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Response of chips and flour from four yam varieties to *Tribolium castaneum* (Herbst) (Coleoptera: Tenebrionidae) infestation in storage

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Chips and flour from four different yam varieties (Ame, Adaka, Nwopoko and Obiaturugo) obtained from the National Root Crops Research Institute (NRCRI), Umudike, Abia State, Nigeria were evaluated for responses to *Tribolium castaneum* (rust-red flour beetle) infestation in the laboratory under prevailing conditions (25-30°C and 70-90 RH) for a period of 90 days. 10 g of either chips or flour of each of the yam varieties were infested with 8 pairs of adult *T. castaneum* in 200 ml air-tight plastic containers. The experiment was set up in a completely randomized design (CRD) and experiments were replicated three times. The result showed that both forms of yam varieties were susceptible to *T. castaneum* but to varying degrees. The variation of susceptibility observed across the treatments showed that Nwopoko chips were the most susceptible and Nwopoko flour was the least susceptible. Development of *T. castaneum* was prolonged on flour than on the chips. Percentage weight loss was highest (3.33) in Adaka flour and weight gain was highest (3.67) in Nwopoko chips. The result also showed variations in the physicochemical and functional properties of the different yam varieties which played a role in pest performance and preference. *T. castaneum* has proved to be a cosmopolitan species that is able to colonize a wide range of substrates including different forms and types of yam cultivated in the Niger delta region of Nigeria. The outcome of this study necessitates the introduction of precautionary measures against this pest in order to prevent it from attaining pest status and causing economic damage to these yam products in storage.

Key words: *Tribolium castaneum*, yam, chips, flour, susceptibility index.

INTRODUCTION

In economic terms, yams (*Dioscorea* spp.) are the world's fourth most important tuber crop (Loko et al., 2013). Yams are perennial herbaceous vines cultivated for the consumption of their starchy tubers cultivated in most tropical countries where 95% of the world's output is produced (FAO, 2010; Babajide et al., 2010). It is a highly popular food crop especially in the yam zones of West Africa, comprising Cameroon, Nigeria, Benin, Togo, Ghana and Cote d'Ivoire (FAO, 2003; Izekor and Olumese, 2010). As a food crop, the place of yam in the diet of the people in Nigeria cannot be overemphasized. It contributes more than 200 dietary calories per capita daily for more than 150 million people in West Africa while serving as an important source of income to the people (Babaleye, 2003). Yam flour, dried cassava chips and yam chips constitute important sources of carbohydrates in the diet of the citizens of West Africa (Obadofin et al., 2013).

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Yam is seasonal and the fresh tubers are highly perishable; postharvest losses can range from 30% to as high as 85% of the total production (Baco et al., 2004). Losses occur at every stage of the market chain ranging from storage to processing and marketing (Obadofin, 2013). Food commodities are usually liable to depredation by pest organisms such as micro-organisms, mites, insects, rodents and birds (Odeyemi, 2001). Insect infestation causes qualitative and quantitative losses of food commodities as they produce excrement and frass during their grain boring and oviposition activities (Rajendran, 2005).

In a developing country like Nigeria where a majority of the population is still dependent on forest and agriculture, storage of these products is a prime concern. Losses of yam in storage constitute a major challenge in storage. In Nigeria, yam is a major food and the tuber needs to be stored for consumption and as seed for the following year's crop. However, it is a highly perishable commodity and is easily contaminated by fungi and bacteria (Ikotun, 1983, 1989) or subject to sprouting due to increased metabolic activity (Ugochukwu et al., 1977). Insects often infest the chips during the process of drying and also in storage (Okigbo and Nwakammah, 2005). In Africa, about 1 million metric tons are lost in storage due to attack by insects and nematodes, which facilitate invasion of rotting organisms (Emehute et al., 1998). Infestation of stored products by storage pests poses nuisance to consumers as it limits the utilization and the economic/market value of products. In order to overcome this high perishability and irregularity of its availability throughout the year, processing yam into chips and flour (Akissoe et al., 2001 Babajide et al., 2008) or by peeling, pre-cooking and sun-drying (Vernier et al., 2005) is an alternative to the consumption of fresh tubers. Ekundayo (1986) reported that the conversion of yam tubers to flour is recommended as a suitable and convenient method of storing the crop to prevent postharvest losses encountered during storage. Vernier et al. (2005) are however of the view that yam chips and flour are often severely attacked by insects and reducing both the qualitative and quantitative values in a few months. This scenario makes availability of information in respect of infestation of stored yam chips and flour extremely necessary. This study assesses the postharvest losses of yam chips and flour attributed to *Tribolium castaneum* in storage so as to generate baseline information on this pest as it affects the quantity and nutritional quality of the products so that an effective means of management can be devised.

MATERIALS AND METHODS

Insect rearing

Adults of *T. castaneum* were obtained from infested wheat flour purchased from a local market in Choba, Rivers State, Nigeria. Wheat flour was sterilized using heat sterilization in a laboratory oven (GNP-9082) at 60°C for 90 min. The adults were subsequently maintained on the sterilized wheat flour in a 1-L Kilner jar and kept in a laboratory under prevailing laboratory conditions (25 to 30°C and 70 to 90% R.H.). On the seventh day, the adults were sieved out and eggs laid were allowed to develop to F_1 progeny in order to obtain adult *T. castaneum* of uniform age (Zakka et al., 2010).

Experimental materials

Dry chips of four varieties of yam namely: Adaka, Ame, Nwopoko and Obiaturugo were obtained from National Root Crop Research Institute (NRCRI), Umudike; half of each variety was ground into flour using an electric blender (Philips HR-2815 model); while the other half was left in chip form for the experiment.

Sexing of adult *Tribolium castaneum*

Adults of *T. castaneum* were sexed using their morphological characteristics; the males have a small patch of short bristles (sex patches) on the inside of the first pair of legs (Beeman et al., 2012) or hairy punctures on the ventral surface of the anterior femur which is absent in the female species (Dobie et al., 1984).

Infestation procedure

Ten grammes of each of the two forms of the different yam varieties (Adaka, Ame, Nwopoko and Obiaturugo) were weighed using a digital balance and kept in 200 ml plastic jars. Eight pairs of the newly emerged adult *T. castaneum* were introduced into each of the jars and left undisturbed on a work bench. The experiment was carried out in a completely randomized design (CRD) in which treatments were replicated three times. At the end of the experiment, the content of each jar was poured onto a transparent plastic tray and the numbers of teneral adults were counted taking note of living and dead insects. The immatures (larvae and pupae) were sieved out and counted. Weight of the different yam varieties and forms was taken in batches at termination of the experiment using an electronic sensitive balance J2003 model and the difference in weight was recorded and percentage weight loss was calculated by taking the difference between the initial and final weights and dividing it by the initial weight. The result was expressed in percentage as

$$\text{Percentage weight loss (PWL)} = \frac{C - T}{T} \times 100$$

Where, C, Initial weight (g); T = final weight (g) (*Jackai* and Asante, 2003).

The susceptibility indices were calculated according to the method of Dobie (1974) in order to determine the most susceptible and resistant varieties. The susceptibility index is given as

$$SI = \frac{Log Y}{T} \times 100$$

Where, SI, Susceptibility index; Log Y, log number of F_1 emerged adults; T, mean developmental period (days), estimated as the time from the day of infestation, to 50% of adult emergence.

RESULTS AND DISCUSSION

Table 1 shows that although more larvae developed in

Table 1. Mean number of *Tribolium castaneum* progeny that developed in chips and flour of four yam varieties.

Substrate	No. of larvae	No. of pupae	No. of immatures (larvae and pupae)	No. of adults	Total progeny
Adaka chips	0.00^{b}	1.33	1.33	2.33	3.67
Adaka flour	0.67^{ab}	1.00	1.67	1.67	3.33
Ame chips	0.67^{ab}	1.00	1.67	1.67	3.33
Ame flour	0.33^{ab}	1.00	1.33	3.00	4.33
Nwopoko chips	0.00^{b}	0.33	0.33	2.33	2.67
Nwopoko flour	1.00^{ab}	0.67	1.67	1.33	3.00
Obiaturugo chips	1.67^{a}	0.33	2.00	1.67	3.67
Obiaturugo flour	1.00^{ab}	0.33	1.33	3.67	5.00
		NS	NS	NS	NS

*Means with the same letters within columns are not significantly different at 5% level of probability.

Table 2. Mean weight loss in yam chips and flour, developmental period and mortality of *T. castaneum* bred on four yam varieties.

Substrates	Percentage weight		Developmental period (Days)	% Mortality	Susceptibility index
	Loss	Gain			
Adaka chips	-	1.67^{bc}	17.50	4.33	3.15
Adaka flour	3.33^{a}	-	16.17	4.67	2.05
Ame chips	-	2.00^{bc}	16.67	4.67	1.90
Ame flour	1.67^{a}	-	18.83	3.67	2.53
Nwopoko chips	-	3.67^{c}	16.17	5.33	3.35
Nwopoko flour	1.67^{a}	-	17.33	5.00	0.72
Obiaturugo chips	-	1.00^{b}	18.83	3.67	1.18
Obiaturugo flour	2.33^{a}	-	18.83	3.33	3.00
			NS	NS	

*Means with the same letters within columns are not significantly different at 5% level of probability.

Obiaturugo chips, there was no significant difference ($P>0.05$) in the number of *T. castaneum* larvae that emerged in the overall except for the Adaka and Nwopoko chips where there was no record of larvae at the end of the experiment. It also shows that number of pupae that developed was not significant in both forms of substrates; however, Nwopoko chips and Obiaturugo flour recorded the least number of pupae. Similar trends were obtained for the total immature stages of *T. castaneum*. Higher numbers of adults developed in Obiaturugo flour followed by Ame flour substrates and the least in Nwopoko flour though in the overall there was no significant difference among the treatments; a similar trend was observed in the mean number of total progeny (Table 1).

Table 2 shows that mean percentage weight loss was highest in Adaka flour, though, it was not significantly different ($P\geq0.05$) from that in flour of the other yam varieties. While yam flour in each variety lost weight at the end of the experiment their corresponding chips gained weight with Nwopoko chips having the highest weight gain followed by Ame chips. There was no significant difference in *T. castaneum* developmental period in both forms of substrates though it took longer days on Obiaturugo flour and chips and the shortest developmental period was recorded in Ame chips. There was no significant difference in percentage mortality across the various substrates. However, highest mortality was recorded in Nwopoko chips and the least in Obiaturugo flour. Table 2 shows that both chips and flour were susceptible to infestation but to varying degrees, nonetheless, Nwopoko chips were the most susceptible to *T. castaneum* infestation and its flour was the least susceptible.

The physicochemical and functional properties of the yam varieties indicate higher oil absorption capacity in Adaka and the least in Nwopoko. Percentage fat was relatively higher in Ame variety and least in Adaka, though it recorded higher percentage dry matter, swelling index and water absorption capacity. Percent Na and P were highest in Ame and Adaka varieties, respectively; Adaka also recorded the least % Na but highest in P and N (Table 3).

Although under standard storage conditions yam chips

Table 3. Physicochemical and functional properties of yam products from four varieties.

Yam variety	OAC	%fat	% CF	% Ash	WAC	SI	GT°C	BD	% MC	% DM	% Na	% K	% P	% N
Ame A	1.1	0.56	0.16	1.0	1.4	1.13	65	0.85	13.00	87.6	0.58	0.23	0.88	0.28
B	1.2	0.55	0.16	1.1	1.2	1.18	68	0.92	12.75	87.5				
Adaka A	1.9	0.36	0.24	0.43	1.6	1.20	64	0.85	12.40	87.8	0.23	0.33	1.55	0.77
B	1.6	0.37	0.20	0.4	1.7	1.19	65	0.86	12.50	88.0				
Nwopoko A	0.9	0.38	0.25	0.9	1.4	1.14	63	0.83	12.59	87.4	0.40	0.28	0.83	0.43
B	1.0	0.39	0.26	0.8	1.2	1.22	67	0.81	18.05	82.0				
Obiaturugu A	1.2	0.42	0.28	1.1	1.6	1.10	68	0.88	12.18	87.0	0.40	0.18	1.10	0.63
B	1.3	0.42	0.25	1.0	1.5	1.17	64	0.88	11.96	87.3				

OAC, Oil absorption capacity; WAC, water absorption capacity; DM, dry matter; BD, bulk density; SI, swelling index; MC, moisture content, GT, gelation temperature.

can be kept for up to two years without pest problem (Vernier, 2005), in this study both products (chips and flour) of the four yam varieties were susceptible to *T. castaneum* infestation. More *T. castaneum* progeny developed on average in flour than in chips. This agrees with the report of Loko et al. (2013) on farmers' knowledge of the insect pest damaging yam chip stocks and diversity assessment that beetles act by penetrating the chips and drastically reducing their parts into powdery waste. This confirms the biology of *T. castaneum,* a secondary pest that has preference for fine flour for development as compared to chips (Odeyemi, 2001; Lale 2002). Yam chips and flour under rural conditions or during trading are often severely attacked by insects (Vernier et al., 2005). It was also observed in Nwopoko that the number of immature stages (larvae and pupae) that developed in the substrates was more in the flour.

With the exception of Adaka yam variety, developmental period of *T. castaneum* in flour was longer in chips. This is a deviation from the normal biology of *T. castaneum*, which is known to be more fecund and to develop faster on flour than on solid substrates or broken crop products (Lale and Yusuf, 2001; Lale and Modu, 2003; Haines, 1991); *T. castaneum*, being a secondary pest ought to perform poorly or slowly on chips in storage. This could be attributed to the relatively high amounts of antibiotic compounds being made more available in the flour which might have negatively affected the biology of *T. castaneum*. The presence of phenolic compounds and saponins (secondary metabolites) in yams as an antibiotic against developing stages of *T. castaneum* was earlier reported by Degras (1993) and IITA (1995). Although all the chips were infested by *T. castaneum*, this form of yam substrate, increased in weight. The increase in weight might be attributed to the higher functional properties such as water absorption capacity (WAC) and swelling index (SI) which are known for having high propensity to increase the hygroscopic property of the substrates, causing it to draw more moisture from its surrounding environment and probably causing desiccation in the insects hence increasing the mortality rate of the insect.

The lower values of susceptibility index recorded across the various forms and types of all the yam varieties used might be attributed to the fact although the improved varieties may have been bred for other traits, they also showed relative resistance to *T. castaneum* infestation. Similar results were obtained by Ashamo (2002) who worked on improved maize varieties and attributed it to inherent traits such as resistance. In another study, Siwale et al. (2009) reported that the lower susceptibility indices they obtained were partly due to low moisture content of the substrates. Moisture content of the yam products was not determined in this study, the overall result suggests that this physical attribute may not have significantly influenced the outcome of the investigation.

The findings of this study have proved that *T. castaneum* is a cosmopolitan species and can colonize a wide range of substrates including different forms and types of yam cultivated in the Niger delta region of Nigeria. This insect is capable of posing a serious threat to yam in storage and consequently to food security, this is particularly significant because yam is one of the major staple foods in Nigeria. It is evident that steps must be taken to protect yams and storage houses from infestation by *T. castaneum* in yam growing areas of the tropics and subtropics.

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