)	Cyanide (mg/kg)
Banana Peel	2.09±0.08e	35.03±0.24d	20.64±0.49a
Cassava Peel	1.35±0.01c	47.85±0.11e	64.42±0.49b
Cowpea seed coat	1.15±0.01b	11.99±0.24a	25.92±1.23a
Melon Shell	0.84±0.6a	33.54±0.53c	27.13±0.18a
Plantain Peel	1.89±0.05d	26.38±0.02b	23.92±0.49a

Each value is the mean ± standard error, n = 3 replicates. Letters as in Table 3, means followed by the same letters within the same column are not significantly different (p>0.05) using New Duncan's Multiple Range Test.

The Effect of Agro-waste Powder on Adult Maize Weevil (*S. zeamais*)

The mortality response of adult *S. zeamais* to five different agro-waste powders regarding the period of exposure is presented in Table 4. The insecticidal effects of different treatment concentrations of powder (0.2 g, 0.4 g, 0.6 g, 0.8 g, 1.0 g, 1.5 g and 2.0 g) were significantly different. After the first day of exposure, the percentage mortality of *S. zeamais* shows no significant difference when comparing the effect of 0.2 g and 0.4 g powdered agro-waste treatments. The control, except 0.4 g of melon shell powder, gave 10.00% mortality, which is significantly higher than the control and adulticidal effects of 0.2 g powder and other 0.4 g powders of the agro-waste. The adulticidal effects of 0.2 g, 0.4 g, 0.6 g, 0.8 g, and 1.0 g powder of cowpea seed coat are not significantly different after the first day of exposure (0.00%, 0.00%, 0.00%, and 3.33% mortality was recorded, respectively). Adulticidal effect of 2.0 g powder of cowpea seed coat and plantain peel (20.00% and 23.33% mortality was recorded respectively) are not significantly different from the effect of 0.6 g powder of melon shell (20.00% mortality recorded), 0.8 g powder of cassava peel (20.00% mortality recorded), 1.0 g and 1.5 g powder of banana peel (20.00% and 23.33% mortality was recorded respectively) and 1.5 g powder of plantain peel (16.67% mortality recorded). The highest percentage of mortality was recorded from the effect of 2.0 g melon shell powder after the first day of exposure (53.33%); this was significantly different (*P* < 0.05) from the effect of other agro-waste powder used.

After the second day of exposure, the adulticidal effects of 0.2 g powder of banana peel, cowpea seed coat, and plantain peel (6.67%, 0.00%, and 3.33% mortality were recorded, respectively) are not significantly different from adulticidal effects 0.4 g powder of cowpea seed coat, plantain peel, and 0.6 g powder of cowpea seed coat (3.33%, 6.67%, and 10.00% mortality was recorded, respectively). The highest mortality of 66.67% was recorded with 2.0 g of melon shell powder; this is significantly different from other agro-waste powders with the same period of exposure. The adulticidal potency of 2.0 g powder of plantain peel (36.67% mortality was recorded), 1.5 g powder of melon shell and cassava peel (43.33% and 40.00% mortality was recorded respectively), 0.8 g and 0.1 g powder of melon shell (36.67% and 40.00% mortality was recorded respectively) are not significantly different (*P* > 0.05).

The adulticidal effect of 0.2 g powder of cowpea pod and plantain peel is not significantly different (*P* > 0.05) from the control; 6.67% mortality was recorded from both agro-waste. The highest mortality was recorded from those treated with 2.0 g powder of melon shell (86.67% was recorded) after the third day of exposure. The effect of 2.0 g powder of melon shell was significantly different (*P* < 0.05) from the 0.2 g, 0.4 g, 0.6 g, 0.8 g, 1.0 g, 1.5 g and 2.0 g powders of other agro-waste used after the third day of exposure. The effects of all agro-waste powders at all concentrations are significantly different from the control (*P* < 0.05) after the fourth day of exposure. The adulticidal effect of 1.0 g powder of melon shell (66.67% mortality was recorded), 1.5 g powder of cassava peel, and melon shell (66.67% and 73.33% mortality was recorded, respectively) are not significantly different (*P* > 0.05) from the effect of 2.0 g powder of plantain peel (73.33% mortality was recorded). After the fourth day of exposure, the highest The adulticidal response of 0.2 g of melon shell powder (33.33%), 0.4 g banana peel, cassava peel, and cowpea seed coat powder (33.33%, 36.67% and 30.00% mortality were recorded respectively), 0.6 g powder of banana peel, plantain peel and 0.8 g cowpea seed coat powder (33.33%, 30.00% and 36.67%) are not significantly different ($P > 0.05$) after the fifth day of exposure.

The highest was recorded with the 2.0 g powder of cassava peel and melon shell (100% mortality was recorded from both treatments); the lowest mortality was recorded from 0.2 g powder of cowpea seed coat (13.33%). The effect of 1.0 g powder of cassava peel and melon shell (86.67% and 93.33% mortality was recorded respectively), 1.5 g powder of cassava peel and melon shell (93.33% and 100% mortality was recorded respectively), 2.0 g powder of banana peel, cassava peel, cowpea seed coat, melon shell and plantain peel (100.00%, 100.00%, 86.67%, 100.00%, and 93.33% mortality was recorded respectively) are not significantly different at $P > 0.05$ after sixth day period of exposure. The lowest mortality was recorded from those treated with 0.2 g powder of cowpea seed coat and plantain peel (20.00% mortality was recorded). The adulticidal effect of 2.0 g of all agro-waste treatment powders is not significantly different ($P > 0.05$) with 1.0 g powder of cassava peel and melon shell (93.33% and 100% mortality was recorded, respectively), 1.5 g powder of banana peel, cassava pee, and melon shell (93.33%, 100.00% and 100.00% mortality were recorded respectively) after the seventh day of exposure.

Lethal Dosage of Agro-waste required to Achieve 50% (LD_{50}) and 90% (LD_{90}) Mortality of *S. zeamais*

The lethal dosage (LD) of five agro-wastes powders against adult *S. zeamais* are presented in Table 5. The required dosage powder of banana peel needed to achieve 50% (LD_{50}) mortality of *S. zeamais* after the first day, fourth day and seventh day of exposure were 3.46 g, 0.95 g and 0.44 g, respectively. The mortality was recorded from those treated with 2.0 g melon shell powder (100% mortality was recorded).

dosage required to achieve 90% (LD_{90}) mortality of *S. zeamais* using banana peel powder is 15.99 g after the first day of exposure, 5.43 g after the fourth and 1.55 g after the seventh day of exposure. The regression linear (R2) calculated for the first day, the fourth day, and the seventh day were 0.96, 0.87 and 0.44.

The powder dosage of cassava peel required to cause 50% (LD_{50}) mortality of *S. zeamais* for the first five days of exposure was 2.74 g, 2.05 g, 1.20 g, 0.74 g and 0.58 g, respectively, while the last two days of exposure were 0.41 g and 0.35 g. The lethal dosage of cassava peel powder needed to achieve 90% (LD_{90}) mortality of *S. zeamais* after different days of exposure were 15.82 g, 13.49 g, 8.47 g, 3.75 g, 3.16 g, 1.49 g, and 1.20 g. The cowpea seed coat powder needed to achieve 50% (LD_{50}) mortality of *S. zeamais* within seven days of exposure were 4.88 g, 4.08 g, 4.12 g, 3.0 g, 1.13 g, 0.77 g and 0.6 g, respectively. The lethal dosage required to cause 90% (LD_{90}) mortality were 17.67 g, 15.66 g, 11.05 g, 9.88 g, 7.36 g, 4.87 g and 2.94 g, respectively.

The lethal dosage of melon shell powder required to achieve 50% (LD_{50}) mortality of *S. zeamais* for seven consecutive days was 1.89 g, 1.49 g, 0.81 g, 0.62 g, 0.41 g, 0.32 g and 0.27 g, respectively. The gram dosage needed to achieve 90% mortality for the first four days of exposure were 11.39 g, 7.88 g, 4.79 g, and 4.62 g, while 2.04 g, 1.26 g, and 1.06 g were required to cause mortality for the fifth, sixth and seventh days respectively. The plantain peel powder was active against *S. zeamais*, with 4.38 g, 3.86 g, 2.06 g, 1.30 g, 0.81 g, 0.65 g and 0.51 g of the powder needed to achieve 50% mortality within seven days of exposure, respectively. The dosage required to attain 90% mortality of *S. zeamais* was 18.27 g, 16.92 g, and 13.66 g, respectively, from the first, second, and third day of exposure. The dosage needed to attain 90% mortality after a period of four, five, six and seven days of exposure were
8.58 g, 3.65 g, 2.77 g and 2.3 g, respectively.

Table 4: Dosage response of adult *S. zeamais* treated with five agro-waste powders

Agro-waste Powder	Dos. (g)	Mean % mortality ± S. E.						
		Day 1	Day 2	Day 3	Day 4	Day 5	Day 6	Day 7
Banana peel		0.00±0.00a	6.67±3.33abc	10.00±0.00bc	16.67±3.33bc	23.33±3.33cd	23.33±3.33b	26.67±3.33bc
Cassava peel		3.33±3.33ab	10.00±0.00bcd	13.33±3.33bcd	20.00±0.00bcd	26.67±3.33de	30.00±0.00bc	33.33±3.33cd
Cowpea seed coat	0.2	0.00±0.00a	0.00±0.00a	6.67±3.33ab	13.33±3.33b	13.33±3.33b	20.00±5.77b	23.33±3.33b
Melon shell		6.67±3.33ab	16.67±3.33de	20.00±0.00def	26.67±3.33def	33.33±3.33ef	36.67±3.33cd	40.00±0.00de
Plantain peel		0.00±0.00a	3.33±3.33ab	6.67±3.33ab	13.33±3.33b	16.67±3.33bc	20.00±5.77b	23.33±3.33b
Banana peel		3.33±3.33ab	10.00±5.77bcd	16.67±6.67cde	26.67±3.33def	33.33±3.33ef	36.67±3.33cd	43.33±3.33ef
Cassava peel		6.67±3.33ab	13.33±3.33cde	23.33±3.33efg	30.00±0.00efg	36.67±3.33fg	43.33±3.33def	50.00±0.00fg
Cowpea seed coat	0.4	0.00±0.00a	3.33±3.33ab	10.00±0.00bc	13.33±3.33b	30.00±0.00def	40.00±5.77cde	36.67±3.33de
Melon shell		10.00±3.33bc	20.00±0.00ef	30.00±0.00ghi	40.00±0.00hij	50.00±0.00hi	56.67±3.33ghi	66.67±3.33ijk
Plantain peel		0.00±0.00a	6.67±3.33abc	13.33±3.33bcd	20.00±5.77bcd	26.67±6.67de	33.33±6.67cd	40.00±5.77de
Banana peel		6.67±3.33ab	13.33±3.33cde	23.33±3.33efg	26.67±6.67def	33.33±3.33ef	50.00±0.00efg	53.33±3.33gh
Cassava peel		10.00±0.00bc	20.00±0.00ef	30.00±0.00ghi	33.33±3.33fgh	43.33±3.33gh	60.00±0.00ghi	63.33±3.33ij
Cowpea seed coat	0.6	0.00±0.00a	6.67±3.33abc	13.33±3.33bcd	20.00±0.00bcd	23.33±3.33cd	36.67±3.33cd	40.00±0.00de
Melon shell		20.00±0.00de	26.67±3.33fg	33.33±3.33hi	40.00±0.00hij	53.33±3.33ij	66.67±3.33ij	73.33±3.33klm
Plantain peel		3.33±3.33ab	10.00±0.00bcd	20.00±0.00def	23.33±3.33cde	30.00±0.00def	40.00±0.00cde	53.33±8.82gh
Banana peel		10.00±0.00bc	20.00±0.00ef	30.00±0.00ghi	40.00±0.00hij	46.67±3.33hi	53.33±3.33fgh	70.00±0.00jkl
Cassava peel		20.00±0.00de	26.67±3.33fg	33.33±3.33hi	50.00±0.00klm	53.33±3.33ij	63.33±3.33hij	76.67±3.33lm
Cowpea seed coat	0.8	3.33±3.33ab	10.00±0.00bcd	16.67±3.33cde	26.67±3.33def	36.67±3.33fg	43.33±3.33def	50.00±0.00fg
Melon shell		26.67±3.33efg	36.67±3.33hij	43.33±3.33jk	53.33±3.33lmn	60.00±0.00jk	73.33±3.33jk	86.67±3.33no
Plantain peel		6.67±3.33ab	13.33±3.33cde	23.33±3.33efg	33.33±3.33fgh	43.33±3.33gh	50.00±0.00efg	60.00±0.00hi
Banana peel		20.00±0.00de	26.67±3.33fg	36.67±3.33ij	50.00±0.00klm	60.00±0.00jk	66.67±3.33ij	80.00±0.00mn
Cassava peel		26.67±3.33efg	33.33±3.33ghi	50.00±0.00kl	60.00±0.00no	73.33±3.33lm	86.67±3.33lm	93.33±3.33op
Cowpea seed coat	1	6.67±3.33ab	13.33±3.33cde	20.00±0.00def	36.67±3.33ghi	46.67±3.33hi	50.00±0.00efg	60.00±0.00hi
Melon shell		33.33±3.33gh	40.00±0.00ijk	56.67±3.33lm	66.67±3.33op	80.00±0.00mno	93.33±3.33mn	100.00±0.00p
Plantain peel		10.00±0.00bc	20.00±3.33ef	30.00±3.33ghi	43.33±3.33ijk	53.33±3.33ij	60.00±5.77ghi	73.33±3.33klm
Banana peel		23.33±3.33def	33.33±3.33ghi	43.33±3.33jk	56.66±3.33mn	66.67±3.33kl	80.00±0.00kl	93.33±3.33op

Cassava peel		33.33±3.33gh	40.00±0.00ijk	53.33±3.33lm	66.67±3.33op	80.00±0.00mno	93.33±3.33mn	100.00±0.00p
Cowpea seed coat	1.5	10.00±0.00bc	20.00±0.00ef	26.67±3.33fgh	36.67±3.33ghi	50.00±0.00hi	63.33±3.33hij	73.33±3.33klm
Melon shell		40.00±0.00h	43.33±3.33jk	60.00±0.00mn	73.33±3.33p	90.00±5.77p	100.00±0.00mn	100.00±0.00p
Plantain peel		16.67±3.33cd	26.67±3.33fg	33.33±3.33hi	46..67±3.33jkl	60.00±0.00jk	73.33±3.33jk	86.67±3.33no
Banana peel		30.00±0.00fg	46.67±3.33kl	60.00±5.77mn	83.33±3.33q	86.67±3.33op	100.00±0.00mn	100.00±0.00p
Cassava peel		40.00±0.00h	53.33±3.33l	66.67±3.33n	86.67±3.33q	100±0.00q	100.00±0.00mn	100.00±0.00p
Cowpea seed coat	2	20.00±0.00de	30.00±0.00gh	43.33±3.33jk	60.00±0.00no	76.67±3.33mn	86.67±3.33lm	93.33±3.33op
Melon shell		53.33±3.33i	66.67±3.33m	86.67±3.33o	100.00±0.00r	100.00±0.00q	100.00±0.00mn	100.00±0.00p
Plantain peel		23.33±3.33def	36.67±3.33hij	60.00±0.00mn	73.33±3.33p	83.33±3.33nop	93.33±3.33mn	100.00±0.00p
Control	0	0.00±0.00a	0.00±0.00a	0.00±0.00a	0.00±0.00a	0.00±0.00a	0.00±0.00a	0.00±0.00a

Each value is the mean ± standard error, n = 3 replicates. Letters as in Table 4, means followed by the same letters within the same column are not significantly different (p>0.05) using New Duncan's Multiple Range Test.

Table 5: Lethal Dosage (LD) of five agro-wastes powders against adult *Sitophilus zeamais*

Agro waste	Exposure Period	Intercept± S.E.	Slope± S.D.	R^2	LD_{50} (LCL - UCL)	LD_{90} (LCL - UCL)	P-value
Banana Peel	Day 1	3.96±0.11	1.92±0.52	0.96	3.46 (2.15 – 5.56)	15.99 (9.93 - 25.74)	0.63
	Day 2	4.35±0.12	1.42±0.70	0.95	2.80 (1.66 – 5.01)	14.31 (8.45-22.41)	0.88
	Day 3	4.66±0.11	1.47±0.68	0.97	1.70 (1.03 – 2.79)	12.61 (7.68 – 20.73)	0.97
	Day 4	5.05±0.09	1.75±0.57	0.87	0.95 (0.63 – 1.43)	5.43 (3.61 – 8.17)	0.47
	Day 5	5.25±0.09	1.73±0.58	0.87	0.72 (0.48 - 1.09)	4.19 (2.78 – 6.87)	0.51
	Day 6	5.41±0.09	1.76±0.57	0.97	0.58 (0.39 – 0.89)	3.16 (2.10 – 4.75)	0.87
	Day 7	5.85±0.07	2.38±0.42	0.94	0.44 (0.32 – 0.61)	1.55 (1.12 – 2.14)	0.74
Cassava Peel	Day 1	4.26±0.11	1.69±0.59	0.97	2.74 (1.69 – 4.44)	15.82 (9.76 – 25.65)	0.90
	Day 2	4.55±0.12	1.38±0.73	0.96	2.05 (1.24 – 3.67)	13.49 (7.78 -20.74)	0.92
	Day 3	4.88±0.10	1.52±0.66	0.96	1.20 (0.75 – 1.93)	8.47 (5.29 – 14.86)	0.94
	Day 4	5.25±0.09	1.86±0.53	0.91	0.74 (0.50 – 1.08)	3.75 (2.55 – 5.52)	0.65
	Day 5	5.43±0.09	1.74±0.58	0.92	0.58 (0.38 – 0.86)	3.16 (2.09 – 4.77)	0.56
	Day 6	5.90±0.07	2.35±0.43	0.91	0.41 (0.29 – 0.59)	1.49 (1.07 – 2.08)	0.63
	Day 7	6.13±0.07	2.50±0.40	0.88	0.35 (0.25 – 0.49)	1.20 (0.86 – 1.67)	0.63
Cowpea seed Coat	Day 1	3.42±0.12	2.29±0.42	0.96	4.88 (2.81 – 8.19)	17.67 (10.53 -29.65)	0.22
	Day 2	3.89±0.11	1.82±0.55	0.10	4.08 (2.51 – 7.05)	15.66 (10.33 – 24.63)	0.91
	Day 3	4.24±0.14	1.24±0.81	0.92	4.12 (2.12 – 7.86)	11.05 (8.59 – 19.04)	0.78
	Day 4	4.49±0.15	1.07±0.94	0.89	3.00 (1.49 – 6.02)	9.88 (6.89 – 16.97)	0.76
	Day 5	4.92±0.09	1.60±0.63	0.86	1.13 (0.72 – 1.76)	7.36 (4.71 – 11.51)	0.44
	Day 6	5.19±0.10	1.65±0.61	0.84	0.77 (0.49 – 1.18)	4.87 (3.17 – 7.48)	0.57
	Day 7	5.42±0.08	2.00±0.50	0.86	0.62 (0.43 – 0.89)	2.94 (2.04 – 4.22)	0.51
Melon Shell	Day 1	4.54±0.10	1.66±0.60	0.98	1.89 (1.19 – 2.99	11.39 (7.21 – 18.00)	0.96
	Day 2	4.78±0.12	1.30±0.77	0.89	1.49 (0.89 – 2.58)	7.88 (5.59 – 14.76)	0.73
	Day 3	5.17±0.09	1.75±0.57	0.86	0.81 (0.54 – 1.21)	4.79 (3.07 – 6.93)	0.58
	Day 4	5.30±0.11	1.45±0.69	0.92	0.62 (0.38 – 1.01)	4.62 (2.95 – 7.79)	0.56
	Day 5	5.73±0.09	1.88±0.53	0.88	0.41 (0.28 – 0.63)	2.04 (1.37 – 3.03)	0.75
	Day 6	6.12±0.08	2.26±0.44	0.85	0.32 (0.23 – 0.46)	1.26 (0.88 – 1.80)	0.83
	Day 7	6.23±0.09	2.13±0.47	0.97	0.27 (0.18 – 0.39)	1.06 (0.72 – 1.57)	0.89
Plantain Peel	Day 1	3.67±0.11	0.99±0.48	0.99	4.38 (2.65 – 7.25)	18.27 (11.05 – 30.21)	0.58
	Day 2	4.12±0.13	1.49±0.67	0.98	3.86 (2.19 – 6.78)	16.92 (9.88 – 29.01)	0.98
	Day 3	4.51±0.12	1.56±0.64	0.93	2.06 (1.26 – 3.34)	13.66 (8.39 – 22.23)	0.77
	Day 4	4.82±0.10	1.59±0.63	0.89	1.30 (0.83 – 2.05)	8.58 (5.46 – 13.49)	0.60
	Day 5	5.22±0.08	2.13±0.47	0.81	0.81 (0.57 – 1.14)	3.65 (2.59 – 5.144)	0.24
	Day 6	5.41±0.08	2.13±0.47	0.89	0.65 (0.46 – 0.92)	2.77 (1.96 – 3.91)	0.61
	Day 7	5.61±0.08	2.06±0.49	0.97	0.51 (0.35 – 0.73)	2.30 (1.50 – 3.09)	0.94

Note: R^2 = Statistical measure of mortality proportion in regression model; S. E. = Standard error
S. D. = Standard deviation; LD_{50} = Lethal dosage at which 50% population response
LC_{90} = Lethal dosage at which 90% population response; LCL = Lower confidence limit
UCL = Upper confidence limit; P-value = Chi -square (X^2) Significant.

Adult Emergency of *S. zeamais* Treated with Agro-waste Powder

Table 6 illustrates the effect of agro-waste powder on adult emergency of maize weevil. There was no adult emergency in maize seeds treated with 2.0 g of cassava peel, 1.5 g and 2.0 g melon shell powders, Maize seed treated with agro-waste powder of 0.2 g of banana peel and 0.2 g of cowpea seed coat powder results had 17 and 18.33 adult emergency, respectively. The protective effectiveness of 2.0 g of Banana peel, Plantain peel, and Cowpea pod powder on maize seeds in respect to maize weevil adult emergency were not significantly different (P>0.05). The adult emergence in the untreated cowpea seeds was significantly different (p < 0.05) from emergence in the treated cowpea seeds. However, there was no significant difference (P>0.05) in adult emergence of maize weevil when compare 0.8 g of Banana peel (7.33 was recorded), 0.4 g and 0.6 g of cassava peel powder (7.33 and 6.33 were recorded respectively), 1.5 g of cowpea seed coat (7.67 was recorded), 0.2 g of melon shell powder with 7.00 adult weevil emergence, and Plantain peel powder at dosage 0.6 g and 0.8 g were 6.67 and 6.33 adult emergence, respectively.

Seed Damage, Weight Loss, and Weevil Perforation Index Caused by *S. zeamais* treated with Agro waste Powders

Percentage seed damage, weight loss, and weevil perforation index are presented in Table 7. Maize seeds treated with 2.0 g of banana peel, cowpea seed coat and plantain peel powder had 21.72%, 23.19%, and 19.19% seed damage, respectively. Zero (0.0%) percentage seed damage was recorded in maize seed treated with 2.0 g of cassava peel, 1.5 g and 2.0 g of melon shell powder. There was no significant difference (P>0.05) when comparing the level of seed damage with maize treated with 1.0 g and 1.5 g of cassava peel powder, 0.8 g and 1.0 g of melon shell powder, and 2.0 g of plantain peel powder. The highest weight loss was recorded with maize treated with 0.2 g of cowpea seed coat powder (30.25%) but was significantly different (P<0.05) from the control (67.03%). The weevil perforation index recorded from the seeds treated with 0.2 g of cowpea seed coat powder (61.52%) was the highest, followed by 0.2 g of banana peel powder with which had 57.67%.

Table 6: Adult emergency of *S. zeamais* in Maize treated with agro-waste powder

Agro-waste Powder	Dosage (g)	Number of Adult Emergency
Banana Peel	0.2	17.00±0.58no
	0.4	11.00±0.58l
	0.6	8.33±0.33ijk
	0.8	7.33±0.33ghij
	1.0	6.00±0.00defg
	1.5	5.33±0.33def
	2.0	2.67±0.33c
Cassava Peel	0.2	11.00±0.58l
	0.4	7.33±0.67ghij
	0.6	6.33±0.33efghe
	0.8	5.33±0.33def
	1.0	0.33±0.33ab
	1.5	1.67±0.88bc
	2.0	0.00±0.00a
Cowpea seed coat	0.2	18.33±0.88o
	0.4	14.00±0.58m
	0.6	11.00±0.58l
	0.8	9.33±0.33k
	1.0	8.67±0.33jk
	1.5	7.67±0.33hij
	2.0	5.00±1.00de
Melon Shell	0.2	7.00±0.58ghi
	0.4	4.67±0.33d
	0.6	2.67±0.33c
	0.8	0.67±0.33ab
	1.0	0.33±0.33ab
	1.5	0.00±0.00a
	2.0	0.00±0.00a
Plantain Peel	0.2	15.67±0.33n
	0.4	9.67±0.33kl
	0.6	6.67±0.33fgh
	0.8	6.33±0.33efgh
	1.0	5.33±0.33def
	1.5	4.67±0.33d
	2.0	0.67±0.33ab
Control	0.0	29.33±0.88p

Each value is the mean ± standard error, n = 3 replicates. Letters as in Table 6, means followed by the same letters within the same column are not significantly different (p>0.05) using New Duncan's Multiple Range Test.

Table 7: Weevil perforation index caused by *S. zeamais* treated with five agro-waste powders

Agro-waste Powder	Dosage (g)	Total No of Seed	Number of Seed damage	% Seed Damage	% Weight Loss	Weevil Perforation Index
Banana Peel	0.2	78.33	17.00±0.58no	21.72±0.87pq	27.36±1.33j	57.67±4.15rs
	0.4	78.67	11.00±0.58l	17.32±2.68n	17.05±0.35i	37.25±33.29op
	0.6	78.00	8.33±0.33ijk	10.70±0.58ijkl	10.19±0.15gh	30.19±4.36lmn
	0.8	78.00	7.33±0.33ghij	9.40±0.44ghijk	8.46±0.15efgh	24.96±1.49ijklm
	1.0	79.00	6.00±0.00defg	7.60±0.11defgh	7.50±0.31defgh	23.17±2.96hijkl
	1.5	78.00	5.33±0.33def	6.85±0.53def	7.23±0.12defgh	18.10±0.94fghi
	2.0	78.00	2.67±0.33c	3.75±0.11bc	4.87±3.55cd	9.57±1.44cde
Cassava Peel	0.2	78.67	11.00±0.58l	14.01±0.93m	16.91±0.46i	37.22±4.01op
	0.4	78.67	7.33±0.67ghij	9.31±0.77fghijk	9.62±0.99fgh	24.54±1.15ijkl
	0.6	80.00	6.33±0.33efghe	7.92±0.42defgh	8.03±0.02defgh	20.99±1.17fghij
	0.8	76.33	5.33±0.33def	6.99±0.46defg	7.39±0.37defgh	18.64±1.98fghij
	1.0	78.00	0.33±0.33ab	0.42±0.42a	0.37±0.37a	1.19±1.19a
	1.5	79.00	1.67±0.88bc	2.14±1.14ab	3.63±1.82bc	5.44±2.86abc
	2.0	79.00	0.00±0.00a	0.00±0.00a	0.00±0.00a	0.00±0.00a
Cowpea seed Coat	0.2	79.00	18.33±0.88o	23.19±0.75q	30.25±0.33k	61.52±2.98s
	0.4	77.67	14.00±0.58m	18.03±0.69no	25.57±0.69j	47.83±2.60q
	0.6	77.33	11.00±0.58l	14.23±0.79m	15.63±0.61i	37.93±3.67p
	0.8	80.00	9.33±0.33k	11.67±0.49kl	10.58±0.18h	30.97±1.71mno
	1.0	78.00	8.67±0.33jk	11.12±0.50jkl	10.57±0.23h	29.54±2.03klmn
	1.5	79.00	7.67±0.33hij	9.70±0.37hijk	9.95±0.09gh	25.80±1.85jklmn
	2.0	79.00	5.00±1.00de	6.31±1.23de	7.24±1.07defgh	16.52±2.78fgh
Melon Shell	0.2	78.67	7.00±0.58ghi	8.89±0.69fghij	9.70±1.25fgh	23.69±2.56ijkl
	0.4	77.00	4.67±0.33d	6.06±0.44de	6.50±0.04cdef	16.01±0.69efg
	0.6	79.67	2.67±0.33c	3.36±0.44b	6.06±0.10cde	8.91±1.27bcd
	0.8	77.00	0.67±0.33ab	0.86±0.43a	0.81±0.42ab	2.29±1.16ab
	1.0	80.00	0.33±0.33ab	0.42±0.42a	0.29±0.29a	1.19±1.19a
	1.5	77.33	0.00±0.00a	0.00±0.00a	0.00±0.00a	0.00±0.00a

	2.0	80.00	0.00±0.00a	0.00±0.00a	0.00±0.00a	0.00±0.00a
Plantain Peel	0.2	78.67	15.67±0.33n	19.91±0.23op	26.24±0.09j	52.86±2.53qr
	0.4	80.00	9.67±0.33kl	12.09±0.49lm	17.87±4.37i	32.09±1.93nop
	0.6	78.00	6.67±0.33fgh	8.56±0.54efghi	10.31±0.49h	22.81±2.24ghijk
	0.8	80.00	6.33±0.33efgh	7.91±0.36defgh	8.09±0.03defgh	20.94±0.51fghij
	1.0	78.00	5.33±0.33def	6.83±0.34def	7.31±0.06defgh	18.08±0.64fghi
	1.5	80.00	4.67±0.33d	5.81±0.44cd	6.87±0.20defg	15.34±0.66def
	2.0	77.00	0.67±0.33ab	0.87±0.43a	0.71±0.36ab	2.31±1.16ab
Control	0.0	77.67	29.33±0.88p	37.81±1.53r	67.03±2.39l	>50.00±0.00s

Each value is the mean ± standard error, n = 3 replicates. Letters as in Table 7, means followed by the same letters within the same column are not significantly different (p>0.05) using New Duncan's Multiple Range Test.

Correlation between cassava peel, phytochemical, antinutrient compositions, adult emergence, seed damage, and weight loss

The correlation coefficient (r) between composition of antinutrient, phytochemical, and biological activities of *Sitophilus zeamais* is presented in Table 8. The correlation analysis showed that there was very strong negative significant correlation between the composition cassava peel Tannin and adult emergence of *S. zeamais* (r = -1.00), percentage seed damage (r = -0.99), and seed weight loss (r = -0.98) caused by the weevil. The correlation between saponin composition of cassava peel with weevil adult emergency (r = 0.19), seed damage (r = 0.25) showed a weak positive relationship and not significantly related, while the relationship was positively moderate with the seed weight loss (r = 0.40) caused by the weevil. The biological activities of *S. zeamais* in respect to adult emergence, seed damage, and weight loss were positive and moderately related to the composition of oxalate in cassava peel, correlation coefficient (r) value was 0.50, 0.54, and 0.68, respectively. The composition of cyanide is negatively weak related to the weevil adult emergence (r = -0.13), seed damage (r = -0.18), and moderate negatively related with weight loss (r = -0.34).

Correlation between melon shell, phytochemical, antinutrient compositions, adult emergence, seed damage, and weight loss

Table 9 showed the relationship between the biological activities of maize weevil and melon shell compositions. The tannin composition of the melon shell shows a strong positive correlation with the weevil adult emergence (r = 0.87) and percentage seed damage (r = 0.93). Percentage weight loss caused by the weevil was moderate positively related with melon shell Tannin (r = 0.65). The correlation relationship between maize weevil adult emergence (r = 0.99), seed damage (r = 97), and weight loss (r = 0.98) indicate a strong positive correlation with melon shell alkaloid composition. This shows that the alkaloid composition increases, and the biological activities of the weevil also increases. Flavonoid composition of melon shell has perfectly strong negative correlation with the maize weevil biological activities, with the adult emergence and seed weight loss correlation coefficient (r) value of - 0.99 and – 0.88 respectively. The percentage seed damage was perfectly negatively significant with the melon shell flavonoid composition (r = -1.00). This indicates an increase in flavonoid composition of the melon shell possibly reduced the biological activities caused by the maize weevil.

Table 8: Correlation between cassava peel, phytochemical, antinutrient compositions, adult emergence, seed damage, and weight loss

Variable	Tannin	Alkaloid	Saponin	Flavonoid	Oxalate	Phytate	Cyanide	Adult Emergency	% Seed Damage	% Weight Loss
Tannin	1	-0.70	-0.19	-0.17	-0.05	0.72	0.13	-1.00**	-0.99*	-0.98
Alkaloid		1	-0.57	0.82	-0.27	-0.00	0.62	0.70	0.66	0.53
Saponin			1	-0.94	0.95	-0.82	-0.99*	0.19	0.25	0.40
Flavonoid				1	-0.77	0.57	0.96	0.17	0.12	-0.05
Oxalate					1	-0.96	-0.92	0.50	0.54	0.68
Phytate						1	0.79	-0.72	-0.75	-0.85
Cyanide							1	-0.13	-0.18	-0.34
Adult Emergency								1	0.99*	0.98
% Seed Damage									1	0.99
% Weight Loss										1

* Correlation is significant at the 0.05 level

** Correlation is significant at the 0.01 level

Table 9: **Correlation between cassava peel, phytochemical, antinutrient compositions, adult emergence, seed damage, and weight loss**

Variables	Tannin	Alkaloid	Saponin	Flavonoid	Oxalate	Phytate	Cyanide	Adult Emergency	% Seed Damage	% Weight Loss
Tannin	1	0.80	-0.98	-0.93	-0.54	-0.99*	-0.76	0.87	0.93	0.65
Alkaloid		1	-0.91	-0.97	-0.94	-0.83	-0.22	0.99	0.97	0.98
Saponin			1	0.99	0.71	0.97	0.59	-0.95	-0.97	-0.80
Flavonoid				1	0.81	0.95	0.47	-0.99	-1.00**	-0.88
Oxalate					1	0.58	-0.14	-0.89	-0.82	-0.99
Phytate						1	0.72	-0.89	-0.94	-0.69
Cyanide							1	-0.33	-0.46	0.00
% Adult Emergency								1	0.99	0.94
% Seed Damage									1	0.89
% Weight Loss										1

* Correlation is significant at the 0.05 level

** Correlation is significant at the 0.01 level

Discussion

Stored product insect pests are problems throughout the world, as they diminish both the quantity and quality of grains. The resultant effect of this is an eminent threat to global food security which might negatively impact peoples' well-being. Efforts by humans to curb the menace of these insect pests have brought about negative effects because of the use of synthetic insecticides. The utilization of wastes to wealth is gaining more attention in applied Entomology in developing nations such as Nigeria (Akowuah *et al*., 2018; Ashamo *et al*., 2021a; b).

The phytochemical and antinutrient compositions of all the agro-waste used in this study showed that the waste contains tannin, alkaloid, saponin, flavonoid, oxalate, phytate and cyanide with different levels of composition in percentage and milligram per gram. The occurrence of some of these compounds may be responsible for the insecticidal action of the agro waste. Some of these secondary metabolites which are in abundant in natural products are capable of altering physiological actions on body (Joshi *et al*., 2009; Edeoga *et al*., 2005). All the agro wastes (cowpea seed coats, cassava peel, melon shell, banana and plantain peels) investigated contains alkaloids, flavonoids and tannins which were the major source of entomocides ever since the discovery of Azadirachtin from *Azadirachta indica* (Maala *et al*., 2000; James *et al*., 2003; Bruce *et al*., 2004). Fernando *et al*. (2005) attributed the effectiveness of plants against insect pest to the present of chemical substances like saponins, tannins, flavonoids and alkaloids.

On insecticidal efficacy of the tested agro wastes, the results showed that the five agro waste powders have good pesticidal efficacy. Result varied with the dosages used and exposure time. Irrespective of the dosage used, it was observed that melon shells are more toxic to adult maize weevil than the remaining four agro wastes powders. The agro wastes powders could have disrupted the movement of the weevil within the seed which could prevent mating of the adult weevil leading to no or low oviposition (Ileke and Oni, 2011; Ashamo *et al*., 2021a; b). The high mortality rate of melon shell and cassava peel powders may be as a results of powders blocking the spiracles which made normal respiratory activities very difficult or as a result of dehydration caused by the agro wastes powders (Adedire *et al*., 2011; Ileke *et al*., 2020a; Obembe *et al*., 2020; Ileke 2021).

Cowpea seed coats, cassava peel, melon shell, banana and plantain peels powders and extracts significantly deterred oviposition by the virtue of number of adult emergence of maize weevil, inability to cause damage and weight loss of the maize seeds. Mortality of adult insect and adult emergence of the weevil as well as the ability to cause damage and weight loss was directly proportional to the increase in dosages and concentrations. It was observed that only the powders and extracts of cassava peel and melon shell were able to prevent the emergence of the adult beetles and as well prevented the damage and weight loss of the protected maize seeds, thereby having 0% weevil perforation index. Cowpea seed coats, banana and plantain peels powders and extracts at high concentrations were able to protect the seeds from being damaged by maize weevil. This is in agreement with the report of Ashamo *et al*. (2021a) who reported that rice husk, maize cob, groundnut and cowpea pods prevented the emergence of adult *Sitostroga cerealella.* Recently, similar observation was also made by Ashamo *et al*. (2021b) on the utilization of rice husk, groundnut pod and wheat husk ash and powders in reducing fecundity of cowpea beetle in stored cowpea seeds. The reduced number of adult emergence could be due to the high mortality rate of the adult weevils due to exposure to the powder and extract of the wastes. High mortality rate of adult insect could reduce the frequency of mating and thereby reduce the number of emergence of insects (Ashamo and Ogungbite, 2014; Oni *et al*., 2015). Similarly, the low percentage of adults that emerged from the treated cowpea could be due to the inability of the eggs to develop into other developmental stages (Adedire *et al*., 2011; Ileke *et al*., 2020a; Obembe *et al*., 2020; Ashamo *et al*., 2021a; b).

Conclusion

Cowpea seed coats, cassava peel, melon shell, banana and plantain peels were found to have potent insecticidal activity toward maize weevil. Melon shell and cassava peel present antifeedant characteristics and affected significantly growth of *S. zeamais*. The order of effectiveness of the wastes can be ranked as follows; melon shell > cassava peel > plantain peel > banana peel > cowpea seed coats. The use of melon shell and cassava peel as bioinsecticides in the control of maize weevil in stored maize seeds among poor resource farmers and foods merchants should be advocated and incorporated into pest management strategies to reduce environmental and agricultural pollution and promote food security in the developing countries. The utilization of these wastes will also help reduce the problems associated with their management.

Abbreviations

FUTA: Federal University of Technology, Akure; ANOVA: Analyses of variance; WPI: Weevil Perforation Index; LD: Lethal Dose; LC: Lethal Concentration

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