

PHYSICAL AND BIOPHYSICAL DETERIORATION OF STORED PLANTAIN CHIPS (*MUSA SAPIENTUM* L.) DUE TO INFESTATION OF *TRIBOLIUM CASTANEUM* HERBST (COLEOPTERA: TENEBRIONIDAE)

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Abstract: Plantain chips (*Musa sapientum* L.) were infested with *Tribolium castaneum* Herbst in the laboratory (64±5% relative humidity and 30±2°C temperature) to evaluate physical and biochemical losses of the chips due to pest damage. Varying levels (4, 8 and 12) of *T. castaneum* adults were introduced into 20 g plantain chips. An uninfested 20 g of chips served as the control. At 2 and 4 months after infestation (MAI), data on weight loss of chips and the cumulative number of *T. castaneum* adult, were taken. The samples were then analyzed for proximate and mineral element composition. Infestation level affected weight loss and final insect count. When chips were stored for 2 months, 7.3 cumulative adults obtained in a sample infested with 12 adults was significantly higher than the 4.0 adults obtained in a sample infested with 4 adults. When stored for 4 months, 5.3% weight loss due to 12 initial adults was significantly higher than weight loss recorded in other lower levels of infestation. The proximate analysis revealed that dry matter, ash and crude fibre were significantly reduced with storage period and initial insect level. Fat, crude protein and moisture increased with infestation level and storage period. In uninfested plantain chips, calcium level was not affected with storage period, while phosphorous and iron were significantly reduced with storage period. Both, the level of infestation and storage period, caused significant reduction of the studied mineral elements. There was an interactive effect of the storage period and infestation level for all studied parameters in the biochemical analysis.

Key words: *Musa sapientum*, plantain chips, *Tribolium castaneum*, storage period, infestation level, qualitative losses, quantitative losses

INTRODUCTION

Plantain and other cooking bananas are staple food grown throughout the tropics and they constitute a major source of carbohydrate for millions of people in Africa, the Caribbean, Latin America, Asia and the Pacific (INIBAP 2001). Due to the perishable nature of the fruits (Adebesin *et al.* 2009), the rate of the post harvest losses of plantain varies from one country to another according to the organization of market chains and modes of consumption. In many producing countries, there are no data on postharvest losses. The assessment of these postharvest losses is rather complex because green mature plantain are consumed as well as overripe fruits. In Cameroon, the most evident postharvest losses are registered at the producer level in farm sites during the raining season (N'da Adopo 1993). In some parts of Uganda, dried forms of the unripe fruits are stored as famine food (INI-BAP 2001). In Nigeria, local farmers peel unripe plantain, slice and sun dry it. This is one of the major methods of reducing postharvest losses of the produce. Flour from the chips is widely used to make cookies and cakes (INI-BAP 2001). However, handling of chips at the farmer and consumer levels does not guarantee an insectproof fate.

Chips are often dried at road sides, displayed in markets in open containers to attract potential buyers and stored in sacks that are susceptible to insect infestation. Plantain and banana flours are currently on sale in some parts of Nigeria. These sales are a strong indication that farmers and plantain processors are beginning to adopt processing options as a means of market diversification and consequently curtailing glut (Adeniji *et al.* 2007)

Tribolium castaneum Herbst, thought to have originated in India, is now found throughout the tropical, subtropical and warm temperate areas of the world. The larvae and adults feed on a wide range of durable commodities and are important secondary pests of cereals, having a preference for the embryo. Other commodities that can be infested by *T. castaneum* include groundnut, spices, coffee, cocoa, dried fruit and occasionally, peas and beans (Haines 1991). *T. castaneum* is a colonizing species. In shelled groundnuts, for example, it is often the first stored product pest to appear after harvest and shell-ing. Successful dispersal can be achieved by flying adults and does not depend on the movement of infested food by people. Grains have a covering coat, and although, *T. castaneum* is a secondary pest (Haines 1991; Adedire

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2001; Lale 2002), lack of a covering coat in plantain chips predisposes chips to insect infestation.

Most studies on postharvest infestation of crop produce by insects in developing countries focused on quantitative losses. There was little emphasis directed towards the impacts of insect infestation on nutritional depletion of stored produce. This present study was therefore designed with the aim of investigating quantitative and qualitative deterioration of stored chips due to infestation of *T. castaneum*.

MATERIALS AND METHODS

Procurement of chips and chips preparation

Bunches of matured but unripe plantain fruits were obtained from Araada Market Ogbomoso, Nigeria. The plantain was peeled and sliced into chips of about 4 mm thickness. It was later sun dried for some weeks till a moisture content of 8.5% was reached. Determination of moisture content was done by the AOAC (1990) method.

Insect culture

T. castaneum adults were obtained from the Entomology Unit of the Agronomy Laboratory, Ladoké Akintola, University of Technology (LAUTECH), Ogbomoso, Nigeria, and were raised on wheat flour as described by Babarinde and Ogunkeyede (2008). Newly emerged adults (2- to 7-day-old) were used for the experiment. Both insect culture and entomological procedures were carried out under an ambient laboratory condition of $64\pm 5\%$ relative humidity and $30\pm 2^\circ\text{C}$ temperature.

Entomological procedures

Twenty grams of plantain chips were weighed with a sensitive balance scale (Gibertini TM 1600®, Italy) into twenty-four 150 ml glass jars. The glass jars were divided into two batches of twelve jars each. Varying numbers (4, 8 and 12) of *T. castaneum* adults were introduced into the glass jars. A glass jar without any insects served as the control. The jars were covered with muslin cloth to allow aeration and prevent other pests from entering. The experiment was set up in triplicates. The first batch of twelve jars was left for two months after which, the chips were removed and reweighed. Weight loss was determined as the difference between the weight of uninfested sample and that of infested sample as a proportion of the weight of uninfested sample expressed in percentage. Thus,

$$WL = [(W_c - W_t) / W_c] \times 100$$

where:

WL – percentage weight loss

W_c – weight of uninfested sample

W_t – weight of infested sample

The number of live *T. castaneum* adults present was recorded. The powdery waste was not discarded but returned into the undamaged chips in the jars and taken to the laboratory for proximate and mineral element analyses. At four months after infestation (MAI), chips were also removed from the second batch jars and the proce-

dures followed were similar to those done for the first experiment of two-month storage.

Proximate and mineral elements analyses

The samples were analyzed chemically according to the official methods of analysis described by the Association of Official Analytical Chemists (AOAC 1990). Mineral element composition was analyzed by atomic absorption spectrophotometer (Bulk 210 model 200).

Experimental design and data analysis

The experiment was laid out in split plot design with initial insect level as main plot and storage period as subplot. Data on weight loss, final insect count, proximate and mineral element analyses were subjected to analysis of variance (ANOVA) and standard deviation was calculated to show variation between replicates. Significant means were later separated with Fisher's least significant difference (LSD) at 5% probability level.

RESULTS

Effect of initial number of *T. castaneum* on the cumulative number of adults

The cumulative number of insects was significantly affected by initial level of insects. When 4 insects were introduced, storing plantain chips for 2 months gave 4.0 cumulative adults, while 12 initial insects gave 7.3 cumulative adults. When plantain chips were stored for 4 months, the initial 4 insects gave 3.3 cumulative adults, which was significantly lower than 9.3 cumulative adults recorded in 12 initial adults. However, storage period did not significantly affect the cumulative number of adults. When plantain was stored for 2 months, the mean number of cumulative adults (5.2) was not significantly different from 5.6 which was the mean number of cumulative adult for 4-month storage of plantain chips (Fig. 1a). Immatures (larvae and pupae) were not found in the sample.

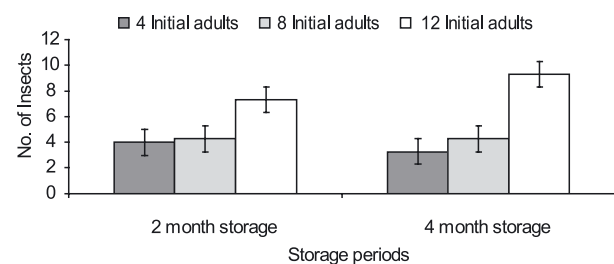


Fig. 1a. Mean cumulative number (\pm SD) of *T. castaneum* in stored plantain chips

Effect of initial number of *T. castaneum* on weight loss of plantain chips

When plantain chips were stored for 2 months, 0.3% weight loss due to 4 initial insects was not significantly different from the 1.9% weight loss due to 12 initial insects. However, when plantain chips were stored for 4 months, 5.3% weight loss due to 12 initial insects was significantly higher than weight loss recorded in other lower levels of initial insects. The mean percentage

weight loss (0.6%) recorded in 2-month storage of plantain chips was significantly lower than 2.9% recorded in the 4-month storage (Fig. 1b).

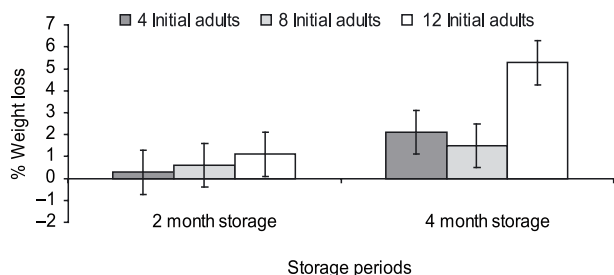


Fig. 1b. Mean percentage weight loss (\pm SD) of plantain chips due to *T. castaneum* infestation

Effect of *T. castaneum* infestation on proximate composition of stored plantain chips

Table 1 shows the effect of *T. castaneum* infestation on proximate composition of stored plantain chips. Both insect level and storage period had significant effect on all proximate parameters. Also, there was an interactive effect of insect level and storage period on the parameters. When no insect was introduced into the chips, storage period caused significant decrease in dry matter content. Ash content initially decreased from 3.1 (g/100 g) at 0 month to 2.9 (g/100 g) at 2 months and later appreciated to 3.1 (g/100 g) at 4 months of storage. Crude fibre and crude fat also decreased. However, crude protein and moisture content significantly increased during storage. When plantain chips were stored for 2 months, insect level caused significant decrease in dry matter, ash and crude fibre. However, fat, crude protein and moisture content significantly increased at 2 months of storage. The same

Table 1. Effect of *T. castaneum* infestation on proximate composition of plantain chips g/100 g (dry matter basis)

Insect Level	Storage period*	Dry matter	Ash	Crude fibre	Fat	Crude protein	Moisture content
0	0	91.2 \pm 0.01	3.1 \pm 0.02	1.3 \pm 0.02	1.2 \pm 0.033	4.3 \pm 0.05	8.9 \pm 0.01
	2	89.1 \pm 0.01	2.9 \pm 0.01	1.2 \pm 0.02	1.2 \pm 0.01	4.8 \pm 0.04	10.9 \pm 0.01
	4	88.8 \pm 0.03	3.1 \pm 0.01	1.2 \pm 0.02	1.1 \pm 0.01	5.0 \pm 0.04	11.2 \pm 0.03
4	0	91.2 \pm 0.01	3.1 \pm 0.02	1.3 \pm 0.02	1.2 \pm 0.03	4.3 \pm 0.04	8.8 \pm 0.01
	2	88.7 \pm 0.01	1.8 \pm 0.01	1.2 \pm 0.02	2.0 \pm 0.03	6.9 \pm 0.05	11.3 \pm 0.01
	4	88.2 \pm 0.02	1.5 \pm 0.44	1.0 \pm 0.01	1.9 \pm 0.02	7.3 \pm 0.04	11.8 \pm 0.02
8	0	91.2 \pm 0.01	3.1 \pm 0.02	1.3 \pm 0.02	1.2 \pm 0.03	4.3 \pm 0.05	8.8 \pm 0.01
	2	87.9 \pm 0.01	1.2 \pm 0.01	0.9 \pm 0.01	2.2 \pm 0.01	8.8 \pm 0.05	12.1 \pm 0.01
	4	87.3 \pm 0.02	1.3 \pm 0.01	0.9 \pm 0.01	2.2 \pm 0.01	9.4 \pm 0.06	12.7 \pm 0.02
12	0	91.2 \pm 0.01	3.1 \pm 0.02	1.1 \pm 0.02	1.2 \pm 0.03	4.3 \pm 0.05	8.8 \pm 0.01
	2	85.4 \pm 0.02	1.1 \pm 0.01	0.7 \pm 0.02	2.5 \pm 0.01	11.7 \pm 0.06	14.6 \pm 0.02
	4	84.9 \pm 0.03	1.1 \pm 0.01	0.5 \pm 0.01	2.5 \pm 0.02	12.2 \pm 0.06	15.1 \pm 0.03
a		0.02	0.12	0.02	0.02	0.05	0.02
b		0.01	0.11	0.02	0.02	0.04	0.01
c		0.03	0.21	0.03	0.03	0.09	0.03

\pm SD – stands for standard deviation of three replicates; *Storage period in months
a – LSD insect level; b – LSD storage period; c – LSD interaction

pattern observed in the 2 months of storage was observed in the 4 months of storage of plantain chips for the studied parameters.

Effect of *T. castaneum* on mineral element composition of stored plantain chips

Initial insect level and storage period had a significant effect on mineral contents of stored chips. Also, there was an interactive effect of initial insect level and storage period on the parameters. When stored for 2 months, calcium steadily decreased with insect level being 0.05% in the control, 0.03% with 4 initial insects, 0.02% with 8 initial insects and 0.01% with 12 initial insects. The same pat-

tern was observed in phosphorous and iron at 2 months of storage. It was noticed that for all parameters, storage period caused a decrease at 2 months. The parameters eventually rose at 4 months. For instance, phosphorous level first decreased from 0.45% at 0 month of storage to 0.36% at 2 months, which later increased to 0.46% at 4 months of storage when no insect was introduced. At the highest level of insects, the same pattern was observed in phosphorous, calcium and iron. Calcium content was not affected by storage period when chips were stored without insects (Table 2).

Table 2. Effect of *T. castaneum* on the mineral element composition of plantain chips

Insect level	Storage period	Calcium [%]	Phosphorus [%]	Iron [mg/kg]
0	0	0.05±0.00	0.45±0.02	81.23±0.02
	2	0.05±0.00	0.36±0.01	76.70±0.01
	4	0.05±0.00	0.46±0.02	80.27±1.05
4	0	0.05±0.00	0.45±0.02	81.23±0.02
	2	0.03±0.00	0.28±0.01	68.37±0.15
	4	0.04±0.00	0.30±0.03	70.53±0.75
8	0	0.05±0.00	0.45±0.02	81.24±0.02
	2	0.02±0.00	0.16±0.01	39.57±0.15
	4	0.03±0.00	0.19±0.01	43.90±0.30
12	0	0.05±0.00	0.45±0.02	81.24±0.02
	2	0.01±0.00	0.07±0.02	31.67±0.15
	4	0.02±0.00	0.12±0.01	33.87±0.35
a		0.00	0.02	0.40
b		0.00	0.01	0.35
c		0.00	0.03	0.70

Explanation – see table 1

DISCUSSION

Susceptibility of plantain chips to *T. castaneum* was studied on the basis of the reproductive biology of the insect species, weight loss of plantain chips due to insect infestation and impact of insects on proximate and mineral element composition of stored chips. The study reveals that *T. castaneum* is a postharvest pest of plantain chips which fed on chips but did not find the chips quite suitable for its reproductive biology. When plantain chips were infested with *T. castaneum*, the cumulative number of *T. castaneum* adult was low, and immature were not found. Apart from the poor suitability of chips for *T. castaneum* reproduction, the other possible reason for this observation could be cannibalism exhibited by *T. castaneum*. According to Haines (1991), cannibalism and predation play an important role in the nutrition of *T. castaneum*. The eggs and pupae are often cannibalized by the adults. The male shows a preference for pupae and the female for eggs. Synthesis of quinones by *T. castaneum* (Haines 1991) could also have affected its reproductive efficiency. Odeyemi *et al.* (2005) reported that when seven biscuit types were infested with *T. castaneum*, none of them allowed adult emergence.

Several works had been done on the pest status of *T. castaneum*. Lale and Yusuf (2000) reported *T. castaneum* in stored pearl millet (*Pennisetum glaucum*). Odeyemi *et al.* (2005) reported it as a pest of biscuits. Ashamo (2002) also investigated its performance in different flours. Turaki *et al.* (2007) studied its performance in different cereals. From this study, percentage weight loss of stored plantain chips due to the feeding of *T. castaneum* was not very high.

Odeyemi *et al.* (2005) reported that percentage weight loss in biscuit types infested with *T. castaneum* ranged from 0.01–2.24%.

The impact of *T. castaneum* on proximate composition of plantain chips was significant. Dry matter and ash content were significantly reduced with storage period and insect level. This implies that insect feeding affected mineral content. It was also observed that crude protein increased when the level of insects rose. This confirms Bamaïyi *et al.* (2007) who reported that the level of nitrogen in stored sorghum increased with storage time when sorghum was infested by *Sitophilus oryzae*. Such changes were associated with insect infestation in several stored grains (Sharma *et al.* 1979; Jood *et al.* 1996). The possible reason for an increase in protein was the addition of insect fragments which were included in the fractions analyzed. It had been shown that length of storage had the largest effect on protein quality (FAO 1984). Jood *et al.* (1993) reported significant increase in total nitrogen, non-protein, total protein and uric acid with increased levels of infestation in wheat and sorghum.

The decrease in carbohydrate values and the increase in moisture content observed in this study confirmed the discovery of Jood *et al.* (1996). The decrease in carbohydrate suggests that *T. castaneum* utilized the energy-giving component of the chips for its physiological activities. Since the results of proximate analysis revealed that ash content decreased with insect level and storage period, the reduction in mineral element composition confirmed the reduction in ash content. With qualitative deterioration of stored chips by *T. castaneum*, its many nutritional

uses (INIBAP 2001) are highly threatened. Also, this study indicates that stored plantain chips can be used as an alternative host by *T. castaneum* when its "more-preferred" food materials are unavailable. Therefore, proper storage techniques and effective control strategies against insects associated with stored products are necessary for the handling of plantain chips.

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POLISH SUMMARY

FIZYCZNE I BIOLOGICZNE NISZCZENIE CZIPSÓW BANANA AFRYKAŃSKIEGO PRZEZ *TRIBOLIUM CASTANEUM* (COLEOPTERA: TENEBRIOIDAE)

W laboratorium banany (*Musa sapientum* L.) zostały zakażone szkodnikiem *Tribolium castaneum* Herbst (w $\pm 50\%$ wilgotności względnej i $30 \pm 2^\circ\text{C}$) w celu wyceeny fizycznych i biochemicznych strat wywołanych przez tego szkodnika. Zróżnicowane ilości (4,8–12) dorosłych osobników *T. castaneum* wprowadzono do 20 g bananów. Grupę kontrolną stanowiło 20 g niezakażonych owoców. Po 2 i 4 miesiącach od zakażenia, zebrano dane dotyczące utraty wagi i łącznej liczby osobników dorosłych *T. castaneum*. Gdy banany były składowane w ciągu dwóch miesięcy, łączna liczba osobników dorosłych wynosząca 7,3 w próbie zakażonej 12 osobnikami, była istotnie wyższa niż 4,0 osobniki znalezione w próbie zakażonej 4 osobnikami. Po okresie składowania wynoszącym 4 miesiące, wystąpiła utrata wagi wynosząca 5,3%, wywołana przez 12 osobników dorosłych i była ona istotnie niższa niż utrata wagi przy innych, niższych poziomach ich wystąpienia. Wykonana analiza ujawniła, że sucha masa, popiół i surowy włóknik były istotnie zredukowane w zależności od okresu przechowywania oraz od początkowej liczby szkodnika. Tłuszcz, białko surowe i poziom wilgotności, wzrastały wraz z poziomem zakażenia i okresem przechowywania. W niezaatakowanych bananach poziom wapnia był niezmienny, a poziom żelaza i fosforu był istotnie zredukowany w miarę przechowywania. Zarówno poziom zakażenia, jak i czas przechowywania spowodowały istotną redukcję zawartości badanych składników mineralnych. W przypadku badanych parametrów w analizie biochemicznej, wystąpił efekt interakcji pomiędzy czasem przechowywania i poziomem porażenia przez szkodnika.