JBiopest 14(2): 154-164**(2021)**

The efficacy of Salt, ginger and two local peppers for the management of plantain chips infested with *Tribolum castaneum* (Herbst) (Coleoptera: Tenebrionidae)

Ojianwuna, C.C. and Enwemiwe, V.N.

ABSTRACT

The red flour beetle, *Tribolum castaneum* (Coleoptera: Tenebrionidae), is one among the major devastating pests of stored plantain chips and stored flours. Their control using synthetic options of insecticide may cause food poisoning and bioaccumulation. The use of botanical treatments and their relatives have stood out by their proven efficacy against insect pests. This present study therefore evaluates the toxicity and repellency of table salt (Sodium Chloride), *Zingiber officinale* and pepper powders (*Aframomum melegueta* and *Dennettia tripetala*) as protectants of dried plantain chips infested with *T. castaneum* in the laboratory using standard methods. The highest percentage mean mortality (%) was recorded in 10g salted chips (65.00±7.88), and 10g *D. tripetala* (72.50±7.88), and repellency in 2g of *Z. officinale* and salt (69.06±5.91 and 51.22±5.91) respectively. Lowest number of holes was recorded in 5g of *D. tripetala* and 2g of salt (1.88±0.88 and 1.50±1.17) respectively. Likewise, the percentage weight loss was recorded in 5g of salt and 2g *D. tripetala* (1.80±0.87 and 62.62±6.87). A significant difference was observed in all the treatment groups ($p< 0.05$). LC_{50} was lowest in salted chips (1.59g) compared to *D. tripetala* (2.02g) and other peppered chips. More so, LC_{95} was lowest in *D. tripetala* (10.80g) compared to salt (36.00g) and other pepper chips. Considering the high mortality recorded in salted and peppered chips, their best concentrations could be adopted as viable alternatives over chemical pesticides in managing *T. castaneum* infestation in storage conditions.

Keywords: Efficacy, *Tribolium castaneum*, pepper powders, table salt, plantain chips, stored products.

MS History: 23.08.2021(Received)-10.10.2021(Revised)-20.10.2021(Accepted)

Citation: Ojianwuna, C.C. and Enwemiwe, V.N. 2021. The efficacy of Salt, ginger and two local peppers for the management of plantain chips infested with *Tribolum castaneum* (Herbst) (Coleoptera: Tenebrionidae). *Journal of Biopesticides*, **14**(2):154-164.

INTRODUCTION

Plantain, especially the dry stored chips serve as important food for flour production and consumptions (Danjuma *et al*., 2008; Isah *et al*., 2009). Dry plantain chips suffer heavy infestation and losses to insect pests in stored condition. The economic and postharvest losses of dry plantain chips and tuber crops due to attack by insect pest in local storage cannot be quantified (Arannilewa *et al.*, 2002). Studies have ascribed world's food infestation to insect and rodent pest, and estimated food losses in the field, during processing and in storage to be 10 to 25% (Abass *et al.*, 2014; Manandhar *et al.*, 2018, Atta *et al.*, 2018). Various forms of postharvest losses other than insect infestations have been identified including seed breakages, fungi contaminations amongst others (Choudhary and Kumari, 2010; Tsado *et al.*, 2015). In stored condition, several insect pests including *Tribolum castaneum* (Herbst) (Coleoptera: Tenebrionidae), *Prostephanus truncatus* (Horn), *Araecerus fasciculatus* (Degeer) (Coleoptera: Anthribidae) and *Dinoderus* spp.

(Coleoptera: Bostrichidae) are among the devastating pests causing potential damages to dried stored plantain chips in hermetic and other polyethylene form of storages (Atta *et al.*, 2019).

As a devastating pest of stored product, *T. castaneum* remains the insect responsible for the remarkable destruction of stored chips and other products annually in tropical and subtropical regions of the world. For instance, stored product loss due to the destructive activities of *T. castaneum* in an untreated vessel accounts for over 23% annually losses in rural Niger in Africa (Baoua *et al.,* 2015). Even though modern storage technologies are predominant, majority of the farmers still store their grains in traditional structures leading to 50 to 100% losses. In India, this has caused 60 to 70% postharvest losses (Prakash *et al.*, 2016). Synthetic pesticides have long been adopted as the main approach for the control of insect pest attack on the field and in storage conditions but their recurrent use is presently of great concern to the environment causing problems (Ojianwuna and Enwemiwe, 2020a). Scientific reports on the effect of chemical pesticides prompted the search for biologically-based alternatives in plant materials which are ecologically-friendly for insect pest control and is still ongoing. There have not been any reported cases of resistance to insect pests due to persistent applications, resurgence in pest populations, bioaccumulation with environmental contamination, injury to beneficial insects, negative effect to applicators, secondary pest outbreaks and other environment-related problems in the use of biological pesticides. Therefore, their applications in various forms are promising (Zadoks and Waibel, 1999). Crop protection through the use of plant materials have been reported particularly with crude extracts of leaf and seeds, crushed plant materials, powders, essential oils, and other various forms (Arannilewa *et al.,* 2002; Arannilewa, 2002; Ajayi and Adedire, 2003; Adedire and Akinneye, 2004; Akinkurolere *et al.*, 2006; Sanon *et al.*, 2008; Sattar *et al.*, 2014, Ojianwuna and Umoru 2010, Ojianwuna and Umoru 2011, Ojianwuna *et al.*, 2011 and Ojianwuna *et al*., 2018).

Considering the potentials of plant protectants and the cost effectiveness of salting, this study was designed to explore the toxicity and repellency of using pepper powders and salt against the infestation by *T. castaneum*. Ginger rhizome (*Zingiber officinale*), seeds of alligator pepper (*Aframomum melegueta*), and pepper fruit (*Dennettia tripetala*). These plant materials and salt are well-known spices used as condiments in the African region. The application of plant protectants in the toxicity of insect pests have been reported as various forms including grounded dusts, essential oils, and powders from roots, leaves and stem of whole plants present some levels of protections on crops against the black bug of rice, flea beetles of okra, beans weevils, caterpillars of tobacco plant amongst other different insect pests both in field and stored conditions (Ojianwuna and Umoru 2010, 2011; Ojianwuna *et al*., 2011, 2018; Sumathi and Ramasubramanian, 2013; Suganthy, 2013; Ilondu and Enwemiwe, 2019; Ojianwuna and Enwemiwe, 2020b). There is however, no information on the use of salt and pepper powders in the biological control of this insect pest on dry plantain chips. Hence the need for report on the evaluation of salting and peppering of dry plantain chips against infestations by *T. castaneum* in stored conditions.

MATERIALS AND METHODS

Source of Insect and Culture

Adult insects used for the study were obtained and identified by National Stored Product Research Institute (NSPRI), Ibadan, Oyo State, Nigeria as *T. castaneum*. These insects were taken to the insectary unit of the Entomology Laboratory of the Department of Animal and Environmental Biology, Delta State University, Abraka, Nigeria, for culture. The culture in the laboratory was done by introducing twenty pairs of unsexed adult weevils into 1L kilner jars containing 1000g of dried plantain chips. The set up was kept undisturbed in the laboratory at conditions of 25.0-32.0°C temperature and 35.0-70.0% relative humidity and covered with a metal screen. Temperature and humidity data was monitored using EOSUN thermohygrometer placed in the laboratory. All adult insects were removed after 2 weeks and left until adult emergence. The emerged adults from this culture, aged 1-3 weeks old were used for the experimental exposures.

Plant Materials and Preparation

High volatile oil variety of ginger rhizome (*Zingiber officinale*), alligator pepper seeds of African type (*Aframomum melegueta*), and African-typed pepper fruit (*Dennettia tripetala*) were dried, ground into powders using fine blending machine, stored in containers and used for treatment applications. Fresh unripe plantains was obtained from the Abraka main market, peeled, chopped into slices of about 5cmx1cmx1cm and solarized for two week under optimum environmental conditions. The dried plantain chips were later oven-sterilized at 60°C for 3hrs to kill any infesting pest during drying. This method was adopted from the description by Rajamma *et al*. (1994).

Contact Toxicity Test

The toxicity test of salt, ginger and pepper powders to the red flour beetles was done by contact and topical application in the laboratory following standard procedures described by Mc Donald *et al*. (1970). Twenty *T. castaneum* of unknown sex and aged 1-3 weeks were placed in 350x350 glass jar containing 20g of treated chips with various concentrations of table salt (Sodium Chloride: NaCl) and pepper powders. Untreated dry plantain chips served as control for experiment. The set up was examined daily for 21 days and the number of insect mortality was recorded. Each treatment concentration was replicated four times and arranged in the laboratory using Complete Randomized Design (CRD). The experiment was repeated twice to confirm records. Percentage insect mortality was calculated according to Baba-Tierto (1994) using the formula:

$$\% \text{ Insect Mortality} = \frac{\text{Number of dead insects}}{\text{Total number of insect}} \text{ X } 100$$

Percentage weight loss was obtain using the formula described by Yusuf and Ahmed, 2005) as follows:

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

Repellency Test

Repellency study was carried out in the laboratory using the filter paper treatment method and the preference area test described by Landani *et al*. (1995) and Mc Donald *et al*. (1970). The test area was the bottom of a 350x350 glass jar. Twenty adult insects were placed into the triplicated glass jars before application of treatment concentrations. A number 1 Whatman filter paper of 11 cm diameter was placed at the neck of the glass jar close to the metallic cork and metal gauze. The treatment concentrations was added on top of the filter paper. Glass jars lined with untreated filter paper containing insects served as control. The set up was equally arranged in Complete Randomized Design (CRD) and repeated twice to confirm records. The number of insects present on control (N Cont.) and on treatment (N Treat.) was recorded after 1 hour exposure and was monitored for 21 days. Percentage Repellency (% Repellency) value was computed using the method of Hossanah *et al*. (1990) as follows:

$$\% \text{ Repellency} = \frac{\text{NCont.} - \text{NTreat.}}{\text{NCont.} + \text{NTreat.}} \text{x}100$$

All negative values were treated as zero.

Data Analysis

Data on percentage adult insect mortality and percentage weight loss of chips were transformed using (log [x+1]) and arcsine (Zar, 1999). Results obtained on percentage repellency, percentage weight loss, and percentage mortality of adult insects were subjected to Analysis of Variance (ANOVA), using XL Statistical software version 2020. Significant differences were observed at p <0.05 and means separated using Tukey's test. Probit model was used to show lethal concentration (LC) of 50% and 95%.

RESULTS

Mortality and Repellency Records

The mortality and repellency of *T. casteneum* adults when exposed for 21-days to increasing concentrations of salt, ginger and pepper powders are presented in Table 1. The findings of this study revealed that salting and peppering stored plantain chips significantly decreased the population or repelled infestations by *T. casteneum* at various concentrations and exposure days. The mean adult mortality recorded in 5.00g *A. melegueta* equates those in 2.00g of salt, while mortality in 10.0g of *A. melegueta* is proportional to *Z. officinale* 10.0g. The proportionality between the treatments was not significantly different (P> 0.05). The highest mortality was recorded with the use of 10.0g of *D. tripetala* while the lowest was recorded with the use of 2.00g of Z. *officinale* (Table 1).

More so, various degrees of repellency were recorded with salting and peppering of plantain chips infested with *T. casteneum*. Z. *officinale* 2.00g conferred the highest repellency while 10.0g of salt recorded the lowest repellency (P< 0.05). Similarly, considering the relationship between mortality and repellency records in all, increased concentration of salt and pepper powders favoured higher mortality while causing reduced repellency in salted chips, and chips treated with *Z. officinale* and *D. tripetala*. Salt and pepper powders were unable to confer 100% protection on chips. Hence none of the treatments showed 100% adult mortality, but the highest concentration of *D. tripetala*, *Z. officinale*, *A. melegueta*, salt and 5.00g of *D. tripetala* caused above 50% mortality compared to other treatment concentrations. There was no significant difference in the mortality of plantain chips stored with 5g and 10g of *A. melegueta*, 5g and 10g *Z. officinale*, 5g of *D. tripetala*, 2g and 5g of salts. There was equally no significant difference (P> 0.05) in the mortality record in 10g of *D. tripetala* and 10g of salt. Furthermore, there was no significant difference (P> 0.05) in the repellency recorded with 2g *A. melegueta* and 2g *D.tripetala*, 10g *A. melegueta* and all concentrations of *Z. officinale*, 5g *A. melegueta*, 10g *D. tripetala* and 2g of salts (Table 1).

Holes and Weight Loss of Dried Chips

Salt, *D. tripetala*, *A. melegueta* and *Z. officinale* were tested to ascertain the numbers of holes and the weight loss in dried stored chips with all concentrations. After dry plantain chips were salted and peppered for 21-days, a reduced mean number of holes and percentage weight loss was observed in the salted chips compared to the peppered chips and control. The differences between the concentrations of salted chips were not significant (P> 0.05) except in 2g of salt for mean number of holes (Table 2). More so, mean number of holes was high in the highest concentration of *A. melegueta* and *Z. officinale*. But the reverse was the case for *D. tripetala*; recording high mean number of holes for the lowest concentration. There was no significant difference (P> 0.05) between the reduced mean number of holes recorded in salted chips, 5g and 10g *D. tripetala* and 5g *A. melegueta* exposed chips. Weight loss in the peppered chips ranged from 62.6 – 80.9% with the highest and lowest recorded in 5g *A. melegueta* and 2g *D. tripetala* respectively. There was no significant difference (P> 0.05) in the percentage weight loss recorded in 2g and 5g *A. melegueta* and *D. tripetala* respectively, and 2g and 10g *Z. officinale* (Table 2).

Exposure Day Records

The mortality record of *T. castaneum* with exposure day for salted and peppered chips is shown in Table 3. The highest adult mortality occurred in 10g of *D. tripetala* within 5 – 8 days of exposure. Most adult mortality occurred within 0 – 12 days of exposure irrespective of the whether plantain chips were salted or peppered. The lowest adult mortality was recorded in 2g and 5g of salted chips and 10g of *Z. officinale* exposed chips at 17 to 21 days of exposure when compared to other treatments. However, no mortality was observed in 5g of salted and *Z. officinale* exposed chips respectively at 13-16 days of exposure. No mortality was equally recorded in 2g of *A. melegueta* and *Z. officinale* respectively from 13-21 days of exposure (Table 3). All concentrations of *D. tripetala* and 10g of salt caused mortality within 0-12 days of exposure. Exposure day records for adult mortality in 5g *Z. officinale* and *A. melegueta,* 10g *Z. officinale,* and 2g and 5g of salt extended till 21 days. The differences were not significant (P> 0.05) for the peppered chips except within 13 to 21 days while being significant (P<0.05) for the salted chips within exposure days (Table 3).

Above 50% repellency was recorded in 10g of *A. melegueta*, all concentrations of *Z. officinale*, and 2g and 5g of *D. tripetala* after 4 days of exposure. The highest repellency was recorded in 2g of *Z. officinale* and the difference was significant. Great repellency was equally recorded in 5g of *D. tripetala* after 4 days of exposure. For salted chips, 70% and above repellency was recorded after 12 days of exposure and the highest repellency after 21 days of exposure. A 10g of *A. melegueta* recorded highest repellency after 12 days of exposure, 10g of *Z. officinale* after 21 days, 10g of *D. tripetala* after 16 days of exposure. Similarly, significantly (P< 0.05) higher repellency was observed for 2g of *A. melegueta* and *D. tripetala* with exposure days respectively (Table 4).

Toxicity Bioassay

The probit estimation of *T. castaneum* exposed to salt and peppered dry plantain chips at 21 days post treatment period is presented in Table 5. After 21 days, 50% mortality of *T. casteneum* adults was achieved for salt and pepper powders at concentrations between 1.59 and 4.31g. Salt recorded the lowest LC_{50} while the lowest LC_{95} was recorded in *D. tripetala*..

DISCUSSION

The adoption of plant protectants over chemical insecticides has been ongoing for decades. Various parts of medicinal plants with proven insecticidal potentials against stored product and field pest has confirmed contact toxicity in studies (Franccedil *et al.,* 2009; Ukeh *et al.,* 2010; Ojianwuna and Umoru 2011, 2012; Ilondu and Enwemiwe, 2019). So far, pepper fruit has reportedly been effective against stored product pests and flea beetles of okra compared to ginger and alligator pepper powders (Ojianwuna *et al.,* 2016; Ojianwuna and Surveyor, 2017; Ilondu and Enwemiwe, 2019; Ojianwuna and Enwemiwe, 2020). According to Ileke and Olotuah (2012), the adoption of biopesticidal plants as alternatives is due to their friendly nature to the environment, limited records of mammalian toxicity, efficacy on targeted pest populations, low injury to beneficial insects amongst others. In this present study, the use of salt, ginger and two local pepper powders at different concentrations decreased populations of the pest and repelled infestations. Several possible reasons may be ascribed to these observations. Salt contains positively charged sodium and chloride ions which have the ability of forming droplets of water and thus increasing the relative humidity in salted chips. This might have made it unfavourable for the insect pest to establish compared to the peppered chips where suffocation and at best repellence of insect pest attacks might have occurred. Table salt contains other cations such as calcium, magnesium, potassium and anions such as bicarbonate, carbonate, nitrate and sulfate (Talley and Talley, 2008). Information on the insecticidal potentials of table salts is lacking or not properly understood. It was observed in this study that after two days of exposure salted chips absorbed water. Also, the mortality and repellency recorded in this study was ascribed to oxygenated volatiles in the constituents of alligator pepper and ginger as reported by Ukeh *et al.* (2009) and in the pepper fruit. The study of Madreseh-Ghahfarokhi *et al.* (2019) reported the effectiveness of using ginger as satisfactory bio-protectant recording insecticidal activities against *Rhipicephalus bursa*. Mortality and repellency caused by ginger in this study were not satisfactory except for the highest concentration that caused 50% mortality.

Table 1. Effect of various concentrations of salt, ginger and two local peppers on the mean mortality, and repellency of plantain chips with *T castaneum*

Treatment	Conc. (g)	Mean Mortality (%)	95% confidence Interval	Mean repellency (%)	95% confidence Interval
Control	0.00	0.00 ± 7.88[a]	0.00 – 0.00	0.00 ± 5.91[a]	0.00 – 0.00
A. melegueta	2.00	20.00 ± 7.88[ab]	4.07 – 35.93	55.35 ± 5.91[cd]	43.39 – 67.31
	5.00	45.00 ± 7.88[bc]	29.07 – 60.93	49.58 ± 5.91[bcd]	37.62 – 61.53
	10.00	52.50 ± 7.88[bc]	36.57 – 68.43	62.62 ± 5.91[d]	50.66 – 74.58
Z. officinale	2.00	17.50 ± 7.88[ab]	1.57 – 33.43	69.06 ± 5.91[d]	57.10 – 81.02
	5.00	40.00 ± 7.88[bc]	24.07 – 55.93	68.48 ± 5.91[d]	56.52 – 80.44
	10.00	52.50 ± 7.88[bc]	36.57 – 68.43	67.40 ± 5.91[d]	55.44 – 79.35
D. tripetala	2.00	35.00 ± 7.88[abc]	19.07 – 50.93	58.48 ± 5.91[cd]	46.52 – 70.44
	5.00	55.00 ± 7.88[bc]	39.07 – 70.93	67.95 ± 5.91[d]	55.99 – 79.91
	10.00	72.50 ± 7.88[c]	56.57 – 88.43	47.75 ± 5.91[bcd]	35.79 – 59.71
Salt	2.00	45.00 ± 7.88[bc]	29.07 – 60.93	51.22 ± 5.91[bcd]	39.26 – 63.17
	5.00	47.50 ± 7.88[bc]	31.57 – 63.43	29.17 ± 5.91[abc]	17.21 – 41.12
	10.00	65.00 ± 7.88[c]	49.07 – 80.43	22.51 ± 5.91[ab]	10.55 – 34.47

Values with same letters are not differ significantly within a column using Turkey's test

Table 2. Effect of various concentrations of salt, ginger and two local peppers on the numbers of holes, and weight loss of plantain chips with *T castaneum*

Treatment	Concentration (g)	Mean No. of holes	95% confidence Interval	Mean weight loss (%)	95% confidence Interval
Control	0.00	16.25 ± 1.88[d]	12.52 – 19.99	100.00 ± 6.87 [c]	86.12 – 113.89
A. melegueta	2.00	7.75 ± 1.88[abcd]	4.02 – 11.49	76.73 ± 6.87[bc]	62.85 – 90.62
	5.00	2.71 ± 1.01[ab]	-1.28 – 6.71	80.90 ± 6.87[bc]	67.01 – 94.78
	10.00	11.11 ± 1.77[bcd]	7.59 – 14.13	64.70 ± 6.87 [b]	50.81 – 78.58
Z. officinale	2.00	5.63 ± 1.88[abc]	1.89 – 9.36	72.30 ± 6.87[bc]	58.41 – 86.18
	5.00	14.00 ± 2.66[cd]	8.72 – 19.28	65.58 ± 6.87[b]	51.70 – 79.47
	10.00	11.08 ± 1.53[bcd]	8.03 – 14.13	68.37 ± 6.87[bc]	54.48 – 82.25
D. tripetala	2.00	5.50 ± 1.88[abc]	1.77 – 9.24	62.62 ± 6.87[b]	48.73 – 76.50
	5.00	1.88 ± 0.88[ab]	-1.86 – 5.61	66.66 ± 6.87[b]	52.78 – 80.55
	10.00	2.57 ± 1.01[ab]	-1.42 – 6.56	70.31 ± 6.87[bc]	56.43 – 84.20
Salt	2.00	1.50 ± 1.17[a]	-2.81 – 5.81	1.46 ± 0.87[a]	-12.43 – 15.34
	5.00	4.43 ± 1.01[ab]	0.44 – 8.42	1.80 ± 0.87[a]	-12.09 – 15.69
	10.00	2.63 ± 0.88[ab]	-1.11 – 6.36	2.05 ± 0.87[a]	-11.84 – 15.93

Values with same letters are not differ significantly within a column using Tukey's test

Table 3. Mortality records with days for *T. castaneum* exposed to salt, ginger and two local peppers.

Mean days ± SE mortality (Days)						
Treatments	**Conc. (g)**	**0-4d**	**5-8d**	**9-12d**	**13 -16d**	**17-21d**
Control	0.00	0.00 ± 0.00[a]	0.00 ± 0.00[a]	0.00 ± 0.00[a]	0.00 ± 0.00[a]	0.00 ± 0.00[a]
A. melegueta	2.00	0.00 ± 0.00[a]	15.00 ± 7.55[abcd]	25.00 ± 7.55[abcd]	0.00 ± 0.00[a]	0.00 ± 0.00[a]
	5.00	15.00 ± 7.55[abcd]	30.00 ± 7.55[abcd]	30.00 ± 7.55[abcd]	5.00 ± 1.24[ab]	10.00 ± 2.13[abc]
	10.00	20.00 ± 7.55[abcd]	45.00 ± 7.55[abcde]	30.00 ± 7.55[abcd]	10.00 ± 2.13[abc]	0.00 ± 0.00[a]
Z. officinale	2.00	5.00 ± 1.24[ab]	25.00 ± 7.55[abcd]	5.00 ± 1.24[ab]	0.00 ± 0.00[a]	0.00 ± 0.00[a]
	5.00	20.00 ± 7.55[abcd]	25.00 ± 7.55[abcd]	30.00 ± 7.55[abcd]	0.00 ± 0.00[a]	10.00 ± 2.13[abc]
	10.00	30.00 ± 7.55[abcd]	25.00 ± 7.55[abcd]	25.00 ± 7.55[abcd]	20.00 ± 7.55[abcd]	5.00 ± 1.24[ab]
D. tripetala	2.00	45.00 ± 7.55[abcde]	25.00 ± 7.55[abcd]	0.00 ± 0.00[a]	0.00 ± 0.00[a]	0.00 ± 0.00[a]
	5.00	50.00 ± 7.55[bcde]	50.00 ± 7.55[bcde]	10.00 ± 2.13[abc]	0.00 ± 0.00[a]	0.00 ± 0.00[a]
	10.00	60.00 ± 7.55[de]	80.00 ± 7.55[e]	5.00 ± 1.24[ab]	0.00 ± 0.00[a]	0.00 ± 0.00[a]
Salt	2.00	5.00 ± 1.24[ab]	25.00 ± 7.55[abcd]	50.00 ± 7.55[bcde]	5.00 ± 1.24[ab]	5.00 ± 1.24[ab]
	5.00	15.00 ± 7.55[abcd]	45.00 ± 7.55[abcde]	30.00 ± 7.55[abcd]	0.00 ± 0.00[a]	5.00 ± 1.24[ab]
	10.00	25.00 ± 7.55[abcd]	50.00 ± 7.55[bcde]	55.00 ± 7.55[cde]	0.00 ± 0.00[a]	0.00 ± 0.00[a]

Values with same letters are not differ significantly within a column and rows using Tukey's test

Table 4. Repellency records with days for *T. castaneum* exposed to salt, ginger and two local peppers.

Treatments	Conc. (g)	Mean days ± SE mortality (Days) 0-4d	5-8d	9-12d	13 -16d	17-21d
Control	0.00	0.00 ± 0.00^{a}	0.00 ± 0.00^{a}	0.00 ± 0.00^{a}	0.00 ± 0.00^{a}	0.00 ± 0.00^{a}
A. melegueta	2.00	30.00 ± 6.48^{abcd}	70.00 ± 6.48^{efghi}	90.00 ± 6.48^{i}	90.00 ± 6.48^{i}	0.00± 0.00^{a}
	5.00	35.00 ± 6.48^{abcde}	45.00 ± 6.48^{bcdefg}	85.00 ± 6.48^{hi}	0.00 ± 0.00^{a}	70.00 ± 6.48^{efghi}
	10.00	70.00 ± 6.48^{efghi}	65.00 ± 6.48^{defghi}	90.00 ± 6.48^{i}	0.00 ± 0.00^{a}	80.00 ± 6.48^{ghi}
Z. officinale	2.00	90.00 ± 6.48^{i}	85.00 ± 6.48^{hi}	0.00 ± 0.00^{a}	70.00 ± 6.48^{efghi}	80.00 ± 6.48^{ghi}
	5.00	70.00 ± 6.48^{efghi}	70.00 ± 6.48^{efghi}	70.00 ± 6.48^{efghi}	0.00 ± 0.00^{a}	85.00 ± 6.48^{hi}
	10.00	70.00 ± 6.48^{efghi}	75.00 ± 6.48^{fghi}	85.00 ± 6.48^{hi}	0.00 ± 0.00^{a}	90.00 ± 6.48^{i}
D. tripetala	2.00	50.00 ± 6.48^{cdefgh}	80.00 ± 6.48^{ghi}	85.00 ± 6.48^{hi}	0.00 ± 0.00^{a}	75.00 ± 6.48^{fghi}
	5.00	85.00 ± 6.48^{hi}	65.00 ± 6.48^{defghi}	90.00 ± 6.48^{i}	0.00 ± 0.00^{a}	80.00 ± 6.48^{ghi}
	10.00	30.00 ± 6.48^{abcd}	45.00 ± 6.48^{bcdefg}	40.00 ± 6.48^{bcdef}	90.00 ± 6.48^{i}	0.00 ± 0.00^{a}
Salt	2.00	25.00 ± 6.48^{abc}	70.00 ± 6.48^{efghi}	75.00 ± 6.48^{fghi}	0.00 ± 0.00^{a}	0.00 ± 0.00^{a}
	5.00	40.00 ± 6.48^{bcdef}	10.00 ± 6.48^{ab}	75.00 ± 6.48^{fghi}	0.00 ± 0.00^{a}	90.00 ± 6.48^{i}
	10.00	15.00 ± 6.48^{abc}	20.00 ± 6.48^{abc}	70.00 ± 6.48^{efghi}	0.00 ± 0.00^{a}	0.00 ± 0.00^{a}

Values with same letters are not differ significantly within a column and rows using Tukey's test

Table 5. Probit estimations of *T. castaneum* exposed to salted and peppered plantain chips

Treatments	95% CI interval			95% CI interval			Tabular	
	LC_{50}	Lower	Upper	LC_{95}	Lower	Upper	χ^2	Value
Control	0.00	0.00	0.00	0.00	0.00	0.00	0.00	7.00
A. melegueta	3.93	0.18	9.45	43.36	16.55	64.41	0.031	7.00
Z. officinale	4.31	0.40	9.28	39.56	16.70	65.37	0.022	7.00
D. tripetala	2.02	0.13	4.18	10.80	5.65	37.18	0.012	7.00
Salt	1.59	0.74	9.88	36.00	4.54	51.92	0.001	7.00

Goodness of fit. The tabular value of x^2 is 7.00 at probability level of 0.05.

In this present study, mean mortality of weevils recorded in 5g *A. melegueta* is proportionate to 2g of salt, and 10g of *A. melegueta* to 10g of *Z. officinale* (P> 0.05).

The highest mortality recorded in this study was observed with the use of 10g of *D. tripetala* and lowest recorded was with the use of 2g of Z. *officinale*. The effectiveness observed in this present study corroborated the findings of Nwosu *et al.* (2018) where below 60% mortality was observed after 48 hrs of exposure through the use of *Z. officinale* and *A. melegueta* against beans weevil. Various degrees of repellency were observed with salting and peppering of plantain chips infested with the red flour beetle. The highest repellency was recorded in the 2g of Z. *officinale* and 10g of salt recorded the lowest repellency and being significant (P< 0.05). It was observed in this study that higher concentrations caused higher mortality and lower concentration caused higher repellency in salted and peppered chips. Similarly, it depicts that increased concentration of salt and pepper powders yielded higher mortality and caused reduced repellency in salted chips, and chips treated with *Z. officinale* and *D. tripetala*. All concentrations of salt and pepper were unable to confer 100% protection on chips but the highest concentration of *D. tripetala, Z. officinale, A. melegueta*, salt and 5.00g of *D. tripetala* caused above 50% mortality compared to other treatment concentrations. The potentials of using ginger powders as control of beans and maize weevils show that higher concentration yielded higher mortality (Edu *et al.,* 2019). Furthermore, Al-Qahtani *et al.* (2012) found that a powder of ginger was highly effective as satisfactory bio-protectant against insect pest activities of date palm. It predicts that increasing the concentration by 2g would increase mortality by 17 to 45%. The finding of this study is in agreement with the study of Rizvi *et al.* (2016) which showed that extracts of ginger was very efficacious for the control of cabbage looper in field condition and at early stage of infestation. However, Edu *et al.* (2019) showed that mortality in maize weevil was 49% when exposed to 60 gram of ginger. In this present study, ginger powders caused 55% mortality in *T. castaneum*.

This predicts that the weevils in this study were susceptible to ginger powders. The study of Adedire and Akinneye (2004) reported that extracts and powders of *Tithonia diversifolia* (Asteraceae) inhibited egg development and caused mortality in adult weevils. Similarly, Derbalah and Ahmed (2011) showed that oil and powders of *Mentha viridis* (Lamiaceae) inhibited emergence to adult and mortality in *Sitophilus oryzae*. This study recorded similar trends as the hermetic protection of plantain chips infestation is ongoing.

All concentrations of salt, *D. tripetala*, *A. melegueta* and *Z. officinale* recorded various levels of mean numbers of holes and weight losses. Salting dry plantain chips for 21 days reduced mean number of holes from 16.25 to 1.50 and 4.43 and percentage weight loss from 100% to 1.46 and 2.05%. Similarly after 21 days, reduced mean number of holes from 16.25 to 1.88 and 14.00 and percentage weight loss from 100% to 62.6 and 80.9%. Edu *et al.* (2019) observed that using ginger powders as biocontrol reduced total weight loss from 38% to 11% in beans exposed to weevil and 47% to 14% in maize exposed to weevils. The differences between the concentrations of salted chips were not significant except in 2g of salt for mean number of holes. Furthermore, mean number of holes was recorded high in the highest concentration of *A. melegueta* and *Z. officinale*. But reduced number of holes was recorded in the lowest concentration of *D. tripetala* ($p > 0.05$). Significant differences was not observed in the reduced mean number of holes with salted chips, 5g and 10g *D. tripetala* and 5g *A. melegueta* exposed chips. Similarly, no significant difference was observed in the percentage weight loss recorded in 2g and 5g *A. melegueta* and *D. tripetala* respectively, and 2g and 10g *Z. officinale* ($p > 0.05$). The study of Onekutu *et al.* (2015) has confirmed that extracts and seed powders of alligator pepper did not protect stored grains infested with beans weevils. This present study observed that alligator pepper and ginger failed to confer protection on seeds against weevil infestation. The increased number of holes and weight loss recorded in all concentrations of pepper powders may be due to compounds that triggered restless behaviour in insect pests causing them to punch holes in chips. It can be deduced that holes in this group may not be ascribed to infestation as recorded in the control groups. Similarly, reduced number of holes observed in the salted chips may be attributed to the compounds in the salt that discouraged penetration by insect pests. Weight gain was observed in salted chips. This due to the fact that salt in this study absorbed water which in turn slightly increased the weight of the chips but decaying of chips was not observed. The study of Ogori *et al.* (2016) equally observed increase in weight by 10% in salted chips. It was surprising to observe repellency in salted chips. The reason to this was not properly understood. The reason why lower concentration recorded high repellency in all treatment is equally not well understood.

The time mortality of *T. castaneum* exposed to salt, ginger and two local pepper in plantain chips showed reduced days compared to the untreated group. The highest adult mortality occurred in 10g of *D. tripetala* within 5 to 8 days of exposure. The highest mortality recorded in this study is proportional to those recorded in the study of Nwosu *et al.* (2018) with the use of *Piper nigrum* between days 1 to 4. In this present study, most adult mortality occurred within 0 to 12 days of exposure irrespective of treatment applied either salt or pepper powders. The occurrence of adult insects in 2g and 5g of salted chips and *A. melegueta* respectively, and all concentrations of *Z. officinale* till 21 days of exposure could mean that the active component of these treatment concentration were not sufficient to cause mortality or that increasing the concentrations may imply higher mortalities with these treatments. More so, the high repellency recorded in the higher concentration of *Z. officinale*, *A. melegueta* and *D. tripetala* with reduced days of exposure predicts that these treatment concentrations have potentials of deterring the activities of the insect under study as increased concentration tends to suffocate them. Lower repellency was equally observed in lower concentrations of treatment. In the salted chips, the high repellency observed with the higher concentrations of salted chips predicts that the presence of humidity as a result of water absorption in salted chips. However, this absorbed water can be conquered in real life situation by solarizing chips. The LC_{50} was observably lowest in salted chips and for LC_{95} lowest in *D. tripetala* compared to other treatment concentrations. More so, in the order of decreasing contact mortality, salt predominated followed by pepper fruit, alligator pepper and then ginger.

REFERENCES

Abass, A.B., Ndunguru G., Mamiro P., Alenkhe B., Mlingi N. and Bekunda M. 2014. Postharvest food losses in a maize-based farming system of semi-arid savannah area of Tanzania. *Journal of stored Product Research* **57**: 49-57.

Adedire, C.O. and Akinneye J.O. 2004. Biological activity of tree marigold, *Tithonia diversifolia,* on cowpea seed bruchid, *Callosobruchus maculatus* (Coleoptera: Bruchidae). *Annals of Applied Biology*, **144**: 185–189.

Ajayi, O.E. and Adedire, C.O. 2003. Insecticidal activity of an under-utilized tropical plant seed oil, *Huracrepitans* L. on cowpea seed beetle, *Callosobruchus maculatus*. (F) (Coleoptera: Bruchidae) *Nigerian Journal of Entomology,* **20**: 74– 81.

Akinkurolere, R.O., Adedire, C.O. and Odeyemi, O.O. 2006. Laboratory evaluation of the toxic properties of forest anchomanes, *Anchomanes difformis,* against pulse beetle *Callosobruchus maculates* (Coleoptera: Bruchidae). *Insect Science,* **13**: 25– 29.

Arannilewa, S.T. 2002. Assessment of the Insecticidal properties of four plant extracts as protectants against the cowpea bruchid *Callosobruchus maculates* (F) (Coleoptera: Bruchidae). *Annals Agricultural Science*, **3**(1): 49– 55.

Arannilewa, S.T., Odeyemi, O.O. and Adedire, C.O. 2002. Effects of medicinal plant extract and powder on the maize weevil, *Sitophilus zeamais* Mots (Coleoptera: Curculionidae). *Annals Agricultural Science,* **3**:1–10.

Atta, B., Rizwan, M., Sabir, A.M., Gogi, M.D. and Ali, K. 2019. Damage potential of *Tribolium castaneum* (Herbst) (Coleoptera: Tenebrionidae) on wheat grains stored in hermetic and non-hermetic storage bags. *International Journal of Tropical Insect Science*, **40**(1-2): 1-11.

Atta, B., Rizwan, M., Sabir, AM., Yaqub, M. and Akhter, M. 2018. Field evaluation of rodenticides treated baits for the effective control of field-rats in rice crop. *World Journal of Agricultural Sciences*, **14**(5): 137-143.

Baba-Teirto, N. 1994. The ability of powders and slurries from ten plant species to protect stored grain from attack by *Prostephanus truncates* Horn (Coleoptera: Curculionidae). *Journal of Stored Product Research*, **30**: 297-301.

Baoua, I.B., Amadou, L., Abdourahmane, M., Bakoye, O., Baributsa, D. and Murdock, L.L. 2015. Grain storage and insect pests of stored grain in rural Niger. *Journal of Stored Product Research*, **64**: 8-12.

Choudhary, A.K. and Kumari, P. 2010. Management of mytotoxin contamination in pre harvest and postharvest crops: present status and future prospects. *Journal of Phytology*, **2**(7): 37-52.

Danjuma, S., Ayertey, J.N. and Cudjoe, A.R. (2008). Weight losses caused by *Prostephanus truncatus* (Horn) (Coleoptera: Bostrichidae) and *Araecerus fasciculatus* Degeer (Coleoptera: Anthribidae) to dried yam chips. *J. Med. Pharm. Sci.,* **4**: 79-85.

Derbalah, A.S. and Ahmed, S.I. 2011. Oil and powder of spearmint as an alternative to *Sitophilus oryzae* chemical control of wheat grains *Journal of Plant Protection Research,* **51**:145-150.

Edu, N.E., Adah, P.O. and Ubi, G.M. 2019. Potential use of Ginger (Zingiber officinale) as biopesticide against bean weevil (*Callosobruchus maculatus*) and maize weevil (*Sitophilus zeamais*). *Journal of Environmental*

Science, Computer Science and Engineering and Technology, **8**(3): 259-264.

Franccedil, T., Michel, J.D.P., Lambert, J.M., Ndifor, F., Vyry, W.M.A., Henri, A.Z.P., Chantal, M. 2009. Comparative essential oil composition and insecticidal effect of different tissues of *Piper capense* L., *Piper guineense* SchumEt. Horn., *Piper nigrum* L. and *Piper umbellatum* L. grown in Cameroon. *African Journal of Biotechnology*, **8**(3): 424-431.

Hossannah, A., Lwandam W., Olesitayo, N., Moreka, L., Nokoe, S. and Chapya, A. 1990. Weevil repellency constituents of *Ocimum suave* leaves and *Eugenia caryophyllata* cloves used as grain protectant in part of Eastern Africa. Discovery and Innovations, **2**: 91-95.

Huang, Y., Chen, S.X. and Ho, S.H. 2000. Bioactivities of methyl ally disulfide and diallyltrisulfide from essential oil of garlic to two species of stored—Product pests, *Sitophilus zeamais* and *Tribolium castaneum*. *Journal of Economic Entomology*, **93:** 537–543.

Ilondu, E.M. and Enwemiwe, V.N. 2019. Field survey of diseases, pest and efficacy of three plant powders against flea beetles of okra (*Abelmoschus esculentus* (L.) Moench. *International Journal of Biosciences*, **15**(1): 553-562.

Isah, M.D., Ayertey, J.N. and Boateng, B.A. 2009. Suitability of dried chips of plantain, Cocoyam, yam and cassava for the development of the larger grain borer *Prostephanus truncatus* (Horn) (Coleoptera: Bostrichidae). *Int. J. Pure Applied Sci*, **3:** 12-20.

Landani, H.D., Davis, F. and Swank, G.R. 1995. A laboratory method of evaluating the repellency of treated paper to stored product insect. Tech Assoc. Pulp-Paper Ind, **38:** 336-340.

Madreseh-Ghahfarokhi, S., Dehghani-Samani, A. and Pirali, Y. 2019. *Zingiber officinale* and *Eucalyptus globulus*, potent lethal/repellent agent against *Rhipicephalus bursa*, Probable carrier of zoonosis. *Journal of Arthropod Borne Disease*, **13**(2): 214-223.

Madreseh-Ghahfarokhi, S., Pirali, Y., Dehghani-Samani, A. 2018. The insecticidal and repellency of ginger (*Zingibero fficinale*) and eucalyptus (*Eucalyptus globulus*) essential oils against Culextheileri Theobald, 1903 (Diptera: Culicidae). *Annals of Para*sitology, **64**(4): 351-360.

Manandhar, A., Milindi, P. and Shah, A. 2018. An overview of the postharvest grain storage practices of smallholder farmers in developing countries, Agriculture, **8**(4): 57.

Nwosu, L.C., Osi, O.A., Adanyi, D.D., Okereke, V.C., Azoro, V.A., Ukpai, K.U., Nzewuihe, G.U., Lawal, I.A., Uwalaka, O.A., Ugagu, G.M., Eluwa, A.M. and Arotolu, T.E. 2018. Insecticidal activities of five medicinal plant materials against *Callosobruchus maculates* Fabricius (Coleoptera: Chrysomelidae) infesting cowpea seeds in storage. *The International Journal of Biotechnology*, **7**(1): 64-69.

Ogori, A.F., Omoniyi, S.A. and Samuel, E. 2016. Effects of inclusion of local pepper powder or salt to cowpea seeds during storage. *International Journal of Pharma Sciences and Research*, **7**(1): 25 -28.

Ojianwuna, C.C. and Umoru, P.A. 2010. Effects of *Cymbopogon citratus* (lemon grass) and *Ocimum suave* (wild basil) applied as mixed and individual powders on the egg laid and emergence of adult *Callosobruchus maculatus* (cowpea bruchids). *African Journal of Agricultural Research*, **5**(20): 2837-2840.

Ojianwuna, C.C. and Umoru, P.A. 2011. Acute toxicity of Lemon grass (*Cymbopogon citratus*) and wild basil (*Ocimum suave*) applied as mixed and individual powders against the cowpea bruchids, *Callosobruchus maculatus*, in cowpea. *African Journal of Agricultural Research*, **6**(29): 6311-6319.

Ojianwuna, C.C., Edafemakor, A.G. and Iloh, A.C. 2011. Toxicity of *Ocimum suave* (wild basil) leaf oil on adult housefly (*Musca domestica*). *International Research Journal of Agricultural Science and Soil Science*, **1**(10): 417-420.

Ojianwuna, C.C. and Enwemiwe, V.N. 2020a. Efficiency of ginger, pepper fruit and alligator pepper in the control of cowpea bruchid (*Callosobruchus maculatus*) (Fabricius, 1775). *FUW Trends in Science and Technology Journal*, **5**(2): 445-450.

Ojianwuna, C.C. and Enwemiwe, V.N. 2020b. Monitoring the toxicity of dry wood termites using three plant powders in laboratory culture. *Journal of Biopesticides,* **13**(2): 150-158.

Onekutu, A., Nwosu, L. and Nnolim, N. 2015. Effect of seed powder of three pepper species on the bionomics of cowpea bruchid, *Callosobruchus maculates* Fabricius. *International Journal of Scientific and Research Publications*, **5**(5): 1-5.

Prakash, B.G., Raghavendra K.V., Gowthami R. and Shashank, R. 2016. Indigenous practices for eco-friendly storage of food grains and seeds. *Advances in Plants and Agriculture Research*, **3**(4): 101–107. DOI: 10.15406/apar.2016.03.00101.

Rajamma, D., Padmaja G. and Lakshmi, K.R. (1994). Residual Cyanide in Processed Cassava Chips Related to Storage Insects. Central Tuber Crops Research Institute (CTCRI), Trivandrum, India, **PP**: 451-452.

Rizvi, S.A.H., Hussain, S., Rehman, S.U., Jaffar, S. and Rehman, M.F.U. 2016. Efficacy of ecofriendly botanical extracts of Ginger (*Zingiber officinale*), Garlic (*Allium sativum*) and Tobacco (*Nicotiana tabacum* L.) for the control of cabbage loopers (*Trichoplusi abinotalis*) under agro ecological conditions of Reshawar, Pakistan. *Journal of Entomology and Zoology Stud*, **4**(1): 88-90.

Sanon, A., Garba, M., Auger, J. and Huignard J. 2008. Analysis of the insecticidal activity of methylisothiocyanate on *Callosobruchus maculates* (F.) (Coleoptera: Bruchidae) and its parasitoid *Dinarmus basalis* (Rondani) (Hymenoptera: Pteromalidae*). Environmental Entomology*, **38**: 129–138.

Sattar, A., Naeem, M. and Ehsan-ul-Haq 2014. Efficacy of Plant Extracts Against Subterranean Termites i.e., *Microter mesobesi* and *Odontoter meslokanandi* (Blattodea:Termitidae). *Journal of Biodivers Biopros* Dev **1:**122.

Suganthy, M.S. 2013. Field evaluation of biopesticides against tobacco caterpillar, *Spodoptera licura* Fab. Infesting *Gloriosa superba* (Linn.), *Journal of Biopesticides*, **6**(2): 90-95.

Sumathi, E. and Ramasubramanian, G.V. 2013. Evaluation of biopesticides against rice black bug, *Journal of Biopesticides.* **6**(2): 117-119.

Talley DM, Talley TS. (2008). Encyclopedia of Ecology. *Elsevier*. USA. **PP**3120

Tsado, E.K., Gana, A.S., Yusuf, S.T., Saniya, E. and Musa, A. 2015. Effect of storage period of paddy rice on grain fissures and breakages of milled rice. *Journal of Environmental Science, Toxicology and Food Technology*. **9**(2): 8-17.

Ukeh, D.A., Birkett, M.A., Bruce, T.J., Allan, E.J., Pickett, J.A. and Mordue, A.J. 2010. Behavioural responses of the maize weevil, *Sitophilus zeamais* to host and non-host plant volatiles. *Pest Management Science,* **66**(1): 44-50.

Ukeh, D.A., Birkett, MA., Pickett, J.A., Bowman, A.S. and Mordue, A.J. 2009. Repellent activity of alligator pepper, *Aframomum melegueta*, and ginger, *Zingiber officinale*, against maize weevil, *Sitophilus zeamais*. *Phytochemistry*, **70**: 751–758.

Zadoks, J.and Waibel, H. 1999. From pesticides to genetically modified plants: History, Economics and Politics. Netherlands. *Journal of Agricultural Sciences.* **48**: 125-149.

Zar, J.H. 1999. Biostatistical Analysis. 4th Edn. Prentice-Hall, New Jersy, USA., **P** 469.

Ojianwuna, C.C. and Enwemiwe, V.N. *

Department of Animal and Environmental Biology, Faculty of Science, Delta State University, Abraka, Delta State, Nigeria.

*Correspondence author

E-mail: enwemiwevictor@gmail.com