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The effect of salting sweetpotato chips prior to drying on infestation by *Araecerus fasciculatus*

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The efficacy of salting sliced sweetpotato chips prior to drying in reducing and (or) controlling damage levels of dried chips in storage by *Araecerus fasciculatus* Degeer (Coleoptera: Anthribidae) was investigated. Eight salt dosage rates, 0 (controls), 0.25, 0.5, 1, 2, 3, 4, and 5 g 100 g^{-1} freshly sliced chips were evaluated. Artificial infestation of dried chips with adult *A. fasciculatus* was conducted. Gravid females were allowed to oviposit for one week and the infested chips incubated until the F_1 generation adults had all emerged under prevailing environmental temperatures of 26.29 ± 1.19°C and relative humidity 68.96 ± 7.39%. The number, weight, and generation time of *A. fasciculatus* that emerged varied significantly depending on the salt dosage rates. Best results were obtained with increasing salt dosage levels. Salt application rate at 2–3% is recommended for on-farm validation.

Keywords: Dried sweetpotato chips; *Araecerus fasciculatus*; Control by salting; Storage; Quasi-staple

Sweetpotato is the third most important source of carbohydrates after banana and cassava in Uganda. With the declining production trend of banana and cassava due to biotic and abiotic factors, sweetpotato is gaining in prominence as a source of food, income generation, and as a component of on-farm food security reserve (Hall, 1995).

Sweetpotato is cultivated in the unimodal and bimodal rainfall areas of Uganda (Hall, 1995). In areas with a bimodal rainfall pattern, sweetpotato is cultivated twice, but in areas of unimodal pattern, cultivation is limited to only one season in a year.

In eastern and northern Uganda where sweetpotato cultivation is limited to one season a year, dried root chips are important components of the diet of the communities, because storage of the fresh roots is not possible over the timescale required.

The most limiting biotic factor of sweetpotato root production in Uganda is the sweetpotato weevil *Cylas* spp. which causes very severe damage at crop maturity especially when harvest period is extended into the dry season. A number of other factors limit the time for which roots can be left in the ground after they reach maturity, and these include development of root sponginess, rots, sun scorch, theft, and rodent infestation (Agona, 1995). Given the perishability of roots once harvested, farmers in Uganda usually process them into dried chips.

Dried sweetpotato chips constitute very important quasi-staple during the dry months of the year when the other sources of carbohydrates are still out of season (Bashaasha *et al.*, 1993). The dried chips are steeped in water, boiled, and seasoned with salt and eaten, or are mixed with cereals such as millet or sorghum and ground into composite flour for making local bread known as 'atap' (Fowler and Stabrawa, 1993; Agona, 1995). Dried sweetpotato chips, however, succumb to insect pest infestation after about 2–3 months of storage (Agona, 1995).

The insect pests of dried sweetpotato chips include *Araecerus fasciculatus* Degeer, *Rhyzopertha dominica* (Fab.), *Dinoderus minutus* (Fab.), *Sitophilus zeamais* (Motsch.), *S. oryzae* (L.), and *Tribolium casteneum* (Herbst) (Agona, 1995). Of the pest complex, *A.*

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fasciculatus is the most important (Agona, 1995). Pest infestation is manifested by perforations of dried chips, development of off-flavours, mouldy chips, mite infestation, reduced flour content, frass, and cast skins of dead insects. To reduce damage levels, farmers always conduct routine inspections and re-drying in the sun. The results are often discouraging since damage levels continue to escalate with prolonged storage duration. Farmers respond to the problem by requesting insecticides. The use of insecticides to prevent and (or) control infestation has many problems. Farmers are resource-poor, lack technical expertise in chemical handling and application, very few insecticides are available, and those which are available, have low shelf-life and are prone to user abuse. The need for effective pest management strategies are, therefore, urgently required.

Various pest management methods, especially for dried cassava chips have been demonstrated. The methods include storage of dry chips in sealed containers (Ingram and Humphries, 1972), varietal manipulation (Pillai, 1977), mixing of chips with common salt prior to drying (Kumar and Karnavar, 1986), and parboiling of roots prior to slicing and drying (Nwana and Azodeh, 1984; Pillai and Rajamma, 1987; Nwana, 1993). Other disinfestation methods, e.g., use of focussed solar energy (Nakayama *et al.*, 1982; Silim and Agona, 1993) have been successfully demonstrated on other insect pests.

This study was conducted to assess the efficiency of salting of freshly sliced sweetpotato chips prior to drying, for the control of *A. fasciculatus*. No reports have been found on the use of this method for dried sweetpotato chips in storage.

The objectives of the study were to:

- (i) evaluate the efficacy of finely ground common salt in reducing and (or) controlling dried sweetpotato chip damage by *A. fasciculatus*;
- (ii) establish the effect of salt dosage levels on the generation (development) time of *A. fasciculatus*; and
- (iii) establish the effect of different salt dosage levels on the weight of adult *A. fasciculatus* at emergence.

Methodology

Freshly sliced sweetpotato chips of medium size, approximately 5 mm thick, were thoroughly mixed with finely ground common salt (NaCl) at the rate of 0, 0.25, 0.50, 1, 2, 3, 4, and 5 g 100 g^{-1} fresh chips prior to drying.

The chips were spread out to dry in the open sun on a wire mesh tray. Each treatment lot was dried separately. Sun drying was discontinued once an equilibrium moisture content (MC) of approximately 11–12% was achieved. This was attained after three days of drying. The MC was monitored by oven-drying at 130°C for 24 h.

The chips were bagged in cotton-woven sample bags and fumigated with phosphine at the rate of 3 g m^{-3} in a fumigation chamber for four days. This was to rid the chips of any prior infestation which might have occurred during the drying period (Hill, 1984; Nwana, 1993). The chips were removed, aired for 6 h to get rid of any residual undecayed fumigant, and were put in 100-L plastic drums fitted with lids until required in order to avoid any cross infestation.

Artificial infestation was carried out on 100-g samples of dried chips kept in 1-L Kilner jars using three-week old *A. fasciculatus* adults at the rate of eight females and four males for each jar. The gravid females were allowed to lay eggs for seven days after which all insects were discarded. The infested chips were retained in the jars coated at the neck with polytetrafluoroethylene (fluon) to prevent insect escape. Additionally, the jars were fitted with muslin cloth at the neck and a perforated screw-on lid to permit maximum aeration to the developing insects. The cultures were placed on a rack in the laboratory under prevailing environmental temperatures of 26.29 ± 1.19°C and relative humidity 68.96 ± 7.39%, until F_1 adult emergence.

There were eight treatments including the control, each replicated four times. The data were analysed as for a completely randomised design (CRD).

Investigative parameters included: (i) total number of adults in the F_1 generation in each treatment; (ii) weight of emerged adults in each treatment; (iii) generation time; and (iv) final moisture content of the chips.

The weights of the weevils were determined soon after emergence using a Stanton 33 BN analytical balance. The final MC of the chips was determined using the oven-dry method as explained above.

Results

The total adult *A. fasciculatus* emergence and MC mean per cent in the different treatments are summarized in Table 1. The mean number, weight, and generation time of *A. fasciculatus* at different dosage rates of salting sliced sweetpotato chips are presented in Figures 1, 2, and 3. The final MC of the treated chips after about four months of storage is presented in Figure 4.

There were significant differences ($P < 0.05$) in the mean number of adult *A. fasciculatus* that emerged in the chips treated at different salt dosage levels prior to drying. The highest number of emergence was observed in the non-salt treated (controls) and none in those chips treated with salt at dosage levels of 4 and 5% (w/w) (Figure 1).

Table 1 Mean number of *Araecerus fasciculatus* that emerged and final moisture content (MC) of treated chips at different salt dosage levels

Salt dosage level (%)	Transformed means of adults that emerged[†]	Actual means of adult that emerged	Final MC (%)
0	2.462	5.750	13.837
0.25	1.868	3.500	14.112
0.50	1.896	3.250	14.850
1	1.117	1.250	16.225
2	0.837	0.250	16.400
3	0.998	0.750	16.925
4	0.707	0.000	17.200
5	0.707	0.000	17.300
S.E.D. (24 *df*)	0.372	1.265	0.339
C.V. (%)	39.770	96.990	3.020

[†]Square root data transformation: $\sqrt{(x + 0.5)}$, was adopted
S.E.D. is standard error of the difference between means
C.V. is Coefficient of Variation

Figure 1 Mean emergence of *Araecerus fasciculatus* infesting dried sweetpotato chips treated at different salt dosage levels; —□—, Mean emerged

Figure 2 Effect of salting chips on the weight of *Araecerus fasciculatus* at emergence; —□—, Weight

Figure 3 Effect of salting chips on the generation time of *Araecerus fasciculatus*; —□—, Time

Figure 4 Final moisture content (MC) of salted dried sweetpotato chips at different dosage rates; —□—, % MC

There were, however, no significant differences ($P > 0.05$) in the mean number of *A. fasciculatus* which emerged in chips treated at salt dosage levels of 0.25 and 0.50% (w/w). Likewise, the difference in the mean number of adults that emerged in chips treated at salt dosage levels of 1, 2, 3, and also 2, 3, 4, and 5% (w/w) were not significantly different (Table 1).

Salting of the chips had a negative effect on the weight of adult *A. fasciculatus* at emergence. Weevils that were bred on non-salted chips were heavier than those from salted chips. The weights decreased with increasing salt dosage rates (Figure 2).

The generation time, i.e., time from egg laying to adult emergence, was significantly affected by the salt treatment on the chips. The generation time of *A. fasciculatus* increased progressively with increasing salt dosage rates up to 2% and decreased at 3% (Figure 3). The shortest generation time was achieved in the controls (89.44 ± 2.63 days) and the highest in the chips treated at rate of 2% (w/w)

(105.50 days). There was, however, only a single adult emergence at 2% (w/w) salt level.

The final MC of the chips after about four months of storage increased significantly ($P < 0.05$) with increasing salt dosage level (Figure 4). The highest MC was attained on chips treated at 5% (w/w) (17.30 ± 0.07%) and the lowest in the controls (13.84 ± 0.29%).

Discussion

The results showed that the treatment of freshly sliced sweetpotato chips with common salt prior to drying significantly reduces and (or) controls damage levels by *A. fasciculatus* during storage. The efficacy of salting chips, however, depends on the dosage levels. Best results are obtained at higher dosage levels of 2% (w/w) and above. At these levels insect adult emergence is limited to less than one. The implication of the number of adults that emerged, however, needs to be corroborated with the actual damage as perceived by the farmers. This would require the establishment of a visual scale of damage. The category scale could be based on the number of holes per unit area.

In spite of the favourable results with the prescribed dosage levels, the quality of the final products could be the determinant factor for farmers' acceptability. The organoleptic quality of the product may be affected at high salt dosage levels. In those areas where dried sweetpotato chips are consumed, the chips are first steeped in water, and seasoned with salt during cooking. It is therefore suggested that low salt dosage levels of 2–3% (w/w) could be recommended. Additionally, to reduce salt levels, it is recommended that salted chips are steeped in water for some time, then de-watered and the chips boiled in fresh water. During cooking, seasoning of the chips to taste with salt may be optional depending on salting preference.

The mechanism by which salting reduces the level of damage by *A. fasciculatus* to dried chips may be linked to one or more of (i) choice of oviposition site, (ii) the survival of deposited eggs, or (iii) survival of larvae after hatching. With respect to egg survival, it is envisaged that the content of freshly laid eggs may be destroyed by desiccation before the egg shell hardens as a result of the osmotic potential created by high salt concentrations. At low salt dosage levels of 0.25, 0.5, and 1% (w/w) it is apparent that the process of plasmolysis may not be triggered due to the equilibria in osmotic potential. However, at higher dosage levels of 2% and above, plasmolysis takes place to the detriment of the egg content.

With respect to survival of the larvae after hatching, it is possible that those larvae developing in a salty environment succumb to dehydration since the body's capacity to conserve water becomes weakened due to the hostile environment. Insects are sensitive to the loss of body water and this is particularly true in environments which increase the rate of water loss (Lessard, 1987). This probably led to the death or reduced rate of growth as reflected by the reduced total number of adults that emerged, reduced adult weight, and prolonged generation time.

Conclusion

The study has shown that salting sliced sweetpotato chips prior to drying to control damage levels by *A. fasciculatus* is very promising. As a practical method for use by subsistence farmers, an application rate of salt is recommended at 2–3% (w/w) level. It is envisaged that at this level, the culinary qualities of the dried chips is not significantly affected. Additionally, since the treatment has been tested on only one species of the pest complex it is recommended that the method of pest control be tested on-farm on the entire pest complex of dried sweetpotato chips under farmers' storage conditions and management practices.

Additionally, since saltiness tends to increase the moisture content of the dried chips when kept for a long time due to the hygroscopic nature of salt, it is recommended that the chips are re-dried periodically. This may not only help in hardening and drying of the chips, thus avoiding microbial activity, but also getting rid of the adult insects which tend to be photophobic.

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