Ashamo *et al.*
Bulletin of the National Research Centre (2022) 46:108
https://doi.org/10.1186/s42269-022-00795-z

Bulletin of the National Research Centre

RESEARCH

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Phytochemical compositions and insecticidal efficacy of four agro-waste used as biological control of cowpea beetle, *Callosobruchus maculatus* (Fab.) [Coleoptera: Bruchidae]

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Abstract

Background: The cowpea bruchid, *Callosobruchus maculatus* is the major postharvest insect pest of cowpea seeds in storage. This had led to huge losses and quality deterioration of stored cowpea seeds that serve as poor man's meat in lieu of expensive meat source in developing countries. This research was carried out to evaluate the bioefficacy of rice husk, maize cob, groundnut, and cowpea pods against *C.* maculatus in the laboratory. Adult insect mortality, eggs laid, adult emergence, damaged seeds, weight loss and beetle perforation index (BPI) were evaluated. Phytochemicals of the wastes were investigated.

Results: The result showed that the agricultural wastes contained alkaloids (1.56–2.77 mg/g), saponin (1.51–3.38 mg/g), phytate (7.00–17.76 mg/g), oxalate (0.32–1.13 mg/g). All agricultural wastes showed a high mortality effect on *C. maculatus*, and their effects increased as the exposure time and concentration/ dosage increased. Beetle mortality was highest in cowpea pod with 80% mortality for powder after 3 and 4 days when applied at 0.5 g/20 g cowpea seed. This showed that cowpea pod powder has the greatest insecticidal activity while the least was observed in maize cob powder (73.33%). Fewer adults emerged with maize cob having the least emergence when applied at 0.2–0.5 g dosage. Extracts of all agricultural wastes tested against *C. maculatus* were able to affect 70–100% mortality after 4 days of application at concentration 0.5 ml with cowpea pod extract causing 100% mortality of beetle after 4 days of application. The calculated lethal dose (LD_{50} and LD_{90}) and concentrations (LC_{50} and LC_{90}) of wastes powders and extracts cowpea pod was observed to have the lowest lethal dose while maize cob wastes were the highest across all period of exposure.

Conclusion: Base on the results obtained, cowpea pod waste was the most toxic in biocontrol of *C. maculatus*.

Keywords: Agro wastes paddy, Beetle perforation index, *Callosobruchus maculatus*, Cowpea seed, Phytochemical

Background

Stored insect pests have become a problem throughout the world as they reduce the quantity and quality of grains. Agriculture plays a vital role in human existence as more than 90% of the world's populations eat and use one or more types of agricultural produce or products on daily basis. The development of any country is directly proportional to the prosperity of their agricultural sector (Ashamo and Ogungbite 2014). The objective of agriculture worldwide is to produce sufficient food for the growing population, generate incomes for farmers, and boost the gross domestic product through the agricultural industry (Ileke and Dare 2018).

The major constrictions in food production in developing nations are the damage caused by insect pests

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and pathogens (Ashamo et al. 2021a). Damage of about 40% loss is recorded in countries where modern storage facilities are not available (Ofuya 2001). These pests are controlled mainly with pesticides when available. These synthetic pesticides comes with problems as a results of indiscriminate use, killing of natural enemies, alteration of the natural ecosystem, and environmental pollution. These environmental health hazards are intolerable and this calls for a new approach in insect pest's management that will be low in terms of cost-effective in the maintenance of pest populations below economic thresholds and thereby preserving the environment. NPC (2009) reported that more than 30% of farm produce in Nigeria is lost through insect attack alone, probably because of the insect's ability to attack both on the field and in storage.

Cowpea (*Vigna unguiculata*) is an important pulse largely produced in Nigeria and infestated by *C. maculatus* (Fab.) Cowpea beetle have been a serious threats to cowpea large production and storage (Ileke et al. 2020a; Obembe et al. 2020). *Cowpea are grown and consumed by subsistence farmers in the semi-arid and sub-humid regions of Africa (*Ileke 2015*), and is an important source of incomes to poor resource farmers (Ileke* 2014, 2015).

The use of plant-derived materials as crops protectan ts is an old practice used all over the world (Aslam et al. 2002; Adesina et al. 2019; Ileke and Dare 2018). Protection of stored products generally involves mixing grains with plant-based protectants (Weaver and Subramanyam 2000; Tapondjou et al. 2002). Control of stored product insects using materials of natural origin is receiving much attention nowadays as a result of their little environmental health hazards (Mohan and Fields 2002; Nadra 2006; Emeasor et al. 2005; Ileke et al. 2020b, c, 2022a). Attention is shifting towards the use of agro wastes in insect pest management (Obi et al. 2016, Ashamo et al. 2021a, b; Ileke et al. 2022b). There is a need for more work is on the insecticidal efficacies that may be present in some of these agro wastes. *Therefore, this study investigate the possibility of controlling the cosmopolitan storage insect pest (C. maculatus) of cowpea seed using powders and extracts from* rice husk, maize cob, groundnut, and cowpea pods. Phytochemical contents of the tested agro wastes were also quantified.

Methods

Insect culture

Newly emerged adult C. maculatus were obtained from infested cowpea seeds in Entomology Research Laboratory. The insects were reared on 600 g of cowpea seeds. Eighty (80) pairs of *C. maculatus* were introduced into a glass Kilner jar holding *V. unguiculata* (variety Ife brown) obtained from Agricultural Development Programme Akure, Ondo State. The culture was placed in an insect rearing cage with an ambient temperature of 28 ± 2 °C and 75 ± 5% relative humidity.

Sample collection and preparation of agro-waste powder

Uninfected cowpea (variety Ife Brown) were collected from the seed unit of the Agricultural Development Project (ADP), Akure, and Sorted and kept in the freezer at – 10 °C for 4 weeks to remove any hidden infestation and then air-dried before usage.

Rice husk, cowpea pod, maize cob and groundnut pod were collected from uninfected plants and unpolluted areas within Akure metropolis, Ondo State and brought to Entomology Research Laboratory, Biology Department, Federal University of Technology Akure (FUTA), Ondo State, Nigeria for subsequent processing.

The agricultural wastes were thoroughly cleaned separately with water, air-dried in the laboratory for 21 days, pulverized into coarse powder using pestle and mortar before grinding in an electric blender, JTC Omni Blender V (Model TM-800). The fine powders were allowed to pass through a nylon mesh of 1mm^2 dimension. The powders were then packed into an air tight containers and put in a refrigerator at 4 °C to retain its good quality before application.

Preparation of agricultural wastes extract

One hundred and fifty grams (150 g) of powdered agro wastes were weighed into separate glass jars and the ethanol was measured into the jars in ratio 1:3 (W/V). The mixture was stirred for about ten minutes until the solution becomes homogenous. The tip of the cover was taped to prevent evaporation and kept in a dark cupboard for 72 h. The dark cupboard was used because light penetration may denature active ingredients that are photosensitive and heating from sunlight may support evaporation. Filtration was carried out on the mixture using a double layer of Whatman no. 1 filter paper and the ethanol was evaporated using a rotary evaporator at 30–40 °C with rotary speed of 3–6 rpm for 8 h (Udo 2011). Extracts were air-dried to remove traces of solvent present in them and were separately kept in air-tight containers. All extracts in bottles with lid were kept in the refrigerator until needed.

Phytochemical test

Phytochemical constituents (saponin, alkaloids, phytate and oxalate) of ethanolic extracts of rice husk, maize cob, groundnut, and cowpea pods were quantified using the methods described by Harborne (1973); Trease and Evans (1985); Sofowora (1993).

Bioassay

Toxicity of agricultural wastes powder to C. maculatus

Twenty grams each of cowpea seeds were weighed into separate plastic containers and the powder of agricultural wastes at different doses of 0.1, 0.2, 0.3, 0.4, and 0.5 g were separately mixed with seeds, after which ten pairs of *C. maculatus* (0–24 h old) were introduced into the containers in three replicates. Untreated cowpea seed was used as control. They were arranged in a completely randomized design. Mortality was assessed every 24 h for 4 days, data on percentage adult mortality was calculated using Abbott's (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 (%).

Live and dead insects were removed and oviposition was counted and recorded after the removal of life and dead insects at day 5.

Treated and control treatments were kept in a protective cage for the emergence of the first filia (F_1) generation. The number of the emerged adult was expressed in percentages (Odeyemi and Daramola 2000) as follows:

$$\%\ \text{Adult emergence} = \frac{\text{Total number of adult emergence}}{\text{Total number of eggs laid}} \times 100$$

Weight loss of the cowpea seeds was expressed as percentage loss in weight as follows:

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

The total numbers of seeds damaged in each treatment were estimated in Percentage as follows:

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

Beetle Perforation Index (BPI) was evaluated using the method Fatope et al. (1995) as follows:

$$\text{BPI} = \frac{\%\ \text{treated cowpea seeds perforated}}{\%\ \text{control cowpea seeds perforated}} \times 100$$

BPI value that exceeds 50 was viewed as an enhancement of beetle infestation.

Toxicity of agricultural wastes extract to C. maculatus

Twenty grams (20 g) each of cowpea seeds were weighed into separate plastic containers and the ethanolic extract of agricultural wastes at different concentrations of 0.1. 0.2, 0.3, 0.4, and 0.5 ml were separately mixed vigorously with the seeds inside the containers. The extracts were air-dried for 5–10 min to remove traces of solvents, after which ten pairs of *C. maculatus* (0–24 h old) were introduced into the containers in three replicates. They were arranged in a completely randomized design. Untreated cowpea seed was used as control. Mortality was assessed every 24 h for 4 days, data on percentage adult mortality was calculated using Abbott's (1925) formula. Live and dead insects were removed and oviposition was counted and recorded. Treated and control treatments were kept in a protective cage for the emergence of the first filia (F_1) generation. Adult emergence, weight loss and seed were calculated using the parameters described above.

Statistical analysis

Data were subjected to analysis of variance (ANOVA) and treatment means were separated using New Duncan's Multiple Range Test. Log-Probit model analysis was carried out on percentage mortality of the adult *C. maculatus* to determine the 50% lethal dose (LD_{50}/LC_{50}) and 90% lethal concentration (LD_{90}/LC_{90}). The ANOVA and Probit analysis were done using Statistical Package for the Social Sciences (SPSS) version 20.

Results

Phytochemical screening of agricultural wastes

Quantitative analysis showed that saponin (3.38), alkaloids (2.77) and oxalate (1.13) were more concentrated in cowpea pod powder. Maize cob had a low saponin (1.15) and phytate value of 7.00. Alkaloid was also low in groundnut pod (1.34), oxalate low in groundnut pod (0.32) and rice husk highest in phytate with 17.76 (Table 1).

Table 1 Quantitative analysis of phytochemicals (mg/g) present in agro wastes

Phytochemicals	MCP	RHP	CPP	GPP
Saponin	1.51	2.35	3.38	1.55
Phytate	7.00	17.76	16.48	16.48
Alkaloid	1.56	2.50	2.77	1.34
Oxalate	0.41	0.36	1.13	0.32

MCP Maize cob powder; *RHP* Rice husk powder, *CPP* Cowpea pod powder, *GPP* Groundnut pod powder

Table 2 Mortality of *C. maculatus* exposed to four Agro wastes powder

Agro waste treatments powders	Conc. (g)	Mean % mortality ± S.E			
		24 h	48 h	72 h	96 h
Rice husk	0.1	30.00 ± 0.00^{bc}	33.33 ± 3.33^{b}	40.67 ± 3.33^{bcd}	50.00 ± 5.77^{bc}
Groundnut pod		30.00 ± 0.00^{bc}	36.67 ± 3.33^{bc}	43.33 ± 3.33^{bc}	50.00 ± 0.00^{bc}
Cowpea pod		36.67 ± 3.33^{bcde}	40.00 ± 0.00^{bcd}	50.00 ± 5.77^{bcde}	53.33 ± 3.33^{bcd}
Maize cob		26.67 ± 3.33^{b}	33.33 ± 3.33^{b}	40.00 ± 0.00^{b}	46.67 ± 3.33^{b}
Rice husk	0.2	33.33 ± 3.33^{abc}	40.00 ± 0.00^{bcd}	$53.33 \pm 3.33b^{cdef}$	60.00 ± 5.77^{bcde}
Groundnut pod		50.00 ± 0.00^{fghi}	46.67 ± 6.67^{cde}	50.00 ± 5.77^{bcde}	60.00 ± 5.77^{bcde}
Cowpea pod		50.00 ± 0.00^{fghi}	50.00 ± 5.77^{def}	56.67 ± 3.33^{cdefgh}	70.00 ± 0.00^{efgh}
Maize cob		30.00 ± 0.00^{bc}	40.00 ± 0.00^{bcd}	46.67 ± 3.33^{bcd}	53.33 ± 3.33^{bcd}
Rice husk	0.3	46.67 ± 3.33^{efgh}	50.00 ± 0.00^{def}	56.67 ± 3.33^{cdefgh}	66.67 ± 3.33^{defg}
Groundnut pod		53.33 ± 3.33^{ghij}	53.33 ± 3.33^{efg}	56.67 ± 6.67^{cdefgh}	63.33 ± 3.33^{cdef}
Cowpea pod		53.33 ± 3.33^{ghij}	56.67 ± 3.33^{efgh}	$60.00 \pm 0.00d^{efgh}$	70.00 ± 0.00^{efgh}
Maize cob		43.33 ± 3.33^{defg}	50.00 ± 0.00^{def}	53.33 ± 3.33^{bcdef}	60.00 ± 0.00^{bcde}
Rice husk	0.4	56.67 ± 3.33^{hijk}	60.00 ± 0.00^{fgh}	63.33 ± 3.33^{efgh}	70.00 ± 0.00^{efgh}
Groundnut pod		56.67 ± 3.33^{hijk}	60.00 ± 5.77^{fgh}	66.67 ± 3.33^{fgh}	73.33 ± 3.33^{efgh}
Cowpea pod		60.00 ± 5.77^{ijk}	63.33 ± 3.33^{gh}	66.67 ± 3.33^{fgh}	76.67 ± 6.67^{fgh}
Maize cob		53.33 ± 3.33^{ghij}	60.00 ± 0.00^{fgh}	63.33 ± 8.82^{efgh}	66.67 ± 3.33^{defgh}
Rice husk	0.5	63.33 ± 3.33^{jk}	63.33 ± 3.33^{gh}	70.00 ± 0.00^{ghi}	76.67 ± 6.67^{fgh}
Groundnut pod		60.67 ± 3.33^{k}	63.33 ± 3.33^{gh}	73.33 ± 3.33^{hi}	80.00 ± 5.77^{gh}
Cowpea pod		63.33 ± 3.33^{jk}	66.67 ± 6.67^{h}	80.00 ± 5.77^{i}	$83.33 \pm 8.82g^{h}$
Maize cob		60.00 ± 5.77^{ijk}	63.33 ± 3.33^{gh}	63.33 ± 3.33^{efgh}	73.33 ± 3.33^{efgh}
Control		0.00 ± 0.00^{a}	0.00 ± 0.00^{a}	0.00 ± 0.00^{a}	0.00 ± 0.00^{a}

Mean followed by the same letters within the same column are not significantly different ($p > 0.05$)

Mortality of *C. maculatus* exposed to four Agro wastes powder

The toxicity of agro wastes powder on *C. maculatus* adult at different doses is presented in Table 2. The percentage mortality varied with the exposure time and the dosage of powders. There were a significant ($p < 0.05$) differences in mortalities recorded by different powders. However, low percentage mortality was recorded by all the powders at 0.1 g/20 g and 0.2 g/20 g cowpea. Moreover, at the highest dosage of 0.5 g, cowpea pod achieved 80% and 83.33% mortality within 72 and 96 h, respectively and their effects were significantly ($p < 0.05$) different from control treatment where there was no mortality recorded. The result shows that cowpea pod powder exhibits the greatest insecticidal activity (83.33%) at 0.5 g dosage followed by groundnut pod powder (80.00%) and then rice husk (76.67%) with maize cob powder having the least activity of 73.33%.

Table 3 Lethal doses (LD_{50} and LD_{90}) of agro-waste powders against *C. maculatus*

Agro waste		Exposure time (Hours) (Lower—Upper Confidence Limit)			
		24	48	72	96
Rice husk	LD_{50}	0.34 (0.27–0.40)	0.27 (0.21–0.35)	0.16 (0.08–0.21)	0.09 (0.03–0.14)
	LD_{90}	7.67 (1.98–15.82)	3.45 (1.63–19.03)	2.71 (1.15–41.12)	2.52 (1.42–7.73)
Groundnut pod	LD_{50}	0.23 (0.15–0.31)	0.23 (0.17–0.30)	0.17 (0.03–0.18)	0.12 (0.07–0.15)
	LD_{90}	6.76 (2.17–10.32)	4.63 (1.32–7.50)	3.84 (1.53–5.44)	1.38 (0.79–5.33)
Cowpea pod	LD_{50}	0.21 (0.13–0.28)	0.20 (0.15–0.26)	0.12 (0.12–0.20)	0.09 (0.04–0.13)
	LD_{90}	6.38 (2.07–10.60)	2.92 (1.40–16.31)	1.51 (0.93–4.03)	1.17 (0.74–2.97)
Maize cob	LD_{50}	0.37 (0.29–0.52)	0.27 (0.21–0.35)	0.19 (0.11–0.26)	0.14 (0.07–0.19)
	LD_{90}	5.97 (1.97–9.66)	4.47 (1.98–7.90)	3.45 (1.63–19.03)	2.97 (1.32–27.12)

The lethal dose (LD) of agro wastes powders against *C. maculatus*

The lethal doses of powders needed to achieve 50% and 90% mortality in *C. maculatus* after 96 h post-treatment are presented in Table 3. The required concentration calculated to cause 50% (LD_{50}) and 90% (LD_{90}) insect mortality after 24 h were 0.32 and 7.67 g; 0.23 and 6.76 g; 0.21 and 6.28 g; and 0.37 and 5.97 g for rice husk, groundnut pod, cowpea pod and maize cob powders respectively. These values were observed to reduce as the period of exposure increased. From the calculations, cowpea pod waste was observed to have the lowest lethal dose while maize cob wastes were the highest across all periods of exposure.

Effect of agro waste powders on oviposition and adult emergence of *C. maculatus*

The effects of the agro wastes powder on the egg-laying and adult emergence of *C. maculatus* are shown in Table 4. All the powders significantly reduced the number of eggs laid by *C. maculatus.* Groundnut pod has the highest effect on oviposition with the mean number of 21.00 at 0.5 g dosage while cowpea pod powder has the lowest effect with the mean number of 40.33 at 0.5 g dosage. At all levels of dosage, the powders reduced the number of adults who emerged. Consequently, no F1 adult of *C. maculatus* emerged from cowpea seed treated with maize cob powder (MCP) at 0.2, 0.3, 0.4, and 0.5 g, followed by groundnut pod 1.39 at 0.5 g dosage with cowpea having the least number of 5.18% adult emergence and significantly ($p < 0.05$) different from that of the control which had 75.00% adult emergence.

Table 4 Effect of agro waste powders on oviposition and adult emergence of *C. maculatus*

Treatment powders	Conc. (g)	Oviposition	% adult emergence
Rice husk	0.1	27.00 ± 4.73^{a}	41.01 ± 3.27^{b}
Groundnut pod		71.00 ± 13.32^{ab}	12.39 ± 5.86^{a}
Cowpea pod		78.33 ± 16.68^{b}	6.77 ± 0.87^{a}
Maize cob		47.67 ± 20.87^{ab}	15.36 ± 15.36^{a}
Rice husk	0.2	23.00 ± 1.15^{a}	32.41 ± 6.28^{b}
Groundnut pod		26.33 ± 6.33^{a}	23.33 ± 17.03^{ab}
Cowpea pod		84.67 ± 15.84^{b}	5.37 ± 1.16^{a}
Maize cob		25.00 ± 3.35^{a}	0.00 ± 0.00^{a}
Rice husk	0.3	27.67 ± 4.81^{a}	16.83 ± 1.68^{b}
Groundnut pod		26.00 ± 3.21^{a}	9.04 ± 7.53^{ab}
Cowpea pod		83.67 ± 30.88^{b}	6.12 ± 3.47^{ab}
Maize cob		29.00 ± 4.58^{a}	00.0 ± 0.00^{a}
Rice husk	0.4	27.6 ± 9.21^{a}	5.94 ± 3.40^{b}
Groundnut pod		27.00 ± 8.51^{a}	1.52 ± 1.5^{ab}
Cowpea pod		51.00 ± 15.04^{b}	5.89 ± 1.12^{b}
Maize cob		27.67 ± 1.85^{a}	0.00 ± 0.00^{a}
Rice husk	0.5	28.33 ± 3.71^{a}	2.02 ± 2.02^{ab}
Groundnut pod		21.00 ± 3.00^{a}	1.39 ± 1.39^{ab}
Cowpea pod		40.33 ± 6.33^{b}	5.18 ± 1.48^{b}
Maize cob		27.67 ± 1.85^{a}	0.00 ± 0.00^{a}
Control	0.0	160.00 ± 0.00^{c}	75.00 ± 0.00^{c}

Mean followed by the same letters within the same column are not significantly different ($p > 0.05$)

Damage assessment of cowpea seeds treated with agro waste powders

Table 5 showed the damage caused by *C. maculatus* on cowpea seeds treated with agro wastes powder as contact insecticides. At all levels of dosage the powder reduced and prevented seed damage and loss in weight of the treated seeds. Maize cob powder prevented seed damage at dosage 0.2–0.5 g seed damage, highest % seed damage was obtained in rice husk treatment (6.45), lowest in cowpea pod (2.79) at 0.1 g dosage. At 0.5 g dosage cowpea (1.19) has the highest seed damage. All values obtained are significantly ($p < 0.05$) different from that of the control treatment which had 70.50. At 0.1 weight loss was highest in rice husk treatment (5.50) and lowest in maize cob treatment (1.20) which are significantly ($p < 0.05$) different from that of the control treatment (60.00). Maize cob powder prevented weight loss at dosage 0.2, 0.3, 0.4 and 0.5 g. %weight loss obtained control was higher than that of all treatments used at all levels of application and significantly ($p < 0.05$) different. Beetle perforation index was zero for maize cob at concentration 0.2, 0.3, 0.4 and 0.5 g.

Mortality percentage of *C. maculatus* exposed to four agro wastes extracts

Mortality % of the various agricultural waste extracts on the survival of *C. maculatus* at different periods after treatment are presented in Table 6. All extracts showed mortality ranging from 33.33 to 100%, dependent on concentrations used and time of exposure. The highest mortality of the beetles was obtained in cowpea pod (76.67%) at 0.5 g concentration within 24 h of application, this was significantly ($p < 0.05$) different from control treatment and the lowest value of 63.33% obtained in maize cob and rice husk treatments. At 96 h after treatment, 100% mortality at concentration 0.5 g was obtained in cowpea pod followed by groundnut pod 90% which was significantly ($p < 0.05$) different from control, while maize cob was the least activity one causing 73.33% mortality.

The lethal Concentration (LC) of agro-waste extracts against *C. maculatus*

The lethal concentration of extracts needed to achieve 50% and 90% mortality in *C. maculatus* after 96 h

Table 5 Damage assessment of cowpea seeds treated with agro waste powders

Agro wastes	Conc. (g)	Mean total no of seeds	Mean no of damaged seeds	Mean % seed damaged	% Weight loss	*(BPI)
Rice husk	0.1	170.67	11.00 ± 2.08^{a}	6.45 ± 1.23^{b}	5.50 ± 1.04^{b}	9.13 ± 1.74^{ab}
Groundnut pod		165.67	8.33 ± 4.37^{a}	5.09 ± 2.78^{ab}	4.17 ± 2.19^{ab}	7.21 ± 1.90^{a}
Cowpea pod		167.33	5.33 ± 1.45^{a}	2.79 ± 1.00^{a}	3.20 ± 0.88^{ab}	3.95 ± 1.42^{a}
Maize cob		169.33	13.67 ± 13.67^{a}	7.95 ± 1.94^{b}	1.20 ± 0.35^{a}	11.2 ± 0.26^{b}
Rice husk	0.2	170.00	7.67 ± 1.45^{b}	4.51 ± 0.86^{b}	4.67 ± 1.48^{b}	6.40 ± 1.22^{b}
Groundnut pod		171.00	4.00 ± 2.08^{b}	2.34 ± 1.22^{b}	2.00 ± 1.04^{ab}	3.32 ± 1.72^{ab}
Cowpea pod		167.67	4.33 ± 0.67^{b}	2.57 ± 0.35^{b}	2.55 ± 0.35^{ab}	3.64 ± 0.50^{ab}
Maize cob		167.67	0.00 ± 0.00^{a}	0.00 ± 0.00^{a}	0.00 ± 0.00^{a}	0.00 ± 0.00^{a}
Rice husk	0.3	170.67	4.67 ± 0.88^{b}	2.73 ± 0.51^{b}	2.33 ± 0.44^{b}	3.87 ± 072^{b}
Groundnut pod		174.67	2.33 ± 1.86^{ab}	1.28 ± 0.99^{ab}	1.17 ± 0.93^{ab}	1.81 ± 0.40^{ab}
Cowpea pod		167.67	3.00 ± 0.00^{ab}	1.79 ± 0.04^{b}	1.78 ± 0.33^{b}	2.53 ± 0.05^{ab}
Maize cob		172.67	0.00 ± 0.00^{a}	0.00 ± 0.00^{a}	0.00 ± 0.00^{a}	0.00 ± 0.00^{a}
Rice husk	0.4	172.33	1.33 ± 0.67^{ab}	0.79 ± 0.39^{ab}	0.67 ± 0.33^{a}	1.11 ± 0.56^{ab}
Groundnut pod		172.33	0.67 ± 0.67^{a}	0.41 ± 0.41^{a}	0.33 ± 0.33^{a}	0.58 ± 0.58^{a}
Cowpea pod		164.33	2.67 ± 0.33^{b}	1.62 ± 0.19^{b}	1.62 ± 0.19^{b}	2.29 ± 0.27^{b}
Maize cob		168.33	0.00 ± 0.00^{a}	0.00 ± 0.00^{a}	0.00 ± 0.00^{a}	0.00 ± 0.00a
Rice husk	0.5	171.00	0.67 ± 0.67^{a}	0.39 ± 0.39^{a}	0.33 ± 0.33^{a}	0.56 ± 0.56^{ab}
Groundnut pod		169.67	0.33 ± 0.33^{a}	0.20 ± 0.20^{a}	0.17 ± 0.17^{a}	0.29 ± 0.29^{a}
Cowpea pod		168.33	2.00 ± 0.58^{b}	1.19 ± 0.35^{b}	1.20 ± 0.35^{b}	1.69 ± 0.50^{b}
Maize cob		167.67	0.00 ± 0.00^{a}	0.00 ± 0.00^{a}	0.00 ± 0.00^{a}	0.00 ± 0.00^{a}
Control	0.00	169.67	120.00 ± 0.00^{c}	70.59 ± 0.00^{c}	60.00 ± 0.00^{c}	$\geq 50.00 \pm 0.00^{c}$

Mean followed by the same letters within the same column are not significantly different ($p > 0.05$)

*Beetle Perforation Index (BPI) value lower than 50 is an indication of a positive protectant effect

post-treatment are presented in Table 7. The required concentration calculated to cause 50% (LC_{50}) and 90% (LC_{90}) insect mortality after 24 h were 0.40 and 3.64 ml; 0.17 and 2.77 ml; 0.15 and 2.34 ml; and 0.43 and 3.96 ml for rice husk, groundnut, cowpea and maize cob extracts respectively. These values were observed to reduce as the exposure period increased. From the calculations, cowpea pod waste was observed to have the lowest lethal dose while maize cob wastes were the highest across all periods of exposure.

Effect of agro-waste extracts on oviposition and adult emergence of *C. maculatus*

The effect of the agricultural wastes extracts on the oviposition and adult emergence of *C. maculatus* is shown in Table 8. Oviposition and adult emergence were reduced with an increase in dosage across the table for each agricultural waste. The highest percentage oviposition 73.67 of adult *C. maculatus* was discovered on the seed treated with 0.1 g groundnut pod extract but significantly ($p < 0.05$) different from that of the control 155.00. At all levels of concentration the extract reduced the number of adults emerged, consequently, no F1 adult of *C. maculatus* emerged from cowpea seed treated with cowpea pod extract at 0.5 ml of concentration. The highest emergence was obtained in maize cob 16.31 at 0.1 ml concentration which was significantly ($p < 0.05$) different from that of the control which had 90.00.

Damage assessment of cowpea seeds treated with agro waste extracts

Table 9 showed the damage caused by *C. maculatus* on cowpea seeds treated with agro wastes extracts as contact insecticides. At all levels of concentration, the extract significantly ($p < 0.05$) reduced and prevented weight loss and damage of the seeds compared with control. Beetle perforation index was zero for cowpea pod at a concentration of 0.5 ml while the highest BPI of 6.66 was obtained in cowpea seeds treated with cowpea and maize cob at concentration 0.1 ml.

Discussion

Misuse of synthetic chemical insecticides was common among poor resource farmers in Nigeria. Farmers apply insecticides at high dosage to effect rapid and immediate kill of storage insect pests which have many

Table 6 Mortality of adult *C. maculatus* in cowpea seeds treated with agro wastes extracts

Agro waste treatments extracts	Conc. (ml)	Mean % mortality ± S.E			
		24 h	**48 h**	**72 h**	**96 h**
Rice husk	0.1	33.33 ± 3.33^{b}	43.33 ± 3.33^{bc}	50.00 ± 5.77^{bc}	56.67 ± 3.33^{b}
Groundnut pod		43.33 ± 3.33^{bcde}	46.67 ± 3.33^{bcd}	53.33 ± 3.33^{bcd}	56.67 ± 3.33^{b}
Cowpea pod		43.33 ± 5.77^{bcde}	50.00 ± 0.00^{bcde}	53.33 ± 3.33^{bcd}	60.00 ± 3.33^{b}
Maize cob		36.67 ± 3.33^{bc}	40.00 ± 0.00^{b}	46.67 ± 3.33^{b}	53.33 ± 5.77^{ab}
Rice husk	0.2	40.00 ± 5.77^{bcd}	50.00 ± 0.00^{bcde}	56.67 ± 3.33^{bcde}	63.33 ± 3.33^{bc}
Groundnut pod		50.00 ± 0.00^{def}	53.33 ± 3.33^{cdef}	56.67 ± 3.33^{bcde}	66.67 ± 0.00^{bcd}
Cowpea pod		53.33 ± 5.77^{efg}	56.67 ± 6.67^{defg}	63.33 ± 3.33^{defg}	66.67 ± 5.77^{bcd}
Maize cob		40.00 ± 0.00^{bcd}	43.33 ± 3.33^{bc}	50.00 ± 0.00^{bc}	60.00 ± 0.00^{b}
Rice husk	0.3	46.67 ± 3.33^{cdef}	60.00 ± 0.00^{efg}	63.33 ± 3.33^{defg}	70.00 ± 0.00^{cde}
Groundnut pod		56.67 ± 5.77^{fgh}	63.33 ± 6.67^{fg}	66.67 ± 3.33^{efg}	70.00 ± 3.33^{cde}
Cowpea pod		63.33 ± 5.77^{ghi}	66.67 ± 3.33^{gh}	70.00 ± 0.00^{fgh}	76.67 ± 0.00^{efg}
Maize cob		43.33 ± 3.33^{bcde}	46.67 ± 3.33^{bcd}	53.33 ± 3.33^{bcd}	63.33 ± 3.33^{b}
Rice husk	0.4	56.67 ± 3.33^{fgh}	63.33 ± 3.33^{fg}	70.00 ± 0.00^{fgh}	76.67 ± 3.33^{efg}
Groundnut pod		63.33 ± 5.77^{ghi}	66.67 ± 3.33^{gh}	70.00 ± 5.77^{fgh}	83.33 ± 3.33^{gh}
Cowpea pod		66.67 ± 5.77^{hi}	76.67 ± 3.33^{hi}	80.00 ± 0.00^{i}	90.00 ± 3.33^{h}
Maize cob		46.67 ± 3.33^{cdef}	60.00 ± 0.00^{efg}	60.00 ± 0.00^{cdef}	66.67 ± 3.33^{bcd}
Rice husk	0.5	63.33 ± 3.339^{hi}	66.67 ± 3.339^{h}	73.33 ± 3.339^{h}	80.00 ± 0.00^{fg}
Groundnut pod		70.00 ± 0.00^{ij}	76.67 ± 6.67^{hi}	83.33 ± 3.33^{i}	90.00 ± 3.33^{h}
Cowpea pod		76.67 ± 5.77^{j}	80.00 ± 5.77^{i}	86.67 ± 3.33^{ij}	100.00 ± 0.00^{i}
Maize cob		63.33 ± 3.339^{hi}	66.67 ± 3.339^{h}	66.67 ± 3.33^{efg}	73.33 ± 3.33^{def}
Control		0.00 ± 0.00^{a}	0.00 ± 0.00^{a}	0.00 ± 0.00^{a}	0.00 ± 0.00^{a}

Mean followed by the same letters within the same column are not significantly different ($p > 0.05$)

Table 7 Lethal Concentration (LC_{50} and LC_{90}) of agro-waste extracts against *C. maculatus*

Agro waste		Exposure time (Hours) (Lower—Upper Limit)			
		24	**48**	**72**	**96**
Rice husk	LC_{50}	0.40 (0.22–0.42)	0.17 (0.09–0.23)	0.09 (0.04–0.29)	0.05 (0.02–0.17)
	LC_{90}	3.64 (2.28–10.58)	2.98 (1.26–18.85)	2.63 (1.70–8.45)	1.62 (0.84–9.82)
Groundnut pod	LC_{50}	0.17 (0.04–0.66)	0.12 (0.02–0.29)	0.07 (0.06–0.14)	0.05 (0.04–0.11)
	LC_{90}	2.77 (1.01–5.84)	2.19 (0.79–3.44)	1.01 (0.67–2.34)	0.44 (0.48–1.29)
Cowpea pod	LC_{50}	0.15 (0.09–0.22)	0.09 (0.03–0.18)	0.06 (0.01–0.18)	0.04 (0.07–0.16)
	LC_{90}	2.34 (1.57–15.79)	1.28 (1.10–12.10)	1.34 (0.52–2.16)	0.68 (0.49–1.12)
Maize cob	LC_{50}	0.43 (0.26–0.52)	0.34 (0.17–0.32)	0.15 (0.06–1.73)	0.08 (0.01–0.13)
	LC_{90}	3.96 (2.54–12.77)	3.46 (1.99–8.20)	2.94 (1.39–6.14)	1.98 (1.03–5.46)

health-related issues among the populace (Ileke and Dare 2018; Ileke et al. 2022b).

The phytochemicals present in the ethanolic agro wastes revealed the presence of saponins, tannins, alkaloids, oxalates, phytates, and flavonoids. The presence of some of these compounds may be responsible for the insecticidal action of the agro-waste (Ashamo et al. 2021a, b). These compounds are secondary metabolites that are capable of producing definite physiological actions on the body (Joshi et al. 2009) and are the most important bioactive constituents of natural products (Edeoga et al. 2005). A plant containing alkaloids, flavonoids and tannins were the major sources of bioinsecticides ever since the discovery of Azadirachtin from the neem tree, *Azadirachta indica* (Bruce et al. 2004; Ileke et al. 2014). Fernando et al. (2005) ascribed the efficacy of plants against insect pests to the presene of chemical substances like terpenoids, saponins, tannins, flavonoids, and alkaloids among others. These bioactive components have been reported to be toxic to bacteria, pests or fungi

Table 8 Effect of agro waste extracts on oviposition and adult emergence of *C. maculatus*

Treatment	Conc. (ml)	Oviposition	% Adult Emergence
Rice husk	0.1	30.33 ± 1.45[a]	20.03 ± 4.50[b]
Groundnut pod		73.67 ± 15.07[b]	9.02 ± 0.94[a]
Cowpea pod		45.00 ± 1.53[a]	10.36 ± 0.60[a]
Maize cob		43.00 ± 5.69[a]	16.31 ± 2.24[ab]
Rice husk	0.2	26.33 ± 0.88[a]	17.89 ± 3.07[b]
Groundnut pod		60.33 ± 8.21[c]	8.14 ± 1.16[a]
Cowpea pod		42.00 ± 1.53[b]	9.53 ± 1.39[a]
Maize cob		38.33 ± 3.33[ab]	15.87 ± 2.08[b]
Rice husk	0.3	24.00 ± 1.00[a]	16.91 ± 3.13[b]
Groundnut pod		53.67 ± 7.12[c]	6.11 ± 3.15[a]
Cowpea pod		39.67 ± 1.45[b]	8.31 ± 1.46[ab]
Maize cob		36.33 ± 2.96[b]	12.72 ± 3.99[ab]
Rice husk	0.4	20.33 ± 2.60[a]	11.50 ± 0.76[a]
Groundnut pod		47.33 ± 9.13[b]	5.45 ± 2.88[a]
Cowpea pod		35.00 ± 1.73[ab]	4.79 ± 1.01[a]
Maize cob		29.00 ± 6.43[a]	9.26 ± 4.33[a]
Rice husk	0.5	18.33 ± 2.33[a]	5.41 ± 2.76[a]
Groundnut pod		33.67 ± 7.31[b]	6.15 ± 1.81[a]
Cowpea pod		25.00 ± 1.73[ab]	0.00 ± 0.00[a]
Maize cob		19.33 ± 3.38[a]	5.11 ± 3.48[a]
Control	0.00	155.00 ± 0.00[d]	67.74 ± 0.00[c]

Mean followed by the same letters within the same column are not significantly different ($p > 0.05$)

(El astal et al. 2005). In this present study, cowpea pod which was the most active agro-waste had the highest composition of saponin, alkaloid and oxalate compared to other agro-wastes tested.

The results obtained from this study showed that the powder and extracts of the agricultural wastes used had distinct effects on the survival of *C. maculatus.* At different dosages, both the powders and extracts of these wastes achieved high beetle mortality. Powders and extracts may rupture the cuticle of insect and cause death through desiccation (Tadesse and Basedow 2005). The high mortality rate of *C. maculatus* may be associated with the inability of the beetle to move freely and also unable to feed on the cowpea coated with these treatments thereby leading to starvation (Adedire et al. 2011; Idoko and Ileke 2020; Ileke et al. 2020a).

The treatments of cowpea seeds with rice husk, maize cob, groundnut and cowpea pod powders and extracts does not affect the emergence of adult insect in low concentrations treated cowpea seeds. This shows that mating took place but their mean adult emergence was low when compared with the controls. The act of weakening of adults by botanical powders and extracts may make them lay fewer eggs than expected, leading to limited hatchability to larvae and final metamorphosis to adults (Adedire and Lajide 2003; Obembe et al. 2020; Ashamo et al. 2021a). The inability of insect eggs to develop into adults may be due to the effect of the powders and oils on the developmental stages of the insect which was unable to feed on treated seeds that prevent them to fully cast off their old exoskeleton which typically rained linked to the posterior of the abdomen (Trindade et al. 2008; Oigiangbe et al. 2010). This lead to reduced seed damage and weight loss as a result of inability of larvae to feed on the protected cowpea seeds (Asawalam et al. 2007; Idoko and Ileke 2020). The secondary metabolites present in these treatments could also be responsible for the inability of the adult insect to emerge as opined by Yang et al. (2006) that secondary metabolites in botanicals are found to disrupt development thereby affecting larva survival.

Agricultural wastes powders were highly effective against *C. maculatus.* The cowpea extract appears to be more effective as it achieved complete mortality of beetles even at low concentrations. However its effect was not significantly ($p < 0.05$) different from other extracts. With the increase in the concentration of these extracts, there was an increase in the mortality of the beetles. The result of this research agreed with previous works in which extracts of botanicals were used in the control of *C. maculatus* and other storage insect pests (Ashamo and Odeyemi 2001; Adedire 2001; Oni and Ileke 2008; Adedire et al. 2011; Ileke and Olotuah 2012). The calculated lethal dose (LD_{50} and $_{90}$) and concentrations (LC_{50} and $_{90}$) of the agro wastes powders and extracts cowpea pod waste were observed to have the lowest lethal dose while maize cob wastes had the highest value across all exposure time.

Conclusions

All the tested agro wastes significantly achieved high mortality of cowpea beetle and significantly reduced seed damage and weight loss due to its ability to inhibit oviposition by adult insects and hatchability of laid eggs hence the significantly lower number of progeny that emerged from the treatments. Cowpea pod was the best among the agro wastes investigated in the management of cowpea beetle. The methods used were simple and can easily be adopted by the farmers to reduce environmental health hazards caused by chemical insecticides as well as reducing environmental pollution caused by agricultural wastes.

Table 9 Damage assessment of cowpea seeds treated with agro waste extracts

Treatment	Conc. (ml)	Total no of seeds	Mean no of damaged seeds	Mean % seed damaged	% Weight loss	*Bettle perforation index (BPI)
Rice husk	0.1	172.76	6.00 ± 1.16^{a}	3.53 ± 0.68^{a}	3.53 ± 0.68^{a}	5.72 ± 1.11^{a}
Groundnut pod		170.00	6.67 ± 1.45^{a}	3.92 ± 0.85^{a}	3.92 ± 0.86^{a}	6.34 ± 1.38^{b}
Cowpea pod		170.67	4.67 ± 0.33^{a}	4.12 ± 0.68^{a}	2.75 ± 0.20^{a}	6.66 ± 1.10^{b}
Maize cob		169.00	7.00 ± 1.16^{a}	4.12 ± 0.68^{a}	4.12 ± 0.68^{a}	6.66 ± 1.10^{b}
Rice husk	0.2	166.67	4.67 ± 0.67^{a}	2.94 ± 0.34^{a}	2.75 ± 0.40^{a}	4.76 ± 0.55^{a}
Groundnut pod		172.67	5.00 ± 1.16^{a}	3.14 ± 1.09^{a}	2.93 ± 0.68^{a}	5.08 ± 1.76^{b}
Cowpea pod		172.00	4.00 ± 0.58^{a}	3.14 ± 0.85^{a}	2.35 ± 0.35^{a}	5.09 ± 1.38^{b}
Maize cob		167.33	6.00 ± 0.58^{a}	3.53 ± 0.34^{a}	3.53 ± 0.33^{a}	5.72 ± 0.55^{b}
Rice husk	0.3	167.67	4.00 ± 0.58^{a}	2.55 ± 0.39^{a}	2.35 ± 0.35^{a}	4.13 ± 0.63^{a}
Groundnut pod		167.67	3.67 ± 1.86^{a}	2.16 ± 1.09^{a}	2.16 ± 1.09^{a}	3.49 ± 1.77^{a}
Cowpea pod		165.67	3.33 ± 0.67^{a}	2.75 ± 1.04^{a}	1.50 ± 0.25^{ab}	4.45 ± 1.68^{a}
Maize cob		171.00	4.67 ± 1.45^{a}	2.75 ± 0.85^{a}	2.75 ± 0.84^{a}	4.45 ± 1.38^{a}
Rice husk	0.4	174.67	2.33 ± 0.33^{a}	1.77 ± 0.34^{a}	1.38 ± 0.18^{a}	2.86 ± 0.55^{a}
Groundnut pod		168.33	3.00 ± 1.53^{a}	1.76 ± 0.90^{a}	3.10 ± 1.45^{ab}	2.85 ± 1.45^{a}
Cowpea pod		171.00	1.67 ± 0.33^{a}	2.16 ± 1.29^{a}	1.00 ± 2.00^{a}	3.50 ± 2.08^{a}
Maize cob		170.67	3.00 ± 1.53^{a}	1.96 ± 0.71^{a}	1.18 ± 0.33^{a}	3.17 ± 1.14^{a}
Rice husk	0.5	165.67	1.00 ± 0.58^{a}	0.79 ± 0.39^{a}	0.60 ± 0.35^{a}	1.27 ± 0.64^{a}
Groundnut pod		172.33	1.33 ± 0.88^{a}	0.79 ± 0.52^{a}	0.12 ± 0.04^{ab}	1.28 ± 0.84^{a}
Cowpea pod		174.67	0.00 ± 0.00^{a}	0.00 ± 0.00^{a}	0.00 ± 0.00^{a}	0.00 ± 0.00^{a}
Maize cob		170.00	1.33 ± 0.67^{a}	0.79 ± 0.39^{a}	0.13 ± 0.03^{ab}	1.27 ± 0.64^{a}
Control	0.00	169.5	105.00 ± 0.00^{b}	61.77 ± 0.00^{b}	61.75 ± 0.00^{b}	$\geq 50.00 \pm 0.00^{c}$

Mean followed by the same letters within the same column are not significantly different ($p > 0.05$)

*Beetle Perforation Index (BPI) value lower than 50 is an indication of positive protectant

Abbreviations
FUTA: Federal University of Technology, Akure; ANOVA: Analysis of variance; SE: Standard error; LD: Lethal dose; LC: Lethal concentration; BPI: Beetle Perforation Index.

Acknowledgements
The first author (MOA) is grateful for the support of the Tertiary Education Trust Fund (TETFund) of the Federal Republic of Nigeria, the year 2015–2016 (Merged) Tetfund Research Project Intervention, towards the research. The authors acknowledged the technical assistance of the Laboratory staff of the Department of Biology, FUTA and Central Research Laboratory, University of Lagos, Lagos Nigeria.

Author contributions
MOA Conceptualization, Methodology, Formal analysis, writing—reviewing and editing. KDI Methodology, Data curation, Formal analysis, writing—original draft. AIO Data curation, Investigation. All authors have read and approved the manuscript.

Funding
Tertiary Education Trust Fund (TETFund) of the Federal Republic of Nigeria, the year 2015–2016 (Merged) Tetfund Research Project Intervention.

Availability of data and materials
Data collected and analyzed during the current study are available from the corresponding author on reasonable request.

Declarations

Ethics approval and consent to participate
Not applicable.

Consent for publication
Not applicable.

Competing interests
The authors declare that they have no competing interests.

Received: 26 September 2021 Accepted: 3 April 2022
Published online: 13 April 2022

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