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Host type and textures on the survival of *Tribolium castaneum* (Coleoptera: Tenebrionidae) parental and filial generations

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Abstract
The effect of eight different hosts in different textures on survival of *Tribolium castaneum* was investigated. The result obtained indicated that survival of parental adult beetles was significantly (P<0.05) higher in broken grains and flours than in whole grains of all cereals both in the first and second generations. Significantly (P<0.05) higher number of larva, pupa and adult progenies emergence of *T. castaneum* was also recorded in flours and broken textures of cereals than in all textures of pulses both in the first and second generations. Besides, more larvae, pupae and adults progenies were emerged in damaged and flour textures of cereals during the first generation than in the second generation that in turn indicated quality degradation of grains as period and generation has increased. In conclusion, cereals in damaged and flour forms in general are the most preferred hosts of *T. castaneum* than pulses.

Keywords: *T. castaneum*, survival, emergence, hosts, textures

1. Introduction
Stored food, including grain, cereals, cereal products, dried fruit food, nuts, spices, drugs and many others are liable to be infested by large number of insects, most of which are cosmopolitan in distribution [1]. These pests are belongs to two major groups of insects; Coleoptera (beetles) and Lepidoptera (moths and butterflies), and several species of them attack crops both in the field and in store [2]. They feed directly on commodities and can be conveniently divided into primary pests (such as *Callosobruchus* sp., *Sitophilus* sp. and *Rhyzopertha* sp.) those that attack intact commodities, and secondary pests (such as Oryzaephilus *sp.*, Cryptolestes sp., *Cadra* sp. and *Tribolium* sp.) which require the commodity to be damaged before they can attack it [3].
Worldwide losses in stored grains caused by insects have been estimated to be between 5-10% in temperate and 20-30% in tropics [4]. These losses during storage by insect pests can reach 50% of total harvest in some countries [5]. These and other factors mentioned above are evidences that indicate the relevance of both primary and secondary insect pests and the presence a need to understand their basic aspects. As a result, it is imperative to design and conduct researches on their basic aspects (like for instance their life cycle, behavior, ecology, economic importance or their status and the like) of such pests including *T. castaneum*. Hence, the current investigation was initiated with the following objectives: 1) to determine the effect of different hosts in different forms to some biological parameters of *T. castaneum*, 2) to determine appropriate hosts of *T. Castaneum* from grains of local market under laboratory condition and 3) to determine the appropriate host textures of *T. castaneum*.

2. Materials and Methods
2.1 Mass rearing of test insects
Adult *Tribolium castaneum* were obtained from Addis Ababa University insect science laboratory and reared on broken grains and flour of different cereal grains (maize, barley, wheat, and sorghum) at 27±2 ºC and 60-65% relative humidity, between December 1 - 22 of 2010.

2.2 Grain collection and preparation
One and half kg (kilo gram) of eight types of grains or hosts were purchased from local market called Merkato (Ehil-berenda). Twenty g (gram) of each of these grains were ground in to

different textures with grinding mill and in to flour form by using an electric milling machine. Two different levels of percentages of broken orunbroken grains were produced by calculating the different percentages from 20 g of different grains, thus constituting 10 (mechanically damaged) and 50% broken (coarse). The different textures produced; 10 and 50% broken, whole flour, and whole grain (control) were kept in an oven at 40◦C for four hours to disinfest from internal infestation. Then 20 g of each of the four distinct textures (including the control) of the grains were put in 32 one liter capacity glass jars each and 7 pairs of 1-3 days old adult *T. castaneum* were introduced in each jar containing 20 g of each of the three distinct forms of the grains. The jars were then covered with nylon mesh and held in a place with rubber bands to allow ventilation and to prevent the escape of the experimental insects. Then the different textures of the grains in each of the 32 glass jars were kept under laboratory condition and female beetles were allowed to lay eggs for 20 days after which all dead or live insects were removed with sieve and counted. Thereafter, the treatments were left and checked daily until larva, pupa and adult emergence respectively. Larva, pupa and adult emergence in each treatment was taken and recorded for 12, 5 and 20 days in succession in each replicate or treatment texture from the start of larva, pupa and adult emergence, respectively. All adults that emerged were removed from each treatment at the time of final recording for a period of two generations. The treatments were arranged in a completely randomized design in three replications.

The treatments were grain textures **(**whole grain, mechanically damaged, coarse and flour), and grain type such as cereals (maize, wheat, sorghum, barley) and pulses (field pea, haricot bean, faba bean, chick pea).

2.3 Data Analysis

Data entry and analysis were done using Microsoft Excel, SAS and MSTAT soft wares. Data were transformed using log transformation and again back transformed in to the original data for presentation. To observe the effect of treatment on parental adults' mortality, and larvae, pupae and adults progenies development in the above experiment, appropriate statistical method, two way ANOVA was used and significant differences between the means was separated using Tukey's honestly significant difference (HSD) test.

3. Results

3.1 The effect of host types and textures on the mortality of parental *T. castaneum* adults

The mean mortality of parental adult flour beetles was significantly (P<0.05) lower in cereals (maize, barley, wheat and sorghum) mechanically damaged, cores and flour textures than in pulses (chick pea, faba bean, field pea and haricot bean) of similar textures. Besides, almost all the parental adults were died in whole grains (control) of all tested hosts and there was no significant difference (P>0.05) between the cumulative mean mortality the experimental insect in them (Table 1).

Table 1: Mean number (Mean± SE) mortality of introduced *T. castaneum* adults

Hosts	Whole grains (control)	Mechanically damaged grains (10%)	Coarse (50%)	Flour
Maize	13.99±0.00Aa	0.99±0.59Bd	0.82±0.45Bd	0.58±0.29Bd
Barley	13.79±0.00Aa	1.00±0.60Bd	0.59±0.29Bd	0.00±0.00Bd
Wheat	13.66±0.02Aa	2.45±0.76Bc	0.58±0.76Cd	0.44±0.54Cd
Sorghum	13.29±0.04Aa	2.63±0.44Bc	2.28±0.66Bc	2.08±0.00Bc
Chick pea	11.58±0.08Aa	7.31±0.34ABb	5.80±0.20ABb	4.13±0.44Bb
Faba bean	13.99±0.00Aa	12.96±0.04Aba	11.58±0.07Ba	13.29±0.05 Aa
Field pea	14.00±0.00Aa	13.99±0.00Aa	13.29±0.05 Aa	12.64±0.24Aa
Haricot bean	14.00±0.00Aa	14.00±0.00Aa	12.90±0.08Aa	11.30±0.03Ba

Means followed by the same letters with in row (upper case letters) and within columns (lower case letters) are not significantly different, P>0.05%, Tukey's studentized range test (HSD).

3.2 The effect of host types and textures on the development of first and second generation (F_1 and F_2) of *T. castaneum* larva, pupa and adult progenies

The mean numbers of F_1 and F_2 *T. castaneum* larva, pupa and adult progenies produced in flour, cores and mechanically damaged textures of barley, maize, wheat and sorghum (cereals) were significantly (P<0.05) higher as compared to in pulses of similar textures both in the first and second generations. The mean numbers of F_1 and F_2 *T. castaneum* larva, pupa and adult progenies produced in the aforementioned textures of cereals were also significantly (P<0.05) higher as compared to the control (whole grains) in both the first and second generations. The maximum of these progenies emergence were being in flours, followed by coarse and mechanically damaged textures of cereals in general. Besides, more *T. castaneum* larvae, pupae and adults were developed during the first generation than in the second generation period of emergence in all hosts (grains) (Tables 2-7).

Table 2: The effect of different types of grains in different textures on the emergence of first generation (F1) of *T. castaneum* larvae (Mean ± SE)

Hosts	Whole grains (control)	Mechanically damaged grains (10%)	Coarse (50%)	Flour
Maize	0.58±0.55Da	27.84±0.03Cb	46.86±0.03Ba	104.1±0.01Ab
Barley	0.00±0.0 0Da	37.91±0.01Ba	47.28±0.15Ba	116.5±0.01Aa
Wheat	0.00±0.00Ca	23.56±0.05Bb	27.89±0.06Bb	101.36±0.05Ab
Sorghum	0.00±0.00Da	13.82±0.074Cc	23.56±0.17Bb	92.98±0. 17Ac
Chick pea	0.00±0.00 Ba	2.01±0.00Bd	3.15±0.49Bc	6.41±0.04Ad
Faba bean	0.00±0.00 Aa	0.00±0.00Ad	1.24±0.55Ac	1.31±0.16Ae
Field pea	0.00±0.00Aa	0.00±0.00Ad	0.00±0.00Ac	2.16±1.35Ae
Haricot bean	0.00±0.00Aa	0.00±0.00Ad	0.00±0.00Ac	0.55±0.29Ae

Mean followed by the different letters with in row (upper case letters) and within columns (lower case letters) are significantly different, $P<0.05$, Tukey's studentized range test (HSD).

Table 3: The effect of different types of grains in different textures on the emergence of second generation (F2) of *T. castaneum* larvae (Mean n± SE)

Hosts	Whole grains (control)	Mechanically damaged grains (10%)	Cores (50%)	Flour
Maize	0.00±0.00Da	37.02±0.01Cb	101.33±0.01Bb	280.83±0.00Ab
Barley	0.00±0.00Da	60.68±.03Ca	111.98±.01Ba	337.84±.00Aa
Wheat	0.00±0.00Da	15.23±0.04Cc	36.16±0.02Bc	125.77±0.01Ac
Sorghum	0.00±0.00Da	32.89±0.02Cb	41.98±0.04Bc	111.98±0.01Ad
Chick pea	0.00±0.00Aa	0.00±0.00Ad	0.00±0.00Ad	0.00±0.00Ae
Faba bean	0.00±0.00Aa	0.00±0.00Ad	0.00±0.00Ad	0.00±0.00Ae
Field pea	0.00±0.00Aa	0.00±0.00Ad	0.00±0.00Ad	0.00±0.00Ae
Haricot bean	0.00±0.00Aa	0.00±0.00Ad	0.00±0.00Ad	0.00±0.00Ae

Means followed by the different letters with in row (upper case letters) and within columns (lower case letters) are significantly different, $P<0.05$, Tukey's studentized range test (HSD).

Table 4: The effect of different types of grains in different textures on the emergence of first generation (F_1) of *T. castaneum* pupae (Mean ± SE)

Hosts	Whole grains(control)	Mechanically damaged grains (10%)	Coarse (50%)	Flour
Maize	0.44±0.29Da	25.30±0.05Cb	44.71±0.05Ba	99.00±0.00Ab
Barley	0.00±0.00Da	34.49±0.03Ca	42.66±0.02Ba	114.61±0.01Aa
Wheat	0.00±0.00Da	13.17±0.09Cc	26.57±0.05Bb	99.02±0.02Ab
Sorghum	0.00±0.00Da	20.40±0.03Cb	44.44±0.14Ba	90.83±004Ac
Chick pea	0.00±0.00Ba	1.66±0.16Bd	2.54±0.37Bd	5.72±0.05Ad
Faba bean	0.00±0.00Aa	0.00±0.00Ad	0.63±0.29Ad	0.92±0.45 Ae
Field pea	0.00±0.00Aa	0.00±0.00Ad	0.00±0.00Ad	2.04±1.18Ae
Haricot bean	0.00±0.00Aa	0.00±0.00Ad	0.00±0.00Ad	0.00±0.00Ae

Means followed by the different letters with in row (upper case letters) and within columns (lower case letters) are significantly different, $P<0.05$, Tukey's studentized range test (HSD).

Table 5: The effect of different types of grains in different textures on the emergence of second generation (F_2) of *T. castaneum* pupae (Mean ± SE)

Hosts	Whole grains (control)	Mechanically damaged grains (10%)	Cores (50%)	Flour
Maize	0.00±0.00Da	33.67±0.01Cb	92.33±0.01Bb	268.16±0.01Ab
Barley	0.00±0.00Da	60.68±0.03Ca	103.73±0.02Ba	337.84±0.00Aa
Wheat	0.00±0.00Da	14.04±0.04Cd	31.37±0.02Bc	113.83±0.01Ac
Sorghum	0.00±0.00Ca	30.41±0.03Bc	36.17±0.04Bc	108.65±0.01Ac
Chick pea	0.00±0.00Aa	0.00±0.00Ae	0.00±0.00Ad	0.00±0.00
Faba bean	0.00±0.00Aa	0.00±0.00Ae	0.00±0.00Ad	0.00±0.00Ad
Field pea	0.00±0.00Aa	0.00±0.00Ae	0.00±0.00Ad	0.00±0.00Ad
Haricot bean	0.00±0.00Aa	0.00±0.00Ae	0.00±0.00Ad	0.00±0.00Ad

Means followed by the different letters with in row (upper case letters) and within columns (lower case letters) are significantly different, $P<0.05$, Tukey's studentized range test (HSD)

Table 6: The effect of different types of grains in different textures on the development of mean number of fist generation (F_1) of *T. Castaneum* adults (Mean ± SE)

Hosts	Whole grains (control)	Mechanically damaged grains (10%)	Coarse (50%)	Flour
Maize	0.26±0.29Da	20.88±0.08Cb	40.69±0.04Ba	98.3±0.01A a
Barley	0.00±0.00Da	31.45±0.03Ca	41.67±0.03Ba	100.57±0.02Aa
Wheat	0.00±0.00Da	11.63±0.08Cc	24.75±0.06Ba	96.73±0.01Aa
Sorghum	0.00±0.00Ca	17.63±0.06Bb	17.98±0.18Ba	88.75±0.01Ab
Chick pea	0.00±0.00Ba	0.63±0.29Bd	1.94±0.25Bc	4.38±0.07Ac
Faba bean	0.00±0.00Aa	0.00±.00Ad	0.29±0.29Ac	0.29±0.29Ad
Field pea	0.00±0.00Aa	0.00±0.00Ad	0.00±0.00Ac	1.18±1.18Ad
Haricot bean	0.00±0.00Aa	0.00±0.00Ad	0.00±0.00Ac	0.00±0.00Ad

Means followed by the different letters with in row (upper case letters) and within columns (lower case letters) are significantly different, $P<0.05$, Tukey's studentized range test (HSD).

Table 7: The effect of different types of grains in different textures on the development of mean number of second generation (F_2) of *T. Castaneum* adults (Mean ± SE)

Hosts	Whole grains (control)	Mechanically damaged grains (10%)	Cores (50%)	Flour
Maize	0.00±0.00Da	29.90±0.00Cb	84.71±0.02Bb	262.03±0.01Ab
Barley	0.00±0.00Da	58.34±0.02Ca	99.00±0.00Ba	301.00±.00Aa
Wheat	0.00±0.00Da	11.67±0.12Cc	29.21±0.02Bc	108.65±0.01Ac
Sorghum	0.00±0.00Da	25.94±0.0Cb	32.89±0.01Bc	103.72±0.01Ac
Chick pea	0.00±0.00Aa	0.00±0.00Ad	0.00±0.00Ad	0.00±0.00Ad
Faba bean	0.00±0.00Aa	0.00±0.00Ad	0.00±0.00Ad	0.00±0.00Ad
Field pea	0.00±0.00Aa	0.00±0.00Ad	0.00±0.00Ad	0.00±0.00Ad
Haricot bean	0.00±0.00Aa	0.00±0.00Ad	0.00±0.00Ad	0.00±0.00Ad

Means followed by the different letters with in row (upper case letters) and within columns (lower case letters) are significantly different, $P<0.05$, Tukey's studentized range test (HSD).

4. Discussion

The death of almost all the parental adults which was observed on whole grains of maize, barley, wheat, sorghum, chick pea, faba bean, field pea and haricot bean in the current study might probably be due to the hardness of the cultivars that cause difficulty to insects to feed on them. In line with this finding it was also reported that survival of parental adult beetles was significantly lower in whole than in broken grains or flour, and for most of local wheat cultivars tested, the whole grains are more resistant to *T. castaneum* than broken grains or flour [6]. Similarly, it was also shown that undamaged grains were relatively resistant to infestation by *T. castaneum* in comparison with broken grains or whole milled flour [7]. Besides, it was also mentioned that *T. castaneum* is a cosmopolitan pest which primarily attacks milled grain products, such as flour and cereals, and both adults and larvae feed on grain dust and broken grains, but not the whole grains [8].

The lowest survival of flour beetles in pulses (chick pea, faba bean, field pea and haricot bean) damaged textures and flours in the present study were probably due to the in appropriateness of this hosts to *T. castaneum* survival which result in more pre adult stage mortality and eggs in viability. Similarly, it was indicated that *T. castaneum* feed on a range of commodity especially cereals and occasionally pulses [9]. The results also showed that both grain type (maize, barley, wheat, sorghum, chick pea, faba bean and field pea) and grain breakage in to mechanically damaged, coarse and flour textures have significant effect on the emergence of *T. castaneum* larvae, pupae and adults progenies. Accordingly, it was also shown that grain breakage has a significant effect on the development of *T. castaneum* [7]. Besides, it was also mentioned that *T. castaneum* is a cosmopolitan pest which primarily attacks milled grain products, such as flour and cereals, and both adults and larvae feed on grain dust and broken grains, but not the undamaged whole grains and spends its entire life cycle outside grain kernels [8].

According to the results of the current study all of the tested textures; flours, coarse textures and mechanically damaged and respectively were the most appropriate textures in almost all types of the cereal hosts for the development of *T. castaneum* larvae, pupae and adults progenies as compared to mechanically damaged texture. And even the mechanically damaged texture was the appropriate texture in almost all types of cereal hosts for the development of *T. castaneum* larvae, pupae and adults progenies as compared to the whole grain (the control). Similarly, the fact that *T. castaneum* is a polyphagous and cosmopolitan pest that feeds and thrives on broken grains, mostly of flour meals was also reported [10]. It was also indicated that both adults and larvae of *T. castaneum* feed on grain dust and broken grains, but not the undamaged whole grains and spends its entire life cycle outside grain kernels [8]. Results of the current laboratory study has also shown that unbroken grains were relatively resistant to the development of *T. castaneum* larvae, pupae and adults progenies, in comparison with broken grains or flour in all hosts in both 1st and 2nd generations. In related studies, it was also reported that whole grains were significantly more resistant to infestation by *T. castaneum* than broken grains or whole flour derived from all the millet cultivars screened [11, 7].

The current results also indicated the failure of *T. castaneum* population to increase with increased in generation period from first to second. This incapability of the insect pests to have a population increase as the generation period increased might probably due to deterioration of the quality of diet as generation increases. Similarly, it was also shown that the quality of diet presented to *T. castaneum* plays a major role in their development and population abundance [12]. Besides, it was also noted that nutritional quality of the flour medium is of the utmost importance to *Tribolium* sp. population dynamics, such that any slight change to the immediate environment can cause a significant decrease in the oviposition rate [13]. It was also reported that as the population density increases, the shared flour medium that *Tribolium* sp. occupy begins to lose its nutritional quality, often accumulating waste products and other ethyl- and methyl benzoquinones, produced by adults and released as defensive compounds [14].

5. Conclusion

In conclusion, cereals in damaged and flour forms in general are the most preferred hosts of *T. castaneum*, unlike pulses in all textures which are not hosts to it, and the whole grains are more resistant to *T. castaneum* than broken grains or flour. This study was done on the effect of 8 different local hosts in 4 different forms to some biological parameter of *T. castaneum* under laboratory condition. Hence, further investigation on the effect more hosts and textures on survival of *T. castaneum* larva, pupa and adult progenies under farmer's storage conditions need to be done. Besides**,** as *T. castaneum* mainly attack damaged cereal grains and flours, care should be taken while harvesting, trashing and transporting cereal grains, and efforts to control it should also focus on cereals than pulses. Furthermore**,** farmers living in developing countries particularly in tropics and sub tropics, including Ethiopia are recommended to store sound grains so that it helps them to reduce the attack of their grains by one of the most economically important storage pest, *T. castaneum*.

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