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A visual scale of loss assessment for dried sweet potato chips due to *Araecerus fasciculatus* Degeer (Coleoptera: Anthribidae) infestation on-farm

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Abstract

A visual scale of damage was established on dried sweet potato chips infested by *Araecerus fasciculatus* under prevailing ambient conditions in the laboratory. The dried chips had been stored for the duration of one week to six months. Five classes of chip damage, including their end-uses, were identified. The classes ranged from 1-5, where Class 1 chips were undamaged and Class 5 the most severely damaged. Severity of damage was established at 0, 0.06, 0.23, 0.60 and 0.74 holes per cm² for the damage class categories 1, 2, 3, 4 and 5 respectively. Weight losses were estimated at 0, 19.2, 20.6, 61.9 and 85.1% for damage classes 1, 2, 3, 4 and 5 respectively. The end-use of chips in each class category declined drastically with increasing levels of damage. Reference photographs of each class category were obtained. The need for a visual scale of loss assessment for dried sweet potato in storage is appraised.

Key words: Loss assessment, visual scale, damage, sweet potato, dried chips, *Araecerus fasciculatus*

Introduction

Dried sweet potato chips in storage are vulnerable to a number of insect pests. Agona (1995) identified six different insect pests occurring on dried sweet potato chips that had been stored for more than six months on-farm in Kumi district, Uganda. Due to insect infestation, dried sweet potato chips become heavily pulverised within to 2 to 3 months of storage, and farmers respond to the problem by either sorting the damaged chips and milling into flour, giving to livestock, distilling into local gin or throwing away. There are no proper pest management methods defined for dried sweet potato chips apart from farmers' method of regular inspection and re-drying in the sun. The lack of pest control measures probably is attributed to the low economic value attached to the dried chips (Davies, 1962). Farmers are therefore handicapped and have since been conditioned to accepting the losses of dried chips as inevitable.

With the increasing food security status being accorded to the crop, especially in the Eastern and Northern districts of Uganda (Hall et al., 1998), the need to understand the damage as well as economic threshold values attributed to the storage pests of dried sweet potato chips in storage is imperative. Currently, there are a number of investigations going on the pest management of dried sweet potato chips in storage. However, it is envisaged that when such measures have been introduced on-farm, determination of their effectiveness will be required (Giga and Katerera, 1990). This therefore calls for the establishment of a loss assessment technique which is easy to apply, interpret and enable reliable and consistent comparisons to be made over time (Adams and Harman, 1977). This will not only help in determining the effectiveness of the novel pest management methods once introduced on-farm, but also the threshold for consumer quality acceptability (Greeley, 1982).

Standard methods for measuring grain losses include the (a) volumetric, standard volume weight or bulk density method, (b) thousand grain mass (TGM) method, (c) count and weigh method and (d) converted percentage damage method (Boxall, 1986; NRI, 1995). However, unlike stored grains, there are no well-developed or standardised loss assessment techniques for dried roots and tubers. In loss assessment of crops due to pest and disease pressures in the field, one method that has been successfully demonstrated is the use of visual scale of damage (Chiappara, 1971; Ciba-Geigy, 1981).

In post-harvest loss assessment, trials with visual scale of damage include the works of Compton (1991), Stabrawa (1992), Compton et al. (1993) and Wright (1995) on maize and dried cassava. The assessments however, gave much less accurate loss estimates on chips than in maize grains. No work so far has been conducted to establish the visual scale of damage for dried sweet potato chips. To underscore the economic importance of the pest complex or a single species, of the insect pests which attack dried sweet potato chips in storage, and/or determine the impact of any technological intervention in their management, it is important that such a scale is established.

The difficulty in assessing losses of dried roots due to insect pests is compounded by the nature of the chip geometry and the different feeding habits of the pest complex. Dried chips are often of various shapes, sizes and compactness. These make it very difficult to determine quantitative and qualitative losses attributed to insects. Also signs of infestation of the chips are exhibited differently by different insect species. For instance sedentary insects *Rhyzopertha dominica* (Fab.), *Prostephanus truncatus* (Horn) and *Dinoderus minutus* (Fab.), always feed internally of the chips, and there is extensive tunnelling and release of powdery wastes. On the other hand, the more vagile insects like *Araecerus fasciculatus* (Degeer), *Sitophilus zeamais* (Motsch.) and *S. oryzae* (L.), feed externally on the chips and always emerge out the chips leaving distinct emergence holes. However, all the larvae of the pest complex feed internally, and their frass and exuviae are packed within the chip. Superficial damage characteristics like emergence holes and powdery waste products are common features of infested dried chips. It is envisaged that if these features are properly defined and related to quantitative (mass) loss, they could be used reliably to ascertain the extent of dried root loss.

Farmers, however, use different criteria to assess dried chip damage which are directly linked with the end-use of the product, storage duration, season and household food security status (Agona, 1995). Based on subjective assessment, dried sweet potato chips are classified as undamaged, lightly or severely damaged. What these subjective categories represent in terms of quantitative loss needs to determined. Chips which are undamaged or lightly damaged are steeped in water, boiled and eaten; and those which are severely damaged are either used in distilling waragi (local gin), fed to livestock or thrown away. There is however, no borderline of defining how light or severe the damage is. Judging from the availability of food, the end use descriptors may not give indications to the overall damage throughout the year. In times of scarcity, even the heavily damaged chips may not be thrown away or given to livestock but will be consumed, and during times of surpluses the lower class categories may not be consumed at all.

There is therefore need to establish damage threshold values due to insect pests on dried sweet potato chips, and a basis for determining the impact of introduced pest management methods on-farm. One method which could be developed and tested on dried sweet potato chips is a standard visual scale of damage (Compton et al., 1993). This however, has to have reliability and should yield consistent results under different situations for a dependable interpretation of results. According to Miller (1991), a visual scale helps the human eye to synthesise complex information and make an immediate assessment of damage.

A study was therefore conducted to develop a visual scale of damage of dried sweet potato chips due to *A. fasciculatus* infestation. The specific objectives of the study were to: (a) develop a visual scale of damage for sliced and dried sweet potato chips in storage, (b) categorise dried sweet potato chips into different damage levels using a visual scale, and (c) determine the apparent weight loss and severity of damage of each category.

Materials and methods

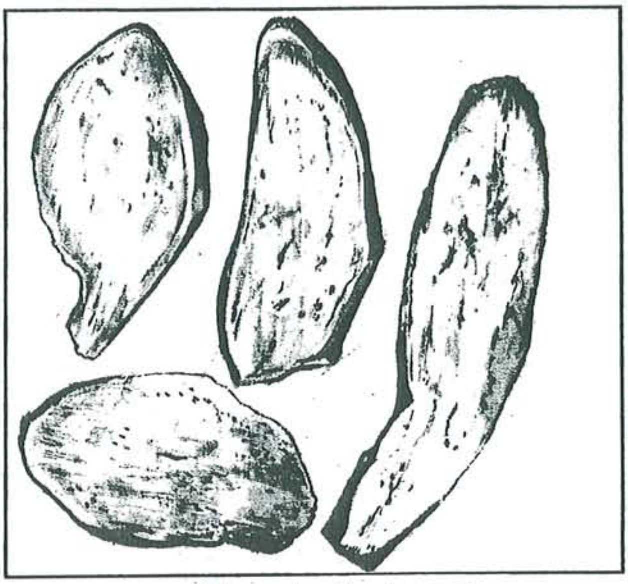
An assortment of chips weighing about 5 kg, of a standard sweet potato variety Tanzania (Osukut), at different damage levels caused by *A. fasciculatus*, were presented to a group of 20 participants attending a Sweet potato Stakeholders Workshop, Serere District Farm Institute, December, 1997. The participants included farmer representatives, district agricultural extension officers and processors from five districts in Uganda where dried sweet potato chip processing, storage and utilisation is a common practice. The participants were divided into groups of four and then asked to 'sort' the chips into different classes depending on the damage level.

The sweet potato chips used in the study had been exposed to the sun and allowed to reach an equilibrium moisture content of about 12-13%. These were artificially infested with *A. fasciculatus* from routine stock cultures under ambient conditions in the laboratory, and were contained in 2-litre glass jars fitted with perforated lids. The insects were allowed to feed and damage batches of chips for periods ranging from one week to six months to obtain a range of damage. The chips were bulked and mixed up randomly in a heap.

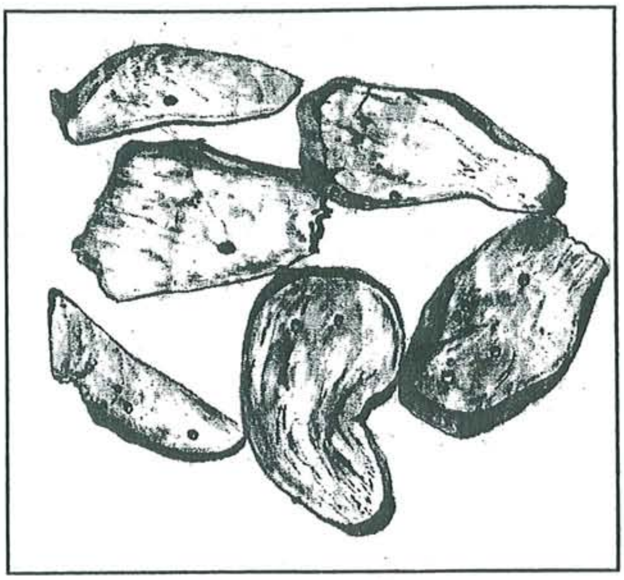
The participants categorised the chips according to different levels of damages and defined five different classes of damaged sweet potato chips viz.

(a) Class 1 = No damage,
(b) Class 2 = Light damage
(c) Class 3 = Medium damage
(d) Class 4 = Medium-high damage and
(e) Class 5 = Severe damage

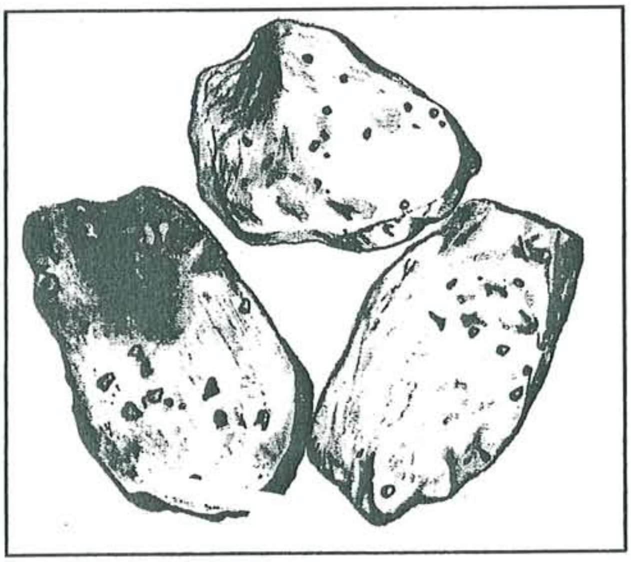
Representative samples from each category were then obtained by coning and quartering method and weighed into 100-g lots. The total surface area of the chips in each lot was established by mapping the irregularly shaped, but flat, chips on a standard graph paper. This was achieved by counting full squares and those squares with more than 50% coverage by the chips. They were all regarded as whole numbers in cm^2; and the area obtained was multiplied by a factor of two to take care of both sides of the chips i.e. upper and lower surfaces, since insect emergence occurs on both sides. The total number of holes in each chip was obtained, and was used to calculate the severity of damage, defined as the number of holes per cm^2. The surface area of the lateral side of the chips was not taken into account because of the thinness of the chips and number of emergence holes was insignificant.



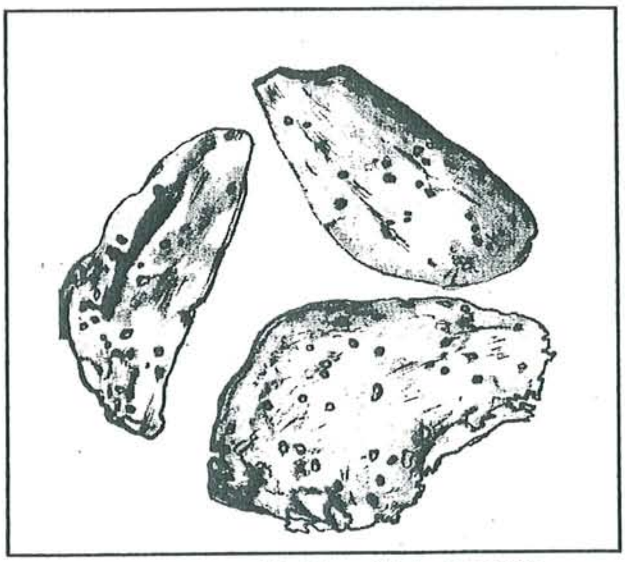
Class 1 = No damage
(0.0)



Class 2 = Light damage
(0.06 ± 0.03)



Class 3 = Medium damage
(0.23 ± 0.11)



Class 4 = Medium-high damage
(0.60 ± 0.03)

Additionally, the apparent weight loss of the dried chips defined as the percent reduction in weight of damaged to undamaged chips, of each visual scale damage category was determined. The weight loss was given by the formula:

$$\text{Apparent weight loss of chips in class category} = \frac{WC1 - WCy}{WCl} \times 100\%$$

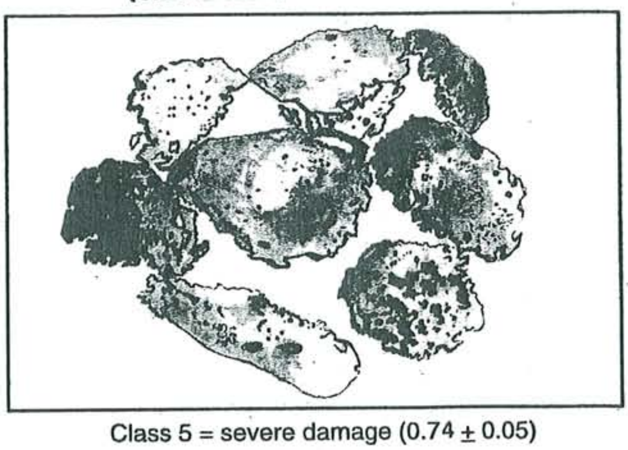
where WC1 = Average weight of Class1 chips

WCy = Observed weight of chip class category

The end-use of chips in each damage category was also established through interviews and discussions with the participants.

Photographs (Fig.1) of chips in each damage class were taken as visual aids in defining the different classes.

The parameters measured for each class category included (a) severity of chip damage, (b) average weight of each chip, (c) apparent weight loss of the chip, and (d) end-use of chips.



Class 5 = severe damage (0.74 ± 0.05)

Fig. 1. Visual scale of damage for sweet potato chips infested by A. fasciculatus (Classes 1-5, figures in brackets indicate severity of damage)

The class categories defined by the five different groups of participants were regarded as treatments and each with 5 replicates. The data were analysed as a completely randomised design.

Results

The results of severity of damage and average weight of each class category are presented in Table 1. Table 2 shows the results of weight loss attributed to *A. fasciculatus* and the end-use of chips in each damage class category.

There were significant differences ($p<0.05$) between the damage class categories (Table 1) in terms of severity of damage and weight reduction. Those chips in Class 1 chips were undamaged and had not incurred any weight losses. The highest weight losses were recorded in Class 5, which were visually the most damaged (Fig. 1). There were however, no significant differences ($p>0.05$) between Class 1, 2 and 3 chips in terms of average chip weight loss. Similarly there were no differences between damage class categories 4 and 5 (Table 1). No significant differences were observed in severity of damage between Class 1 and 2 chips, but in the other classes significant differences occurred (Table 1).

There was a progressive increase in weight loss from Class 1 through to Class 5. Likewise, the method of preparation and end-use of the chips continuously changed with increasing level of damage until it fell below the level acceptable for human consumption (Table 2). There were however, no marked differences in weight reduction of Class 2 and 3 chips. Class 5 chips were the most pulverised with the least weight. The differences in chip size were results of *A. fasciculatus* damage.

Table 1. Severity of infestation (holes cm^{-2}) in five damage classes and chip weight after infestation by *A. fasciculatus*

Class	Severity of infestation (Mean ± SE)	Average chip weight (g) (Mean ± SE)
1	0.00± 0.00	11.81± 0.98
2	0.06± 0.03	9.55± 0.64
3	0.23± 0.11	9.38± 4.42
4	0.60± 0.03	4.50± 1.95
5	0.74± 0.05	1.76± 0.80
CV (%)	17.38	30.44
SED (20 d.f.)	0.06	2.26

Table 2. Average chip weight loss in damaged sweet potato chips due to *A. fasciculatus* infestation and the end-use of chips in different damage class

Damage class category	Weight loss (%)	End-use
1	0.0	steeped, boiled and eaten
2	19.2	steeped, boiled and eaten
3	20.6	ground into composite flour for bread
4	61.9	livestock feeding, distilling local gin
5	85.1	Discarded

Discussion

The suggested visual scale of sweet potato damage due to *A. fasciculatus* infestation based on the average number of insect emergence holes and chip weight, reflected the magnitude of qualitative and quantitative losses during storage. It is possible that farmers' acceptance of any grade of chips is based on subjective assessment of the level of damage and relative apparent weight of the chips. Getting true values for weight losses of damaged chips are quite difficult (Compton et al., 1992), but when Class 1 chips are used as the reference point, relative loss estimates in each class category can be established fairly well. It is assumed that Class 1 chips are intact, and thus when a standard weight of 100 g of chips in each class category are used, any observed difference between the average chip weight of the damaged to undamaged, is attributed to insect feeding. The visual characteristics of each damage category, backed up by the reference photographs, could provide a useful tool in loss assessment and in helping farmers to determine the end use of undamaged and damaged chips quickly. The derived visual scale can also be used in determining the effectiveness of pest control interventions for dried sweet potato chips on-farm (Boxall, 1986).

The method developed here, however, entails the counting of all the holes and determination of the total area of the chips. The basic requirement are chips that are thin and flat, although chips which are uneven can be broken into shapes which can easily be mapped. Despite the difficulties, the method differs from Wright's (1991) in which graph paper is placed on specific areas of damaged chips subjectively. The suggested method of loss assessment for dried sweet potato chips therefore minimises subjectivity.

To refine the proposed visual scale of damage in order to provide consistent and reliable results in the loss assessment of dried sweet potato chips due to insect infestation standardisation of the number of emergence holes with observed weight would be required. One method which could be applied is the volumetric, standard volume weight or bulk density method since volume is correlated with weight loss (Wright, 1991). It is however, difficult to employ the method because highly infested dried chips are porous to water, making the apparent displacement inaccurate (Compton, 1991).

Generally, the results obtained clearly show that infestation of dried sweet potato chips by *A. fasciculatus* negatively affects the size, weight and the visual characteristics. These factors play significant roles in decision making by farmers in determining the end use of the product and marketing pricing. During an earlier survey (Agona, 1995), farmers acknowledged damage by stored products insect pests, and gave various uses of dried chips ranging from eating to throwing away depending on the infestation level.

It is therefore evident that, superficial damage characteristics, e.g. presence of emergence holes, help in decision making for determining the end-use of the chips by farmers. Heavily infested chips, including Classes 3,4 and 5, are known to be bitter. It is not uncommon for farmers to fortify the flavour of bread (Atap) made from composite flour including damaged chips with tamarind in the districts of Kumi, Soroti and Katakwi in Eastern Uganda (Agona, 1995).

In establishing damage class category, caution should be taken however, on the use of some parameters to avoid overlap between classes. For instance, it was very difficult to establish the exact number of holes in Class 5 chips. The chips heavily mined leading to significant reduction in dry matter content and holes coalescing, leaving only a leathery skin. The observation is in agreement with Compton et al. (1993) findings. Thus, the use of holes *per se* cannot be used as the only variable to discriminate classes. The visual scale devised here is based on damage holes, should not be considered totally exclusive (Greeley, 1982). Other parameters like chip mouldiness, dryness, discoloration and flavour could be important. Other factors may include household food security situation and consumer economic status.

Recommendations

It is recommended that the established visual scale of damage for dried sweet potato chips due to *A. fasciculatus* is tested on-farm against the whole pest complex of chips in storage to ensure consistency in categorisation. It is important that such a scale is tested over a period to determine loss estimates by known pest infestation levels. This could help in determining the threshold values due to pest infestation in time and space; and the impact of novel pest control interventions on-farm. It is further recommended that farmers are exposed to the reference photographs as visual aids in loss assessment. Lastly but not least, more work is required to develop a function of variables that can best describe the five damage categories.

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