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Susceptibility of Some Staple Processed Meals to Red Flour Beetle, *Tribolium castaneum* (Herbst) (Coleoptera: Tenebrionidae)

F.A. Ajayi and S.A. Rahman
Nasarawa State University, Keffi, Faculty of Agriculture, P.M.B. 135,
Shabu-Lafia Campus, Nasarawa State, Nigeria

Abstract: Seven processed staple meals (millet, wheat, sorghum, yam, cassava, maize flour(s) and semovita grits) were evaluated in the laboratory under ambient conditions (28-34°C and 58-75% r.h.) for their susceptibility to the red flour beetle, *Tribolium castaneum* (Herbst). Experiment was conducted using five pairs of 3–5 day old *T. castaneum* on 5 g of processed staple meals in a 25 mL glass jars. Insects were allowed to mate and oviposit for a period of twenty days and at the end of twenty days both live and dead insects were removed. Insect count was started from the day of emergence in each treatment and was carried out for twenty days in each treatment and replicate. Significantly ($p \leq 0.05$) more *T. castaneum* adults developed in wheat, millet, sorghum and maize flour(s) with Susceptibility Indices (SI) of 8.65, 6.26, 4.46 and 3.19, respectively. Fewer adults emerged in semovita grits, cassava and yam flour with SI of 2.69, 2.27 and 2.22, respectively. Developmental Period (DP, in days) for cassava flour was 54.8 days; while the least DP was 27.0 days in wheat. The results also showed that moisture contents of the processed meals played a significant role in the susceptibility of the processed meals to *T. castaneum* with values of $Y_1 = 68.57 + 2.61X$, ($R^2 = 0.66$) for developmental period and $Y_2 = -2.37 + 0.63X$, ($R^2 = 0.67$) for susceptibility indices. The economic implications for bulk purchase of processed staple meals for house holdings are discussed.

Key words: Red flour beetle, *Tribolium castaneum*, susceptibility index, developmental period, processed staple meals

INTRODUCTION

Nigeria is an agrarian country with much of the food produced still at the subsistent level. A lot of the food produced are processed at the homestead level for consumption and also made available for sale in the open market. Nigerians eat a lot of processed meals in various forms. More so, the consumption of these processed meals cut across all the ethnic tribes and religious groups in the country.

These Processed Staple Meals (PSM) when available or purchased by a household in a large quantity and are not immediately all consumed are often kept in storage where they are infested by a major secondary pest of stored products, the red flour beetle, *Tribolium castaneum* (Herbst) (Coleoptera: Tenebrionidae). *T. castaneum* has been reported to be a major pest of processed or damaged grain in storage (Haines, 1991). The pest is a polyphagous, cosmopolitan insect, feeding mostly on stored flour and other milled cereal products or broken wheat (Cotton, 1963) and farm-stored cereals (Madrid *et al.*, 1990). It has also been reported to have a long association with human stored food, but milled grain products such as flour appear to be their preferred food (Campbell and Runnion, 2003). According to Tanzubil (1991), the process of threshing grains before consumption predisposes them to infestation to attack by *T. castaneum.*

The ability of *T. castaneum* to colonize a wide range of substrate has made it one of the stored product pests that has been used widely for various ecological studies (Campbell and Runnion, 2003). The red flour beetle has been reported to be highly mobile within patches of food such as grain or flour (Hagstrum, 1973) and also readily disperse within patches of flour throughout the adult stage (Ziegler, 1976). Female *Tribolium* sp adults are long live and lay eggs more or less continuously throughout their life span (Howe, 1962). Also, *T. castaneum* has been reported to be highly influenced by the type of quality of substrate present for oviposition and subsequent emergence of adults with flour that has not been infested earlier being preferred for successful colonization (Ziegler, 1976).

Corresponding Author: F.A. Ajayi, Nasarawa State University, Keffi, Faculty of Agriculture, P.M.B. 135, Shabu-Lafia Campus, Nasarawa State, Nigeria

In the present study, seven Nigerian processed staple meals that are often sold in the open market and used variously by different household to prepare different meals were evaluated for their susceptibility to the red flour beetle, *Tribolium castaneum* (Herbst).

MATERIALS AND METHODS

Insect rearing, procurement and treatment of processed staple meals: The culture of *Tribolium castaneum* used for the study was established from an infested batch of millet purchased from a local market in Lafia, north central Nigeria. The colony of *T. castaneum* was maintained subsequently on crushed millet (cv. Dauro) under ambient laboratory conditions (28-34°C and 58-75% r.h.). Experiment was conducted under these conditions between March-August, 2004.

Five hundred gram each of the seven Processed Staple Meals (PSM) (millet, wheat, sorghum, maize, semovita, yam and cassava flour(s) were obtained in the open market in Lafia. These batches of processed staple meals were carefully wrapped in a transparent polyethylene bag and kept in a deep freezer (at temperature below 0°C) to kill any viable eggs, larvae or adults that may be harbored in the meals. These were kept in the deep freezer for a period of 30 days before use. The salient uses and categorization of these processed staple meals are presented in Table 1.

Another batch of PSM was purchased at the same time from the same lot and this was used for determining the moisture content of the meals.

Determination of moisture content and insect infestation of processed staple meals: Ten gram each of the seven Processed Staple Meals (PSM) were used to determine the moisture content of the PSM by using the standard conventional method of determination of moisture content, which is

$$\frac{C-T}{C} \times 100$$

Where C = initial weight of PSMs
T = final weight of PSMs (after subjecting meals to 105°C in the oven for 24 h)

This procedure was carried out at five different times (weekly) for each PSM with each period being taken as a replicate of the treatments.

The Processed Staple Meals (PSM) that had been disinfested in the deep freezer were equilibrated for 5 days to prevailing laboratory conditions according to the method of Lale and Mustapha (2000) before use. Thereafter, each PSM were sieved by using a 0.5 mm orifice sieve. The fine powder products obtained were saved for subsequent experiment.

Table 1: Categorization and uses of processed staple meals screened for susceptibility to *Tribolium castaneum* (Herbst)

		Categorization		
Processed staple meals	Botanical name	Type of crop	Family	Domestic use
Millet flour	*Pennisetum glaucum* (L.) r.Br	Cereal	Graminae	Used for preparing a local solid porridge called madidi and often use in a mixture of food while feeding infants
Wheat flour	*Triticum aestivum* L.	Cereal	Graminae	Used in various homes as a major substitute for commercial quaker white oats meal in preparing porridge
Sorghum flour (Guinea corn flour)	*Sorghum bicolor* (L.) Moench	Cereal	Graminae	Used for preparing local porridge (pap) often mixed with infant's food and for preparing masa a local fried delicacy
Maize flour	*Zea mays* L.	Cereal	Graminae	Generally used for preparing a solid porridge eaten with soup
Semovita* (grits)		Cereal	Graminae	Used for preparing a white solid porridge food eaten with soup
Yam flour	*Dioscorea* sp.	Tuber crop	Dioscoreaceae	Used for preparing a black solid porridge called amala, eaten with soup
Cassava flour	*Manihot esculenta* Crantz	Tuber crop	Euphorbiaceae	Used for preparing a white solid porridge called Lafun, eaten with soups

*This is a registered trade name of a commercial product of Flour Mills of Nigeria Plc. made from mixture of maize and possibly other cereals

Five gram each of the sieved PSM were weighed into a 25 mL glass jars. Five pairs of 3-5 day old *T. castaneum* were introduced into each glass jar and covered with a lid containing ventilation holes (diam. 0.25 mm). The insects were allowed to mate and oviposit for a period of twenty days before both live and dead insects were removed. Thereafter, the treatments were left and checked daily until adult emergence. Adult emergence in each treatment was taken and recorded for twenty days in succession in each replicate or treatment from the start of adult emergence. All adults that emerged were removed from each treatment at the time of recording.

Experimental design and statistical analysis: The experiment was carried out in a completely randomized design with each treatment being replicated five times thus giving n = 35. Susceptibility I

dices (SI) were calculated according to the method of Dobie (1974) and are given as:

$$SI = \frac{Log_e}{D} F_1 \times 100$$

Where F_1 is the total number of emerging adults and D the median developmental period (estimated as the time from the middle of oviposition to the emergence of 50% of the F_1 generation). The Developmental Period (DP, in days) was calculated as the period from the date of infestation to the date of first emergence in each treatment of the replicates. Percentage data were arc sine transformed and all data were then subjected to ANOVA and differences between means were determined using the Least Significant Difference (LSD) statistic ($p \leq 0.05$). Regression analysis was used to determine the causal relationship between moisture content, susceptibility indices and developmental period.

Household survey was also conducted along with the experiment to determine the rate of damage on processed staple meals due to infestation of red flour beetle. The information collected from 15 households in each case with structured interview schedule include the quantity of processed meals purchased, storage period and level of damage caused by the red flour beetle. Analysis of the survey data was done using descriptive statistics such as mean, percentage and coefficient of variation.

RESULTS AND DISCUSSION

Analysis of variance showed significant differences among the Processed Staple Meals (PSM) ($p \leq 0.05$) in their susceptibility indices (SI) to *Tribolium castaneum* (Herbst) (Table 2). A significant higher value of SI was recorded for wheat flour (8.62) than for all other PSM. There is a higher significant difference ($p \leq 0.05$) between the SI of millet flour (6.26) and that of wheat flour or sorghum flour (4.46). However, no significant differences were recorded ($p \geq 0.05$) between the SI of semovita (2.69) and maize flour (3.19) nor between yam flour (2.22) or between semovita, cassava flour and yam flour.

Table 2 also indicates that the mean Developmental Period (DP) of *T. castaneum* in the processed staple meals ranged from 27.0 days in wheat flour to 54.8 days in cassava flour with higher significant ($p \leq 0.05$) differences among the treatments. Based on the Susceptibility Indices (SI) values, the processed staple meals were identified as slightly susceptible-Yam flour, cassava flour and semovita (2.22–2.69); moderately susceptible – maize flour and sorghum flour (3.19-4.46) and susceptible-millet flour and wheat flour (6.26-8.62).

The results (Table 2) also showed significant difference ($p \leq 0.05$) between mean moisture content of the processed staple meals with ranges between 6.50% as recorded in semovita and 14.20% for millet flour. Table 3 shows the relationship between moisture content, susceptibility indices and developmental period, with values of $Y_1 = -2.37 + 0.63X$ ($R^2 = 0.67$) for susceptibility indices and $Y_2 = 68.57 + 2.61X$ ($R^2 = 0.66$) for developmental period.

Table 2: Relative susceptibility of seven processed staple meals to *Tribolium castaneum* (Herbst) and mean moisture content

Processed staple meals	Mean development time (days)	Susceptibility Indices (SI)	Mean moisture content (%)
Millet	29.2	6.26	14.20 (22.14)[a]
Wheat	27.0	8.62	13.90 (21.89)
Sorghum	36.0	4.46	12.00 (20.25)
Maize	40.8	3.19	10.50 (18.93)
Semovita	44.0	2.69	6.50 (14.76)
Yam	49.8	2.22	9.30 (17.74)
Cassava	54.4	2.27	7.10 (15.48)
SED	1.80	0.35	0.54
LSD ($p \leq 0.05$)	5.00	0.72	1.50

[a]Figures in parentheses are arc sine values to which SED and LSD are applicable

Table 3: Regression analysis showing the effects of moisture content on susceptibility index and developmental period of *Tribolium castaneum* (Herbst) on staple processed meals

Endogenous Variable	Constant	Coefficient	R^2
Susceptibility	-2.37*	0.63*	0.67
Index (SI)	(-2.80)	(8.14)	
Development	68.57*	2.61*	0.66
Period (DP)	(18.58)	(7.08)	

* Significant at 1% level of probability, Figures in parentheses are t-values

Table 4: The rate of economic damage caused by red flour beetle *Tribolium castaneum* (Herbst) on processed staple meals in the selected households

	Proportion of processed staple meals damage (%)						
Estimate	Cassava	Maize	Millet	Semovita	Sorghum	Wheat	Yam
Maximum	27.23	33.06	42.31	30.14	36.18	49.04	21.68
Minimum	12.19	15.98	13.28	14.26	15.27	15.16	10.32
Average	18.42	22.05	34.21	20.49	27.63	40.03	14.15
Std. Deviation	4.24	6.84	22.24	5.53	9.39	27.62	2.69
CV	0.23	0.31	0.65	0.27	0.34	0.69	0.19

CV = Coefficient of Variation

Tribolium castaneum (Herbst) has been reported to be very prolific and has the ability to produce millions of progeny within a life span (Haines, 1991). A major factor influencing the proliferation and development of *T. castaneum* is the quality of diet (Apert, 1987). According to Booth *et al.* (1990) development of *Tribolium* sp. generally takes about 20 days on a good qualitative diet with other factors being optimal. However, when he diet presented for development is of less quality, developmental period takes a longer time and it can be as long as 45 days or more (Haines, 1991). In the present study, period of 54.8 days was recorded for *T. castaneum* reared on cassava flour and as low as 27.0 day was recorded in wheat flour.

Much of the work that has been reported on the rearing of *T. castaneum* in the laboratory has been on mixture of diet of wheat and oats resulting in shorter developmental period (Haines, 1991). It is possible that these substrates presented very good qualitative nutrients for the development of *T. castaneum.* In the present study, *T. castaneum* developed in the wheat flour and millet flour within a very short time and hence a lot of progeny were recorded within this period culminating in very high susceptibility indices. The quality of the food presented, in this case the processed staple meals is a factor in the development of *T. castaneum* and ultimately their susceptibility to the store pest. Wheat and millet belongs to class of cereals that are high in crude protein and other nutrient constituents such as thiamine, riboflavin and niacin (Rehm and Espig, 1991), compared to other substrates presented for development. Cassava flour, yam flour, sorghum flour, maize flour and semovita are basically eaten as starchy food products. According to Campbell and Runnion (2003) a small difference in the quality of flour can cause a significant difference in the development of *T. castaneum.*

Tribolium castaneum has been reported to be well adapted to dry conditions and are therefore regarded as unspecialized feeders (Haines, 1991). The moisture content of the processed staple meals used in this study ranged from 6.50 to 14.20%. All the processed staple meals except semovita that is produced by commercial production are produced locally and are thus presented for sale in the open market where the product are open to atmospheric moisture. It is likely that the level of moisture content of the processed staple meals plays a significant role in the rapid development of *T. castaneum* as compared with those that has low moisture content. This factor coupled with the quality of the processed staple meals greatly affects the development and susceptibility of the meals to *T. castaneum.* Semovita though is commercially produced, is often sold in a polyethylene bag which prevents it from being open to atmospheric moisture.

Table 4 revealed that millet and wheat meals suffered greater damage compared to others. The rate of damage in the case of yam and cassava flour was lower and more stable among the households. The coefficient of variation of 0.65 and 0.64 for millet and wheat flour, respectively implies that there was high variation in the rate of damage caused on the meals by the red flour beetle among the sampled households. It is an indication that there could be more risk in storing wheat and millet flours; while storing cassava and yam flour could involve less risk.

The implication of these results are that households that make large or purchases large quantity of processed staple meals from the market due to improved economy can loose such produce if the products are infested with *T. castaneum,* thus leading to wastage. This is because *T. castaneum* imparts a brownish tinge and pungent disagreeable odours in commodities, which is as a result of secretions by adults of benzoquinones from a pair of abdominal defense glands (Appert, 1987; Haines, 1991). Flours are therefore rendered useless and panification reduced (Lale *et al.*, 2002).

CONCLUSIONS

The fact that a household purchases a particular type of processed staple meals does not stop the produce from being infested by the store pest. Cross infestation of produce has been reported in *T. castaneum* (Okonkwo, 1983). *T. castaneum* is a colonizing species (Dawson, 1977), with a long life-span and long reproductive period (Haines, 1991). Thus the preparation and storage of ready-to-use flour, especially flour from wheat, millet, sorghum, maize, cassava, yam and semovita for prolonged periods, should be de-emphasised amongst farmers, food handlers and households in sahelian Africa and Asia where facilities to keep abate *T. castaneum* are not available. If this is not unavoidable then measures must be taken to protect such product in storage.

REFERENCES

Appert, J., 1987. The Storage of Food Grains and Seeds. Macmillan Publ. Ltd., London. pp: 146

Booth, R.G., M.L. Cox and R.B. Madge, 1990. IIE Guides to Insects of Importance to Man. 3. Coleoptera. International Institute of Entomology (An Institute of CAB International). The Natural History Museum, London, pp: 374.

Campbell, J.F. and C. Runnion, 2003. Patch Exploitation by Female Red Flour Beetles, *Tribolium castaneum*. J. Insect Sci., 3: 1-8.

Cotton, R.T., 1963. Pests of Stored Grains and Grain Products. Burgess Publ. Co., Minneapolis, MN. pp: 318.

Dawson, P.S., 1977. Life history strategy and evolutionary history of tribolium flour beetles. Evolution, 31: 226-229.

Dobie, P., 1974. The Laboratory Assessment of the Inherent Susceptibility of Maize Varieties to Post-Harvest Infestations by *Sitophilus zeamais* Motsch. (Coleoptera: Curculionidae). J. Stored Prod. Res., 10: 183-197.

Hagstrum, D.W., 1973. Infestation of Flour by *Tribolium castaneum*; Relationship Between Distribution of Eggs and Adults in a Dispersing Population. Ann. Entomol. Soc. Am., 66: 587-591.

Haines, C.P., 1991. Insects and Arachnids of Tropical Stored Products. Their Biological and Identification. 2nd Edn. Natural Resources Institute, Chatham Kent (UK) pp: 246.

Howe, R.W., 1962. The Effect of Temperature and Humidity on the Oviposition Rate of *Tribolium castaneum* (Herbst.) (Coleoptera: Tenebrionidae). Bull. Entomol. Res., 53: 301-310.

Lale, N.E.S. and A. Mustapha, 2000. Potential of Combining Neem (*Azadirachta Indica* A. Juss) Seed Oil with Varietal Resistance for the Management of the Cowpea Bruchid, *Callosobruchus maculatus* (F.) In Nigeria. J. Stor. Prod. Res., 36: 215-222.

Lale, N.E.S., F.A. Ajayi, B.M. Sastawa and P.E. Odo, 2002. Effects of grain breakage and processing method on the development of *Tribolium castaneum* (Herbst) (Coleoptera: Tenebrioridae) in grains and products from cultivars of dry season (Masakwa) sorghum (*Sorghur bicolor* Moench) in Maiduguri, Nigeria. Nige. J. Exp. Applied Biol., 3: 45-49.

Madrid, F.J., N.D.G. White and S.R. Loschiavo, 1990. Insects in stored cereals and their association with farming practices in Southern Manitoba. Can. Entomol., 122: 515-523.

Okonkwo, N.J., 1983. The pests of stored pearl millet, *Pennisetum americanum* (L.) (K. Schum) in Northern Nigeria. M.Sc. Thesis, Ahmadu Bello University, Zaria, Nigeria. pp: 129.

Rehm, S. and Espig, 1991. The Cultivated Plants of the Tropic and Subtropics. Cta Pub. Wagenigen, the Netherlands, pp: 562

Tanzubil, P.B., 1991. Reducing Post-harvest Losses in Stored Grain. Agric. Exten. Bull., Ghana MOA/NAES, Accra.

Ziegler, J.R., 1976. Evolution of the migration response: Emigration by *Tribolium* and the influence of age. Evolution, 30: 579-592.