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Efficacy of Processing Selected Dried Chips with Fermented Maize Water and Lime Juice on Infestation and Damage by *Araecerus fasciculatus*

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Abstract
The Coffee Bean Weevil (*Araecerus fasciculatus),* Degeer (*Coleoptera Anthribidae*), is an important pest causing economic damage to several stored produce including cocoa, coffee, dried cassava chips and yams in Nigeria. The usage of synthetic insecticide proved to be effective to control these pests to a greater extent but its usage poses health and ecological problems to man and the environment. There is a need to source for eco-friendly, safe, readily available and effective pest control measures. There is a paucity of information on the usage of fermented maize water and lime juice on the management of storage pests, especially *A. fasciculatus*. The bioactivities of fermented maize water (FMW) and lime juice (LJ) on A. *fasciculatus* in stored cassava, potato, yam, and plantain chips were investigated. Different concentration levels of FMW and LJ was prepared and applied on the chips appropriately. The setup was arranged in a completely randomized design in the laboratory and replicated four times. Data were collected on developmental period, adult longevity and percentage damage. Results showed the potency of FMW and LJ to be dose-dependent. The FMW and LJ were found to delay the developmental period and shorten adult longevity of *A. fasciculatus*. Regardless of the FMW and LJ treatment combination level, they significantly reduce the level of damage of *A. fasciculatus* on chips. The results suggest that processed chips were protected against the Coffee Bean Weevil attack, reducing the level of damage, therefore their application can be scaled up and incorporated into Integrated Pest Management (IPM) practices.

Keywords: *Araecerus fasciculatus*, Fermented maize water, Lime juice, Damage, Processed chips.

Efficacité du traitement des cossettes séchées sélectionnées avec de l'eau de maïs fermentée et du jus de citron vert sur l'infestation et les dommages causés par *Araecerus fasciculatus*

Résumé
Le charançon du grain de café (Araecerus fasciculatus), Degeer (Coleoptera Anthribidae), est un ravageur important causant des dommages économiques à plusieurs produits stockés, notamment le cacao, le café, les chips de manioc séchées et les ignames au Nigeria. L'utilisation d'insecticides de synthèse s'est avérée efficace pour lutter davantage contre ces ravageurs mais son utilisation pose

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des problèmes sanitaires et écologiques à l'homme et à l'environnement. Il est nécessaire de s'approvisionner en mesures de lutte antiparasitaire respectueuses de l'environnement, sûres, facilement disponibles et efficaces. Il y a peu d'informations sur l'utilisation de l'eau de maïs fermentée et du jus de citron vert pour la gestion des ravageurs des entrepôts, en particulier A. *fasciculatu*s. Les bioactivités de l'eau de maïs fermentée (FMW) et du jus de citron vert (LJ) sur A. *fasciculatus* dans le manioc, la pomme de terre, l'igname et les chips de plantain stockés ont été étudiées. Différents niveaux de concentration de FMW et LJ ont été préparés et appliqués sur les puces de manière appropriée. La configuration a été arrangée dans une conception complètement randomisée en laboratoire et reproduite quatre fois. Des données ont été recueillies sur la période de développement, la longévité des adultes et le pourcentage de dommages. Les résultats ont montré que la puissance de FMW et de LJ était dose-dépendante. Il a été constaté que le FMW et le LJ retardaient la période de développement et raccourcissaient la longévité adulte d'A. *fasciculatus*. Quel que soit le niveau de combinaison des traitements FMW et LJ, ils réduisent significativement le niveau d'endommagement d'A. *fasciculatus* sur les copeaux. Les résultats suggèrent que les copeaux transformés ont été protégés contre l'attaque du charançon du grain de café, réduisant ainsi le niveau de dommages. Par conséquent, leur application peut être étendue et intégrée aux pratiques de lutte antiparasitaire intégrée (IPM).

Mots-clés : *Araecerus fasciculatus*, Eau de maïs fermentée, Jus de citron vert, Dégâts, Copeaux transformés.

Introduction

Root and tuber crops such as cassava, yam and sweet potatoes, and fruit crops especially plantain are among the most important staple foods in Sub-Saharan Africa (Osei *et al.*, 2009). They are both staple foods and cash crops for many households in the rural areas of Africa. The popularity of these crops for household cash income has increased recently as a response to acute nutrition needs to be caused by longer droughts in 2016, fall armyworm (*Spodoptera frugiperda*) outbreaks in 2016 and the emergence of maize lethal necrosis (FAO, 2017). Further, several private sector investors in the processing industry are also contributing to the increased demand for roots and tubers through the manufacture of starch from cassava, confectionery from sweet potato and beer from banana. The most important staples food crops obtained and produced in Sub-Saharan Africa comprised about 53% cereals, 31% roots and tubers, 6% grain legumes, and 5% each of groundnuts, plantains and bananas (Eke-Okoro *et al*., 2014), Pharmaceutical and industrial raw materials are also obtained from roots and tuber crops and they also have commercial advantages (Paulino and Yeung, 1981). Over half of the world's cassava and yam is produced in the humid and sub-humid tropics of sub-Sahara Africa. The bulk of root and tuber crops produced in Africa are mostly produced by small-scale farmers who rely on traditional non-mechanized methods (CABI, 2005).

In an attempt to reduce post-harvest losses, these products are converted into chips, dried adequately and stored for certain periods until needed (Jonathan *et al.,* 2011). Dried chips can be further milled into flour, which can be reconstituted in boiling water to form a thick paste, consumed for meals in tropical areas as a source of carbohydrates (Ayodele *et al.,* 2013). The main objectives of preparing tubers into dried chips by farmers are to reduce deterioration and physical damage after harvesting, remove parts that are not edible and marketable, earn substantial income, to reduce costs of transportation, and to provide raw materials for agro-industries (Ferraro *et al.,* 2016).

Most of the crops produced in Africa suffer high yield losses due to the numerous diseases and pests' infestation The world needs abundant food for survival and insect pests remain a major constraint to production in the field and storage. In storage, insect pests infest commodities; resulting in qualitative losses such as reduction of nutritive and market values, promotion of mould development and quantitative losses weight losses of over 30% in

about one month of storage (CABI, 2005). Storage losses of dried chips vary according to region, environmental conditions, main pests, storage structure and method of storage (Kossou and Bosque-Perez, 1998). Some of the insect pests that are associated with dried tubers and plantain chips include *Prostephanus truncatus* (Horn) (Coleoptera: Bostrichidae), *Araecerus fasciculatus* (Degeer) (Coleoptera: Anthribidae), Rhysopertha and *Dinoderus* species. (Coleoptera: Bostrichidae). Among these insects, the Coffee bean weevil, *A. fasciculatus*, is a major insect pest of dried tubers and plantain chips and it poses a problem to many agricultural produce and products in the store. Research has shown that this weevil is polyphagous as it attacks coffee, cocoa, groundnut, maize grains dried fish and chips of cassava, water yam, sweet potato, plantain, white yam and Chinaberry fruit (Woodruff, 1972; Alba-Alejandre *et al.,* 2018; Kumar and Ray, 2021). Arbogast *et al*. (2002) classified *A. fasciculatus* as a tropical pest that is capable of attacking a host of the most highly valued agricultural produce and products in the tropics including cocoa, coffee, dried cassava chips and yams, maize, groundnuts, Brazil nuts, nutmegs. There is, however, a paucity of information on control of this insect, hence there is the need to study the management of *A. fasciculatus* on different hosts especially dried tubers and plantain chips. The general objective of this study was therefore to evaluate the efficacy of processing dried chips of selected tubers and plantain with fermented maize water and lime juice on infestation and damage by *Araecerus fasciculatus*.

Materials and Methods

The Study Sites

The research work was carried out in the Entomological Research Laboratory of the Department of Crop Protection and Environment Biology, University of Ibadan, Ibadan. All experiments were carried out at a temperature of 27±3°C, 65±5% relative humidity and 12 hours of photophase.

Preparation of Fermented Maize Water (FMW) and Lime Juice (LJ)

Ten-kilogram maize seeds and lime fruits were obtained from Bodija Market, Ibadan. They were washed thoroughly to remove dirt and soaked in cold water for three days in the Entomology Research Laboratory of the Department of Crop Protection and the Environmental Biology University of Ibadan for the process of fermentation, thereafter, ground to form a paste. The paste obtained was mixed with water and sieved by using a muslin cloth to remove big particles. The sieved maize paste was left for 48 hours to decant. Fermented maize water was separated after 48 hours and was used for the study. Five kilograms of matured lime fruits were washed thoroughly with clean water to remove dirt. They were then sliced into two to squeeze out the juice. It was stored in a refrigerator in the laboratory before use.

Preparation of dried chips

The food materials used for this study were cassava, potato, water yam, white yam and plantain obtained from Bodija market, Ibadan. The food crops were peeled manually with a sharp stainless-steel kitchen knife sliced into chips of approximately 3 x 1 x 1 cm and were thoroughly washed to remove all mud, dirt, and sand. Each sliced chip was batched into set of 1kg and was subjected to different processing methods before drying. Cassava was first soaked inside water for 48 hours (FAO, 2008) and after blanching for 2 minutes at (100°C) using water, lime and fermented maize water at different ratios (Table 1) with continuous stirring of the mixture. Water yam, White yam potato and plantain passed through the same processing of blanching without prior soaking inside water. Treated food chips were later spread on a perforated tray oven-dried at 70°C for an average of six days till uniform moisture content was reached.

Efficacy of the treatment on the developmental period and adult longevity of *A. fasciculatus* on different dried chips

A 200g samples of each treatment prepared were weighed with a sensitive balance scale (Gibertini TM 1600®, Italy) and placed in rearing jars, each treatment was replicated 4 times, 10 pairs of *Araecerus fasciculatus* were introduced to them to feed and oviposit, with a rearing jar without any insects served as the control. The jars were covered with a muslin cloth to allow aeration and prevent other pests from entering. The setup was arranged in a completely randomized design (CRD) in the laboratory and monitored daily. Data were collected on the developmental period; adult longevity was

Table 1: Treatments and their application rates

S/N	Chips (1kg)		Water (ml)		FMW (ml)		Lime Juice(ml)		Description (Treatments)
1	Cassava	+	1000	+	0	+	0	Control	CA_1
2	Cassava	+	750	+	250	+	0	Control	CA_2
3	Cassava	+	747.5	+	250	+	2.5	Treatment 1	CA_3
4	Cassava	+	745	+	250	+	5	Treatment 2	CA_4
5	Cassava	+	742.5	+	250	+	7.5	Treatment 3	CA_5
6	Cassava	+	740	+	250	+	10	Treatment 4	CA_6
7	Potato	+	1000	+	0	+	0	Control	PO_1
8	Potato	+	750	+	250	+	0	Control	PO_2
9	Potato	+	747.5	+	250	+	2.5	Treatment 1	PO_3
10	Potato	+	745	+	250	+	5	Treatment 2	PO_4
11	Potato	+	742.5	+	250	+	7.5	Treatment 3	PO_5
12	Potato	+	740	+	250	+	10	Treatment 4	PO_6
13	Water yam	+	1000	+	0	+	0	Control	WA_1
14	Water yam	+	750	+	250	+	0	Control	WA_2
15	Water yam	+	747.5	+	250	+	2.5	Treatment 1	WA_3
16	Water yam	+	745	+	250	+	5	Treatment 2	WA_4
17	Water yam	+	742.5	+	250	+	7.5	Treatment 3	WA_5
18	Water yam	+	740	+	250	+	10	Treatment 4	WA_6
19	White yam	+	1000	+	0	+	0	Control	WH_1
20	White yam	+	750	+	250	+	0	Control	WH_2
21	White yam	+	747.5	+	250	+	2.5	Treatment 1	WH_3
22	White yam	+	745	+	250	+	5	Treatment 2	WH_4
23	White yam	+	742.5	+	250	+	7.5	Treatment 3	WH_5
24	White yam	+	740	+	250	+	10	Treatment 4	WH_6
25	Plantain	+	1000	+	0	+	0	Control	PL_1
26	Plantain	+	750	+	250	+	0	Control	PL_2
27	Plantain	+	747.5	+	250	+	2.5	Treatment 1	PL_3
28	Plantain	+	745	+	250	+	5	Treatment 2	PL_4
29	Plantain	+	742.5	+	250	+	7.5	Treatment 3	PL_5
30	Plantain	+	740	+	250	+	10	Treatment 4	PL

determined when all the *A. fasciculatus* exhibited morbidity.

Efficacy of fermented maize water and lime on the damage of *A. fasciculatus* on different dried chips

Two sets of 200g sample of each treated dried chips were placed in 2L capacity kilner jar, the jars were covered with a muslin cloth to allow aeration and prevent other pests from entering. In the first set, twenty day-old adults of *A. fasciculatus* were introduced into the kilner jars and the set up was arranged in the laboratory using a CRD. The experiment was replicated four times. The setup was left for 90 days after which, the chips were reweighed. Weight loss was determined as the difference between the weight of the uninfested sample and that of the infested sample as a proportion of the weight of the uninfested sample expressed in percentage.

$$WL = [(Wc - Wt)/Wc] \times 100$$

Where:

WL = percentage weight loss

Wc = weight of uninfested sample

Wt = weight of infested sample

Data were subjected to analysis of variance (ANOVA) and standard error was calculated to show variation between replicates. Significant means were later separated with Tukey Honestly Significantly Difference (Tukey HSD) test at 5% level of probability ($P < 0.05$).

Results

Efficacy of processing dried chips with fermented maize water and lime

Processing of chips with fermented maize water and lime significantly influenced ($P<0.05$) insect

developmental period, adult longevity and percentage chips damage (Fig 1 – Fig 3). On cassava, treatment CA_6 had the highest ($P < 0.05$) developmental period (70 days) which was significantly higher than other treatments while treatment CA_1 had the lowest developmental period (47.75 days). Adult longevity recorded on treatment CA_1 (80.25days) was significantly longer ($P < 0.05$) than the remaining treatments while treatment CA_6 had the least adult longevity (31.75 days). The percentage damage was significantly higher in treatment CA_1 (21.25 days) ($P < 0.05$) than the rest of the treatment while CA_6 had the lowest percentage damage (0.63%). (Fig 1 – Fig 3).

On potato, treatment PO_6 and PO_5 had the highest significant developmental period (59.75 and 54.5 days) ($P < 0.05$) than other treatments. Insect developmental periods in treatments PO_2, PO_3 and PO_4 (47.00, 49.25, 49.75 days) respectively were not significantly different ($P > 0.05$) from one another. Treatment PO_1 had the lowest developmental period (45.50 days) (Fig. 1). Among the potato treated, PO_1 (91.50 days) had the longest adult longevity while PO_6 recorded the lowest (32.25 days) adult longevity (Fig. 2). On percentage damage, damage on PO_1 treatment (15.63%) was significantly higher than the rest of the treatment while there was no significant difference among the damage recorded on PO_4, PO_5 and PO_6 (0.84, 0.56 and 0.34 %) respectively (Fig. 3).

On water yam, there was no significant difference ($P > 0.05$) in developmental period among treatments WA_4, WA_5 and WA_6 (72.75, 73.75 and 77.00 days), but was significantly different ($P < 0.05$) from treatment WA_1 (56.25 days). Adult longevity of coffee bean weevils was influenced by different treatment applications, with the longest observed on treatment WA_1 (105 days) and lowest on WA_2 (33.75 days). The highest percentage damage was observed on WA_1 (20.88 %) while damage on treatments WA_4, (0.80 %), WA_5 (0.50 %) and WA_6 (0.38 %), were not significantly difference from one another (Fig. 3).

It was observed on white yam that treatment WH_6 (78.25 days) recorded the highest developmental period but not significantly higher than treatment WH_4 (74 days) and WH_5 (78.25 days) ($P > 0.05$), but the least developmental period was recorded on WH_1 (50 days). Treatments greatly influenced adult longevity on white yam from 99.50 (WH_1) days to 33.50 (WH_6) days. The highest percentage damage was recorded on WH_1 (21.61) and the least on WH_6 (0.66 %) due to the influence of treatment on the dried chips (Fig. 3).

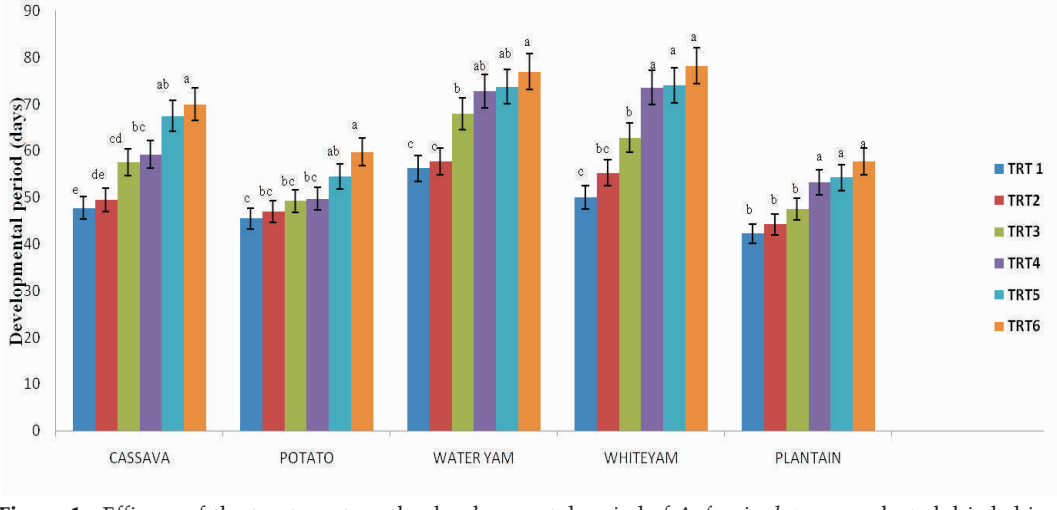


Figure 1: Efficacy of the treatment on the developmental period of *A. fasciculatus* on selected dried chips (Bars with the same letters are not significantly different using Tukey's HSD Test at α.05)

Legend: TRT1 = Control 1; TRT2: Control 2; TRT3 = Treatment 1; TRT4 = Treatment 2; TRT5 = Treatment 3; TRT6 = Treatment 4

Treatment application of fermented maize water and lime on plantain influenced coffee bean weevils' developmental period, adult longevity and damage assessment (Fig 1 - 3). PL_6 (57.75 days) recorded the highest developmental period but not significantly higher ($P > 0.05$) than PL_4 (53.25 days) and PL_5 (54.25 days) respectively. On treatments PL_1, (42.25 days) PL_2, (44.25 days) and PL_3, (47.5 days), the influence of treatment on the developmental period was not significantly different from one another. Adult longevity was significantly higher in PL_1 (68.50 days) and lowest on PL_6 (33 days). Treatment applications greatly influenced percentage damage from a high of 37.13 % (PL_1) to a low of 0.38 % (PL_6). Effects of all treatment applications on percentage damage were significantly different from one another (Fig. 3).

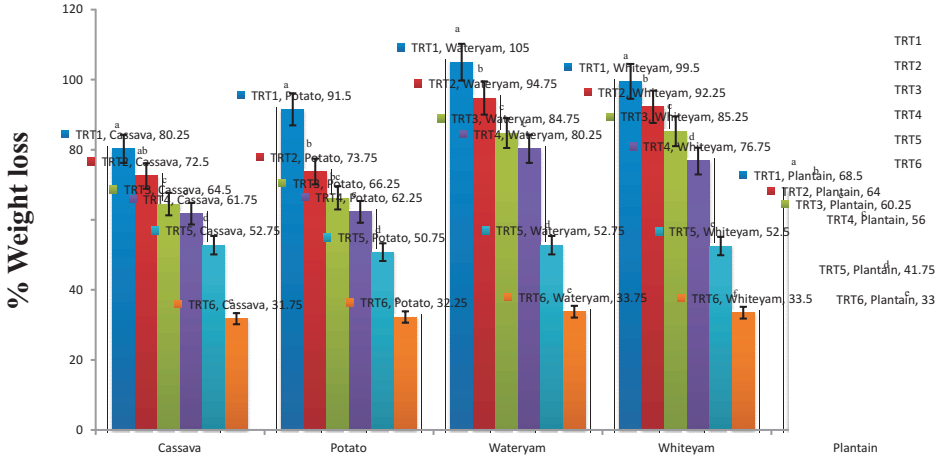


Figure 2: Efficacy of the treatment on the adult longevity of *A. fasciculatus* on selected dried chips (Bars with the same letters are not significantly different using Tukey's HSD Test at α.05)

Legend: TRT1= Control 1; TRT2: Control 2; TRT3 = Treatment 1; TRT4 = Treatment 2; TRT5 = Treatment 3; TRT6 = Treatment 4

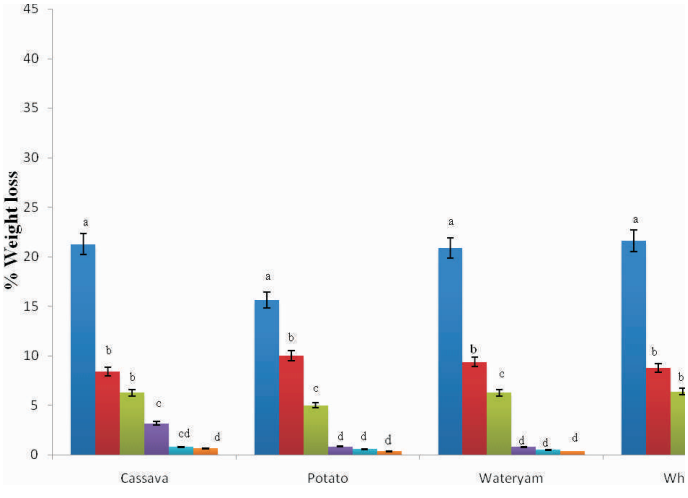


Figure 3: Efficacy of the treatment on the percentage damage of *A. fasciculatus* on selected dried chips (Bars with the same letters are not significantly different at Tukey's HSD Test at α.05)

Legend: TRT1= Control 1; TRT2: Control 2; TRT3 = Treatment 1; TRT4 = Treatment 2; TRT5 = Treatment 3; TRT6 = Treatment 4

Discussion

The study conducted on the management of *Araecerus fasciculatus* by blanching selected dried chips with FMW and LJ proved to be active by extending the developmental period of *A. fasciculatus*, reducing adult longevity and percentage damage recorded on different treated chips. This agrees with the report of Nwana and Azodeh (1984) who worked on the intensity of damage by the coffee bean weevil, *Araecerus fasciculatus* (Degeer) to yam chips blanched before drying and observed a reduction in the damage level. The same trend of results was observed in all the parameters tested in this study. The developmental period in all the dried chips -followed the same trend, which indicated that treatment six (6) which had the highest percentage of lime (10ml) gave the most effective result. These treatments retarded the development of *A. fasciculatus* in all the dried chips used as well as reduced their life span. The addition of lime and fermented maize water sustained the phytochemicals found in all of the treatments and promoted their efficiency by having pesticide characteristics. These are similar to the findings of Adusei- Mensah *et. al* (2014) and Amoura *et al* (2021) who reported on insecticidal and repellent properties of *Citrus aurantifolia* against Carpenter ant (*Camponotus nearcticus*). Phytochemical screening revealed the presence of important secondary metabolites such as alkaloids, phenols, saponin and tannin, which reduced the level of infestations of *A. fasciculatus* on stored chips. This is in line with the studies of Cowan (1999), Rattan, (2010) and Ajao *et al* (2020) who reported that secondary metabolites could serve as defense mechanism against predation by insects.

Conclusion

When chips were blanched with fermented maize water and lime *A. fasciculatus* a prolonged developmental period was experienced and short adult longevity as well as low percentage damage. The addition of lime and fermented maize water retained the phytochemicals present in all the treatments and facilitated the efficacy of the treatment by working as a pesticide. The treatments used (fermented maize water and lime juice in different combinations) allowed the insect to oviposit and the eggs were able to hatch but their development prolonged and adult longevity was very short due to reduced feeding on the food materials provided. There is a need to confirm if the application of fermented maize water and lime will not have deleterious effect on the taste, colour, smoothness, elasticity, viscosity, odour, stickiness and overall acceptability of cassava, potato, water yam, white yam and plantain. Further research will be carried out on this. As a result of the findings of this study, fermented maize water and lime juice can be incorporated into integrated pest management programmes due to its efficacy and ecologically/ organically compliant.

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