Progeny Production of *Sitophilus zeamais* (Motchulsky) (Coleoptera: Curculionidae) and *Tribolium castaneum* (Herbst) (Coleoptera: Tenebrionidae) on Maize Kernels

Lawrence E. Wongo[1] and Arnold N. Onyango[1,2]

[1]Department of Food Science and Postharvest Technology, Jomo Kenyatta University of Agriculture and Technology, P.O. Box 62000, Nairobi, Kenya; [2] Okayama University, Japan.

ABSTRACT

Rates of population growth of *Sitophilus zeamais* (Motschulsky) and *Tribolium castaneum* (Herbst) on whole and processed forms of maize, and loss in dry weight of some of the forms of maize were determined. The forms of maize used were whole maize kernels, 10% maize grits, 100% maize grits and maize flour. The population of *S. zeamais* increased rapidly in whole maize kernels and 10% maize grits treatments, causing a mean loss in dry weight of 10.8% and 9.2% respectively, in 73 days. Comparatively fewer *S. zeamais* adult progeny were produced in the 100% maize grits treatment and in maize flour, and all adult weevils died within 2-3 weeks. The population of *T. castaneum* increased slowly in the whole and 10% maize grits treatments, causing only 1.48% dry matter loss in whole maize kernels during the 75-day developmental period. The population of *T. castaneum* increased significantly ($P<0.05$) in the 100% maize grits treatment than in the whole or 10% maize grits and considerably large numbers of *T. castaneum* adults were produced in the maize flour.

KEYWORDS: Maize, cracked, grain, pests, *Sitophilus zeamais*, *Tribolium castaneum*

1.0 INTRODUCTION

Maize (*Zea mays* (L.)), is one of the most important food crops in sub-Saharan Africa and a major staple food crop grown in many parts of Kenya (Anonymous 1984). Unfortunately, maize and its products usually experience severe quantitative and qualitative loss as a result of infestation by many species of storage insect pests. These losses can be very high, particularly within the tropical and sub-tropical regions, because of the high temperatures and relative humidity (r.h.), which favour rapid multiplication of storage insects throughout the year. Among the various storage insect pests of maize are the maize weevil, *Sitophilus zeamais* (Motschulsky) and the red flour beetle, *Tribolium castaneum* (Herbst), both of which are cosmopolitan insect pests of stored cereal grains of economic importance, having achieved pest status in many parts of Africa, including Kenya. *Sitophilus zeamais* is more commonly associated with whole maize grain (Longstaff 1981) and causes serious damage to maize in the warm sub-tropical and tropical climates (Dobie *et al.* 1985). *Tribolium castaneum* is more frequently a pest of damaged small-grained cereals including flour. Earlier, Pant and Dang (1969) reported that *T. castaneum* developed successfully in flour of *Penisetum typhoides*. Haubruge and Verstraeten (1987) found that *T. castaneum* populations developed faster on whole maize grains, in the presence of *Prostephanus truncatus* a storage insect pest that is capable of causing severe damage to maize on the cob, than would otherwise be the case. They suggested that this probably reflects the status of the species as secondary and primary pests of whole maize and its products respectively. Freshly hatched larvae of *T. castaneum* could not attack undamaged wheat, but some older larvae did although they grew slowly in the undamaged grain.

The present study was conducted to determine the relative success of *S. zeamais* and *T. castaneum,* to multiply in whole maize and its processed forms, under controlled laboratory conditions. The parameters measured were the number of progeny produced and the resultant loss of grain weight.

2.0 MATERIALS AND METHODS

2.1 Test insect species

The two economically important insect species of stored-products used in the study were *S. zeamais,* a primary insect pest of stored cereal grains and *T. castaneum,* a secondary insect pest of stored grains and its products. Both species were obtained from laboratory cultures at the National Research Laboratories (NARL) of the Kenya Agricultural Research Institute (KARI). *Sitophilus zeamais* was maintained for several generations on whole maize and *T. castaneum* on a mixture of 95% maize flour and 5% yeast extract. The insects were reared in a constant temperature and humidity room at 27 ± 3 °C and 65 ± 5% r.h., before being used for the tests.

2.2 Test maize grain

The maize grains used in the tests were obtained from the Jomo Kenyatta University of Agriculture and Technology (JKUAT) Tuition Farm. The grains were placed in a deep freezer at -14°C for two weeks to disinfest them of any insects from the field. The maize was then stored in a controlled temperature and humidity (CTH) chamber at 5 °C, until used in the tests. The maize was partitioned into three particle-size ranges. Whole grain maize was shelled and passed twice through a 5/16-inch (8 mm) round-hole sieve to remove dust, small pieces and broken kernels. Visual analysis of six 200g random samples showed that the whole grain contained no less than 98% whole kernels ($\bar{x}$= 98.3, s = ± 0.2, $P<0.05$). The 100% maize grits (particle size 1.0-4.8 mm) was maize grain broken by coarsely grinding it in a coffee grinder and passing it through a 2.38 mm wire screen sieve, but not through a 1.67 mm wire screen sieve. Maize flour was prepared by grinding whole maize using a laboratory hammer mill (Mitamura Riken Kyogo Inc. Tokyo, Japan), then passing it through a 841-micron screen sieve, but not through a 105-micron screen sieve. Most of the embryo remained in the maize flour.

The maize preparations were then tempered to a moisture content of approximately 13.5% wet-weight basis (w.b.), as determined using the standard air-oven method (Hart *et al.* 1959), and sealed in containers for seven days at -15 °C before use to ensure that it was free of any foreign insects. The sealed materials were then equilibrated at room temperature for three days before infestation.

2.3 Infestation with insects

Four treatments of maize were tested, namely; whole kernels, 10% maize grits, 100% maize grits and maize flour. Six 300g samples of each treatment medium were prepared, placed in 0.5 litre mason jars and infested with each insect species.

For the 10% maize grits sample, the jars were agitated to uniformly disperse the maize grits in the whole maize as homogeneously as possible. All mason jars were fitted with 60 mesh brass wire screen, covered with filter paper to allow free air movement while preventing entry of dust and insects from escaping. Fifty unsexed adult insects of each species, 1-2 week old (Dobie 1974), were placed in each jar and allowed to mate. The females were allowed to oviposit eggs for seven days, after which they were discarded. All jars were held in the CTH chamber at 28 ± 1°C and 67 ± 3% r.h., with a 12:12h light to dark period.

In case of *S. zeamais*, the whole maize grain was sieved after 73 days to remove adult progeny insects and frass. The grain was weighed, moisture content determined, and the percentage loss of dry weight calculated. Insects, frass and maize grits were removed from the 10% maize grits treatment by sieving. After removing the insects and frass from the treated samples, the weight and moisture contents were determined, and the percentage weight losses calculated. The weight losses arising from portions of the 100% maize grits and maize flour eaten by the weevils were assessed as the difference between the dry weight of samples at the time of infestation and day 73 after adjusting for moisture at the end of the experiment.

In case of *T. castaneum*, the whole kernel treatment was sieved through a U.S Standard No. 10 sieve after 75 days to remove insects and frass. The weight and moisture content were determined, and the percentage weight loss in whole maize calculated. The adult insects, pupae and larger larvae (third instar and older) were removed by sieving and then counted. The percentage weight losses in the 100% maize grits and maize were computed as the difference between dry weight of samples at the time of infestation and day 75 of the fraction of the same samples at the end of the experiment.

2.4 Statistical analysis

Data on adult progeny insect populations and those of the weight losses of grain from each test, expressed as percentages, which were transformed by taking the arcsin of the squareroot, were analyzed using a Statistical Analysis System (SAS) (SAS Institute Inc., Cary, NC 1985) computer package as a completely randomized design, by one-way analysis of variance (ANOVA) procedure, to determine the performance of each insect species in the different forms of maize. Differences among treatment means for each parameter were determined on the basis of Fisher's Least Significant Difference (LSD) test, at $P = 0.05$, when the F-test indicated significant differences (Snedecor and Cochran, 1980). No comparison of species of insect was performed based on their responses to the different maize forms, because of their different feeding behavior and biology.

3.0 RESULTS AND DISCUSSION

3.1 Effect on *S. zeamais*

Table 1 summarizes the results for the data on the performance of *S. zeamais* in the different forms of maize grain. *Sitophilus zeamais* populations developed rapidly in both the whole maize and 10% maize grits treatments. The mean percentage weight loss for the whole grain treatment was 10.8%, whereas in the 10% maize grits treatment, the mean percentage weight loss was 9.2%. The means were not significantly different at the 0.1 level (Table 1).

Table 1. Mean numbers of insects and percentage weight loss resulting from 50 adults of *S. zeamais* in 300-g samples of whole and processed maize

Treatment	Mean number of insects	Mean % weight loss (± SD)
Whole maize	1343.8 a	10.8 ± 1.70 a
10% maize grits	1151.2 a	9.2 ± 0.85 a
100% maize grits	77.3 b	2.9 ± 0.22 b
Maize flour	52.2 b	1.3 ± 0.12 b

n = 6; Means in column followed by the same letter are not significantly different according to Fisher's LSD at 0.05 level

Apparently, there were sufficient whole maize kernels to produce as many weevils in the 10% cracked treatment as in the whole grain. Losses in the 100% grits and maize flour samples were negligible and not significantly different ($P>0.05$) from each other, but were statistically different ($P<0.05$) from the other two treatments. Morrison (1964) observed that maize weevils produced more adult progeny in whole kernels than in halved or smaller pieces of sorghum kernels and our results corroborate this. In addition, this is in agreement with the established status of this species as an internally feeding primary pest of stored sound and whole grains. The female of the species of this insect escavates a hole through the pericarp to the endosperm into which it deposits an egg, and then secretes a mucilaginous eggplug on top of the egg as the ovipositor is withdrawn (Longstaff 1981). The newly hatched larva feeds and develops, finally emerging as an adult. One reason for this behavior is the fact that the larva of this species is legless and, by placing its egg directly within the endosperm portion of the maize kernel, the young larva does not have to wander around for long in search of food, exposed to its predators. This is probably one reason among others, that *S. zeamais* cannot successfully develop in flour. All of the adult weevils died within 2-3 weeks after being placed in maize flour, while nearly all the adult progeny insects, including the original adults in the whole maize and 10% maize grits were alive after 73 days. In another test in the laboratory (unpublished), most individuals in a population of *S. oryzae* survived for more than 90 days on clear wheat flour, so the early mortality of the weevils in maize flour could not be plausibly explained.

3.2 Effect on *T. castaneum*

Many of the *T. castaneum* adults observed in the different maize sample treatments were newly emerged, indicating that the developmental period of the species may be about 70 days in these media forms under the conditions of the study. The insects developed slowly and caused little weight loss in the whole maize and 10% maize grits. In the 100% maize grits and maize flour, a slightly higher and significantly different ($P<0.05$) weight losses were observed from the other two treatments. In addition, the beetles effected a ten-fold population increase in the 100% maize grits (Table 2). The population of adult progeny insects increased very rapidly in the maize flour. This finding is consistent with the results reported by Li-Li and Arbogast (1991), who found that egg production, development and survival rates were significantly higher on flour and gritted maize grain than on undamaged maize kernels.

Table 2. Mean numbers of insects and percentage weight loss resulting from 50 adults of *T. castaneum* in 300-g samples of whole and processed maize

Treatment	Mean number of insects	Mean % weight loss (± SD)
Whole maize	270.7 a	1.48 ± 0.15 a
10% maize grits	246.7 a	1.92 ± 0.24 a
100% maize grits	610.0 b	4.78 ± 0.89 b
Maize flour	1419.0 c	5.66 ± 0.71 b

n = 6; Means in column followed by the same letter are not significantly different according to Fisher's LSD at 0.05 level

Weston and Rattlingourd (2000) also reported that *T. castaneum* reached the highest numbers on split maize kernels than in whole kernels. Results of the effect of processing millets and gritting, or damaging wheat, significantly increased their susceptibility to *T. castaneum, T. confusum* and other storage insects. Furthermore, millets in the flour form experienced the most damage by these insects (Gueye and Delobel 1999, Sinha 1972, Howe 1973, White 1982). Wongo and Pedersen (1989) and White (1982) found that exposure of the germ was generally necessary for survival and development of young *T. castaneum* larvae and that, the rate of development increased with the degree of exposure of the germ. Newly hatched larvae of *T. castaneum* were observed to encounter some difficulty in penetrating the intact pericarp. However, gritting the maize and exposing the germ rendered the grain suitable for larval penetration, feeding and development, since *T. castaneum* is basically an external feeding secondary pest of stored grain (White 1982). Although it is commonly believed that *Tribolium* spp. cannot attack whole kernels, Birch (1947) and Daniels (1956) reported them developing on whole wheat. The "whole maize" used in this study had up to 2% broken kernels, which could have been influential in the population development of the beetles, but it is obvious that whole kernels of maize are not as susceptible as broken kernels.

4.0 CONCLUSION

Our results indicate that *S. zeamais* performed better on whole maize and 10% maize grits, causing considerable damage and weight loss to the two forms of grain respectively, but not on 100% maize grits and maize flour. In contrast, *T. castaneum* performed better on the flour and gritted maize than on the whole maize and 10% maize grits, as indicated by the comparatively large numbers of progeny produced on the 100% grits and maize flour, and the increased weight losses. This indicates that larval feeding is greatly enhanced by processing whole maize. It is also clear from the results that stored maize and other cereal grains in sound, whole and clean condition may be damaged by *S. zeamais*, a primary insect pest of stored grain. Furthermore, the study also indicates that, once grain is damaged, either mechanically or through insect infestation, it becomes prone to attack by secondary insect pests of stored grain, such as *T. castaneum*. Even though *T. castaneum* does not normally cause severe damage and weight loss to grain, it is capable of inflicting economically significant quality loss due to contamination, which may cause rejection of the grain or render it unfit for both human and livestock consumption. In addition, *Tribolium* spp. and other externally feeding species of insects, as well as associated moulds, are known to cause considerable seed damage and loss.

ACKNOWLEDGEMENT

We acknowledge the Department of Food Science and Post-harvest Technology, Jomo Kenyatta University of Agriculture and Technology (JKUAT), for providing laboratory space and equipment. We are also grateful to the JKUAT Farm for the maize and The National Agricultural Research Laboratories (NARL) of the Kenya Agricultural Research Institute (KARI), for providing the insects used in this investigation.

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