South Asian Journal of Experimental Biology

ISSN: 2230-9799 Vol. 2, Issue 3, Page 108-117 http://www.sajeb.org

REGULAR ARTICLE

Capacity of biodemographic developpment of *Tribolium castaneum* Herbst (Coleoptera, Tenebrionidae) and *Sitophilus zeamais* Motschulsky (Coleoptera, Curculionidae) in stored cereals in Senegal

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ARTICLE INFO

Article History:
Received: 3 May 2012
Revised: 24 May 2012
Accepted: 10 June 2012

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Keywords: food security, *Sitophilus zeamais*, *Tribolium castaneum*, cereals, losses, storage

ABSTRACT

To contribute to food security and reduce poverty among Senegaleses'populations through a strategy of integrated management of insect pests of cereal crops, experiments were conducted on corn and millet (in the grain form and flour form) to track development of *T. castaneum* and *S. zeamais* after infestations controlled. The mean duration of development of *S. zeamais* was 35.33 days in the kernels of corn. Its development was more favorable in corn stored in the form of grain but the grain was more resistant to *Sitophilus* after processing into flour. Millet was found to be more protected against attacks by *S. zeamais*. The average duration of development of *T. castaneum* was shorter in the grains of millet than in corn. The transformation of these grains into flour influenced the development of *T. castaneum* which was accelerated in the corn flour and slowed in the millet. The nature of the food affected the weight of *T. castaneum* when several grains were made available.

1. Introduction

In Senegal, as in most developing countries, particularly those in the Sahel, cereals are the staple diet of rural and urban populations. Several species and varieties of cereals are grown, but the millet, corn, rice and sorghum are among the major ones (Gueye et al., 2011).

Pearl millet (*Pennisetum glaucum* (L) R. Br), an annual cereal grass, is the staple food of millions of people in the Sahel zone and nearly 40% of the world production of millet comes from Africa (Dabre, 2008). Corn in American origin, is one of the twenty most important foods for human consumption as well in America and Africa (Camara, 2009). Indeed, food is usually attacked by insects during their storage since the beginning of human civilization. Losses are considerable in the humid tropics as the climate favors the development of pests (Dabre, 2008). In warm regions, several species are particularly recognized for their voracity to the stored corn. *Sitophilus zeamais* Motschlsky is universally recognized as one of the largest devastators of stored grains not only for its own consumption, but also because it opens the door to a wide variety of secondary pests like the red flour beetle (*Tribolium castaneum* Herbst) (Coleoptera, Tenebrionidae) which accelerates the damage

(Throne, 1994; Dabre, 2008).

Initial infestation of corn by *Sitophilus zeamais* occurs in fields just before harvest and insects are driven into the store where the population builds up rapidly (Appert, 1987; Adedire and Lajide, 2003; Asawalam et al., 2008). A single female can lay 300-400 eggs during its life; it lays eggs preferably in the apical third of the grain (Delobel and Tran, 1993). Development time for the full life cycle of this species is on average 36 days with a temperature between 27 and 31° C and 70% relative humidity.

Tribolium castaneum Herbst is a pest of stored products, best known in the tropics and subtropics. The insect is considered a secondary pest strict causing extensive damage on millet stocks beaten throughout the Sahelian zone. In case of heavy infestation, the adult releases substances that confer quinoline pungent odor and makes the bread difficult.

For a good knowledge of the Life history of these insects, it is essential to know how they react to changes in the nature of food resources.

is the present investigation was a part of the comprehensive approach for studying the effect of the nature of the food on the development capacity of *Sitophilus zeamais* and *Tribolium castaneum*, grain storage pests, temperature and to the ambient relative humidity.

2. Materials and Methods

2.1. Sampling

The samples were taken respectively on corn for *S.zeamais* and on millet for *T.castaneum*. The different localities sampled are: Mbam (14°07' North and 16°26' West) in the region of Fatick, Sandiara (14°26' North and 16°47' West) in the region of Thiès, Karang (13°36' North and 16°25' West) at the border between Gambia and Senegal and Diaroumé (12°59' North and 15°37' West) in the region of Sédhiou.

In each locality, grains of millet and corn were collected in infested attics producers. These samples were then brought to the laboratory and preserved in jars of 17cm in diameter and 23cm in height until adult emergence that was used for breeding.

2.2. Breeding ground and selection of couples

The insects used were reared in the laboratory in glass jars containing millet and corn.

For couples, we removed first of all insect mass rearing and three days later, we used a sieve. Then adults were isolated in Petri dishes after two days to ensure three days old. Sex determination was done according to Delobel and Tran (1993) who reported that in *T.castaneum*, there was the presence of a tuber pilifere rounded at the base of the anterior femur in males and absent in females. For *S. zeamais*, after removing adults jars, they were placed in Petri dishes for two days and then, in a dark room to isolate pairs. These were then placed in Petri dishes 9 cm in diameter and 1.5 cm containing the cereal to infest.

2.3. Development of T. castaneum and S. zeamais on corn and millet husk

The cereals used for experimentation as an insect food were millet and corn. The experiment was done on millet and corn shell. In our experiments the temperature varied from 28.5 to 31 ° C and humidity of 41-67%. It had 15 boxes numbered 1 through 15 for each cereal corresponding to 15 repetitions. For insects having the same surface for the incubation, 20g of grains were used repeatedly. The content of the boxes was infested by three pairs of *T. castaneum* from millet (Figure 1A) on the one hand and three pairs of *S. zeamais* from corn (Figure 1B) on the other hand, aged at least three days and 10 days more to ensure that spawning to well and truly begun (females of *T. castaneum* and *S. zeamais* begin their spawning from the age of three days). The date of infection, corresponding to the first day of the experiment, was noted. Couples were used to infest successively three boxes at a rate of 24 per box.

The dishes were then placed in the experimental chamber. The first experiment was done with individuals of *T. castaneum* from millet and the second with *S. zeamais* from corn. The device used was the block of Fisher. At the end of development, observation of adults began the third week and was done daily. The total number of insects per box per day was counted and every individual was then weighed less than 24 h after its emergence.

At the end of these obserations, life-history parameters were determined as follows:

- **The development time:** Among Coleoptera, spawning was spread and lasted almost the entire adult life. Development time ranges from oviposition (egg laying) to adult emergence;

- **The Weight:** the average weight was obtained by dividing the sum of individual weights by the number of individuals;
- **The sex-ratio** which gives the percentage of females compared to all descendants.

2.4. Development of T. castaneum and S. zeamais on corn flour and millet

The same experimental protocol was used for infestations of corn flour and millet from communities Sandiara, Mbam, Diaroumé and Bambey. It had 12 boxes numbered 1 through 12 for each crop and corresponding to 12 repliacates. 10 g of flour was used repeatedly by insects to provide a substantially identical surface nesting. For each insect species, a box was infested by an elderly couple from at least three days and 10 days. Each pair was used to infest a box. The couple spent 24 h in each box before being removed. The dishes were then placed in the experimental room. Observation of larval emergence (which was done daily) starting on the tenth day because it was difficult to count the eggs, without providing a means to experience. The total number of larvae per box per day was counted. This observation was followed by the larvae of pupae. For each of these stages of development, the first day of appearance was noted. It was the same for the emergence of adults. At the end of development we counted the number of adults per box per day. Each individual was then weighed less than 24 h after its emergence.

3. Results

3.1. Life-history parameters of T. castaneum on corn and millet

3.1.1. Average duration of the development cycle

The average duration of the development cycle varied with food for *T. castaneum*. This duration was more important in corn (36.3 ± 1.4 days) than in millet (29.38 ± 1.45 days). The results are given in Table 1.

3.1.2. Weight of adults

Insects that emerged in each food were individually weighed 24 h after discharge. Our results indicated that the average weight of *T. castaneum* had increased in corn (2.02 ± 0.17 mg) in absolute value greater than those operating in millet (1.99 ± 0.15 mg). These results are shown in Table 1.

3.1.3. Sex-ratio

The sex ratio (percent female) was in favor of male *T. castaneum* both in corn than in pearl millet (Table 1).

Foodstuffs	Corn kernels	Millet grains
Development time (days)	36,3 ± 1,4	29,38 ± 1,45
Mean weight (mg)	2,02 ± 0,17	1,99 ± 0,15
Number of adults sexed	218	160
males	133	107
females	85	53
R (%)	38,99	33,13

Table 1: Average length of development, Average weight and sex ratio (R) of T. castaneum based food from 28.5 to 31° C and 41-67% RH.

3.2. Settings Biodemographic S. zeamais on corn grain and millet

3.2.1. Average Length of development cycle

The average duration of the development cycle was 35.33 ± 5.51 days in corn. *S. zeamais* had not lain on millet during the 24 h of infestation. The results are reported in Table 2.

3.2.2. Weight of adults

Our results indicated that the average weight of *S. zeamais* increased appreciably in corn and it was 2.37 ± 0.15mg. There were no adults on target. These results are summarized in Table 2.

3.2.3. Sex ratio

The sex ratio (percent female) was in favor of males of *S. zeamais* in corn (Table 2).

Foodstuffs	Corn kernels	Millet grains
Development time (days)	35,33 ± 5,51	0
Mean weight (mg)	2,37 ± 0,15	0
Number of adults sexed	37	0
Males	26	0
Females	11	0
R (%)	29,73	0

Table 2: Average length of development, Average weight and sex ratio (R) of *S. zeamais* based food from 28.5 to 31 ° C and 41-67% RH.

3.3. Biodemographic parameters of T. castaneum on corn flour and millet

3.3.1. Kinetics appearance of larvae

The average number of larvae of *T. castaneum* ob-

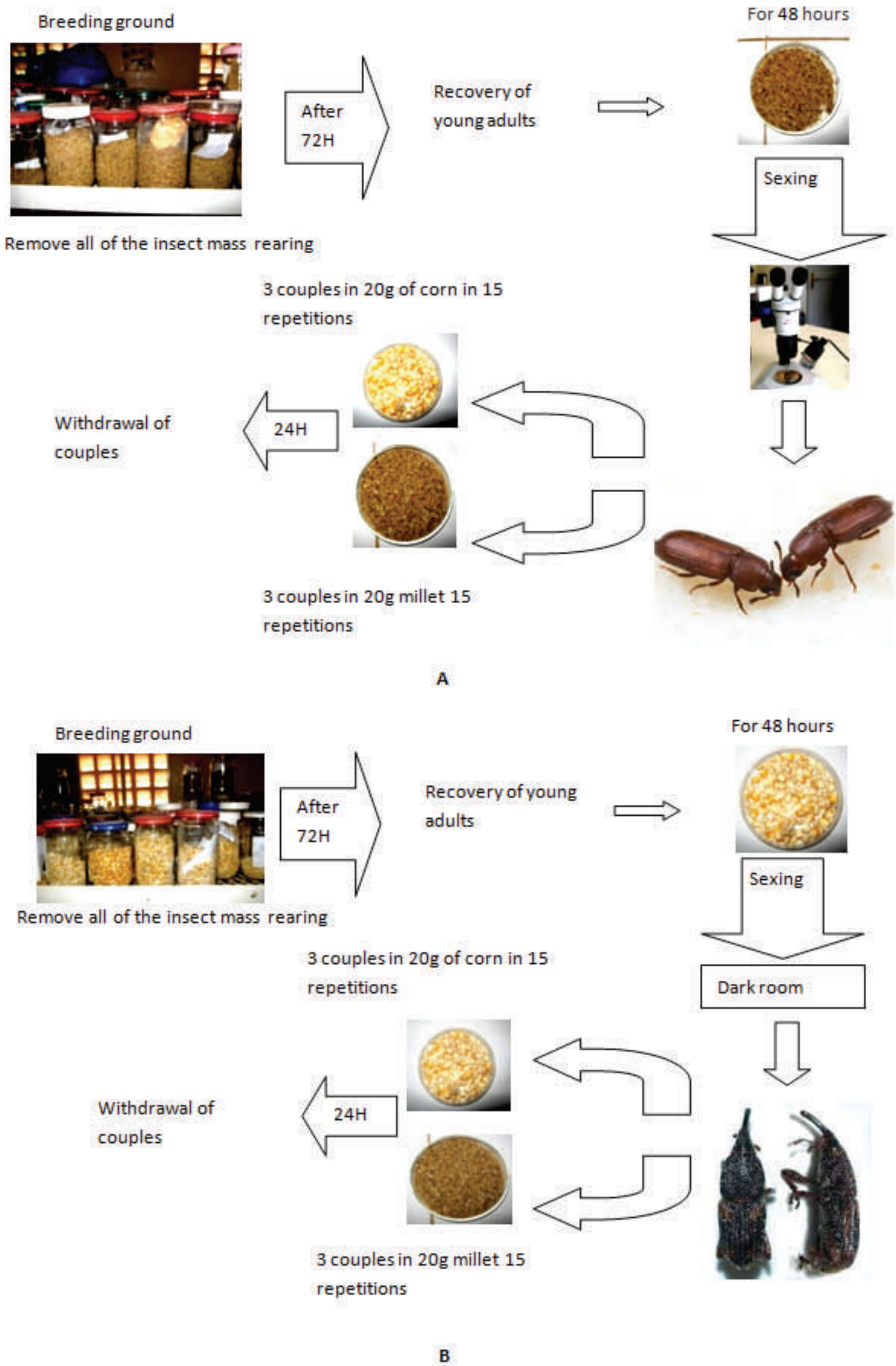

Figure 1: Experimental.

served after ten days of experimentation decreases gradually. The maximum was observed at the first day of appearance of larvae up to 7.57 on the millet flour and 7.33 on corn meal. The results are given in Table 3.

Days	1	2	3	4	5
Average number of larvae *T.castaneum* on corn flour	7,33	2,33	1	0	0
Average number of larvae *T.castaneum* on millet flour	7,57	1,5	1	1	1,8

Table 3: Average number of larvae of *T. castaneum* in corn flour and millet at 28.5 to 31 ° C and 41-67% RH.

From day one, the average number of larvae was substantially the same on millet flour (7.57) and corn (7.33). The average number decreases as the days up to vanish from the fourth day to *T. castaneum* infesting corn flour. The average number of larvae increased slightly from day 5 (1.8) for *T. castaneum* on millet flour (Figure 2).

3.3.2. Average length egg-pupa and pupa-adult T. Castaneum

Our results indicated that the egg-pupal period of *T. castaneum* was longer in millet flour (25.22 ± 0.83 days) than corn (21.25 ± 0.71 days). By cons, the pupa-adult period was approximately the same for *T. castaneum* in flour of corn and millet, respectively, 6.25 ± 0.71 days and 6.09 ± 1.51 days (Table 4).

Foodstuffs	Corn flour	Millet flour
Egg-pupal duration (days)	21,25 ± 0,71	25,22 ± 0,83
Pupa-adult period (days)	6,25 ± 0,71	6,09 ± 1,51
Development time (days)	26,25 ± 0,46	30,33 ± 0,87
Mean weight (mg)	2,03 ± 0,17	1,91 ± 0,13
Number of adults sexed	57	68
Males	31	40
Females	26	28
R (%)	45,61	41,18

Table 4: Average length egg-pupa and pupa-adult, Average length of development, Average weight and sex ratio (R) of *T. castaneum* based foods from 28.5 to 31 ° C and 41-67% RH.

3.3.3. Average Length of development cycle

The average duration of the development cycle varied with food for *T. castaneum*. This time was more important millet flour (30.33 ± 0.87 days) than corn flour (26.25 ± 0.46 days). The results are given in Table 4.

3.3.4. Weight of adults

Our results indicated that the average weight of *T. castaneum* has increased in the corn flour (2.03 ± 0.17 mg) and were more important than playing in the millet flour (1.91 ± 0.13 mg). These results are shown in Table 4.

3.3.5. Sex ratio

The sex ratio (percent female) was in favor of male *T. castaneum* as well in corn flour as millet (Table 4).

3.4. Biodemographic Parameters of S. zeamais on corn flour and millet

S. zeamais has not laid during the 24 h of infestation on corn flour and millet. Even after five days of infection, no eggs were laid. Thus, the Biodemographic parameters are not determined.

3.5. Comparison of Biodemographic parameters of T. castaneum according to the nature of food

3.5.1. Average Length of development cycle

The average duration of the development cycle varied with the type of food for *T. castaneum* (Figure 3). In corn, this duration was 36.3 ± 1.42 days in the grains and 26.25 ± 0.46 days in the flour. This period was 29.38 ± 1.45 days in the grains and 30.33 ± 0.87 days in the millet flour. For a given grain, the same letter on the bar chart shows that the values they do not differ at $p < 0.05$ (Student's t test).

	Corn kernels	Millet grains	Corn flour	Millet flour
Corn kernels	-	t = 0,74	t = 0,06	t = 0,28
Millet grains	-	-	t = 0,13	t = 0,04 P < 0,05*
Corn flour	-	-	-	t = 0,35
Millet flour	-	-	-	-

Table 5: Comparison of average length of development cycles *T. castaneum* depending on the type of food.

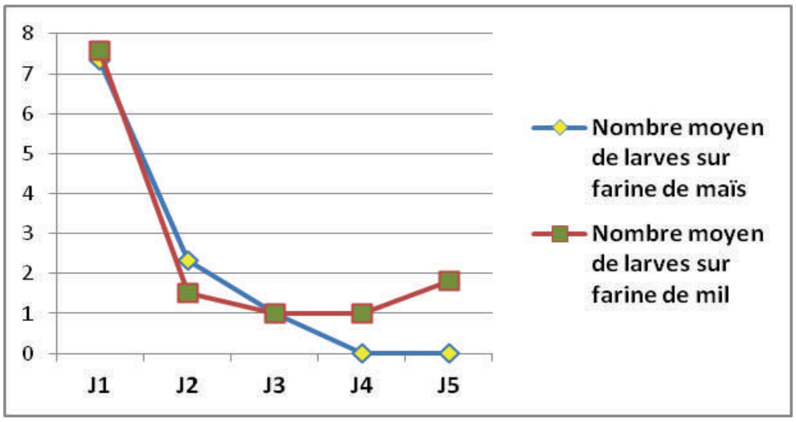

Figure 2: Kinetics of appearance of larvae of *T. castaneum* on corn flour and millet based on days.

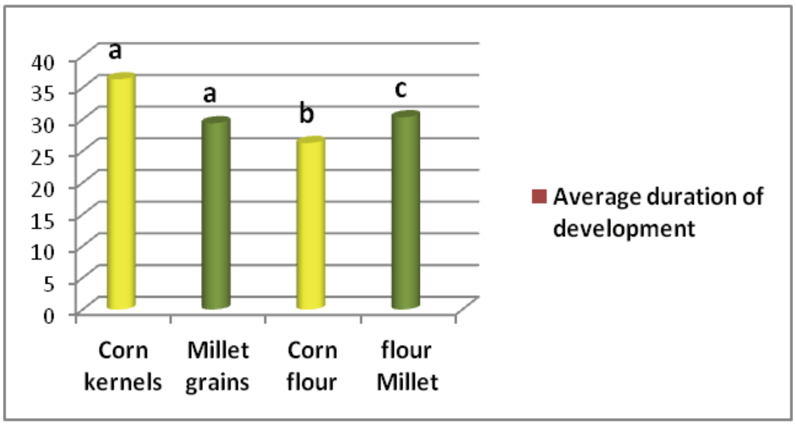

Figure 3: Average length of the development cycle of *T. castaneum* depending on the nature of the food.

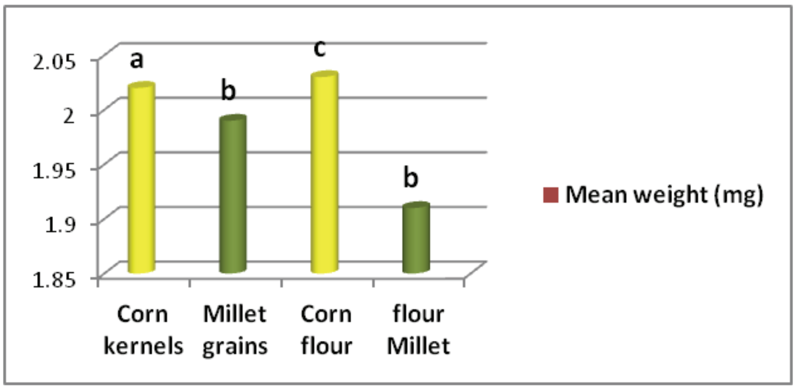

Figure 4: Average weight of *T. castaneum* images depending on the nature of the food.

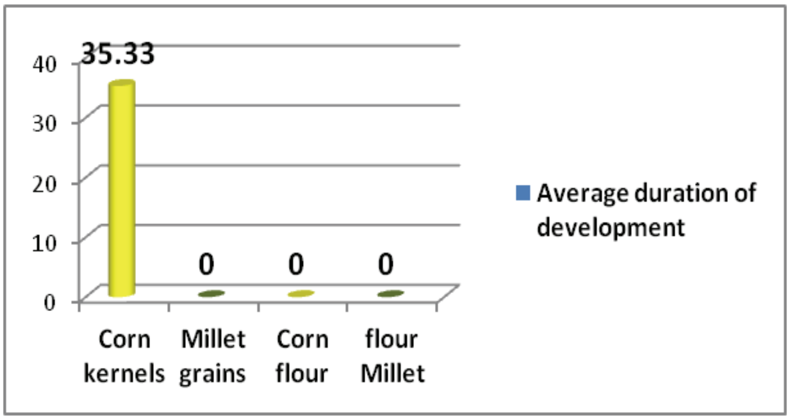

Figure 5: Average length of the development cycle of *S. zeamais* depending on the nature of the food.

The results are given in Table 5. The average duration of the development cycle on target was lower for insects moving in the grains (29.38 ± 1.45 days) than those reared in flour (30.33 ± 0.87 days). The opposite was observed in corn (36.3 ± 1.42 days in the grains and 26.25 ± 0.46 days in the flour). In addition, the average duration of development differed significantly from *T. castaneum* in the corn kernels in *T. castaneum* in grain of millet (t = 0.74) as well as in the millet flour and corn (t = 0.35). These same results are found in grains and corn meal (t = 0.06).

3.5.2. Weight of adults

Our results indicated that the average weights for *T. castaneum* have evolved in the grains of millet are 1.99 ± 0.15 mg and 1.91 ± 0.13 mg in the flour. The average weight was much more important for insects that grow in the corn kernels (2.02 ± 0.17 mg) and corn meal (2.03 ± 0.17 mg) (Figure 4). For a given grain, the same letter on the bar chart shows that the values they do not differ at $p < 0.05$ (Student's t test).

The weight difference between the means was significant imagoes of *T. castaneum* raised on corn kernels and those reared on millet grains (t = 0.13). The same situation was observed between *T. castaneum* raised on corn meal and *T. castaneum* on millet (t = 0.83). We also note a significant difference between *T. castaneum* raised on grains and one that has grown on corn meal (t = 0.47). These results are summarized in Table 6.

	Corn kernels	Millet grains	Corn flour	Millet flour
Corn kernels	-	t = 0,13	t = 0,47	t = 0,53
Millet grains	-	-	t = 0,12	t = 0,02 P < 0,05*
Corn flour	-	-	-	t = 0,83
Millet flour	-	-	-	-

Table 6: Comparison of average weights of *T. castaneum* depending on the type of food.

3.5.3. Sex ratio

The sex ratio (percent female) was in favor of males regardless of the nature of the food for *T. castaneum* (Table 7).

Foodstuffs	Number of adults sexed	Males	Females	R (%)
Corn kernels	218	133	85	38,99
Millet grains	160	107	53	33,13
Corn flour	57	31	26	45.61
Millet flour	68	40	28	41,18

Table 7: Emergence of adults and sex ratio (R) of *T. castaneum* depending on the type of food.

3.6. Comparison of Biodemographic parameters of S. zeamais according to the nature of food

The average duration of *S.zeamais'* development was 35.33 ± 5.51 days in the corn kernels. There was no emergence in the milllet's grains, in the millet's flour and also in the corn flour (Figure 5).

4. Discussion and Conclusion

The results obtained from the kernels of corn and millet for *T. castaneum* showed that the average duration of development was shorter on the millet grains (29.38 ± 1.45 days) than those of corn (36.3 ± 1.42 days). This shows that the grains of millet are more favorable to the development of *T. castaneum* than corn. Indeed, the envelope of corn is less resistant favors the attack of *T. castaneum* in these grains. According to Kouassi (1991), more grain was protected by a tough shell, unless it was impregnated with moisture and the shorter the duration of insect development. Indeed, *T. castaneum* was a secondary pest attack weak grains intact but microscopic lesions sufficient to allow the larvae to enter the grain. Note that most of the grains used were low in farmers attacked by primary pests like moths and some beetles like *Sitophilus zeamais*, *Sitophilus oryzae*, *Rizopertha dominica* during storage. Moreover, these are the few holes left by these primary pests and broken grains caused in the course of hype intensified attacks *T. castaneum*. Some boxes that contained fewer grains attacked gave little rise. Our results are similar to those of Bekon and Fleurat-Lessard (1989) reported that secondary pests can not depreciate the grains until their openings for access roads.

T. Castaneum was able to grow in their cereal grain storage cubes but also, to move from one grain (millet) to another (corn).

Moreover, the weight of the insect in corn kernels (2.02 ± 0.17 mg) was higher than that obtained in the grains of millets (1.99 ± 0.15 mg). Weight gain of insects depends on the nature of the support and protection food grains. Referring to the grain size, we can say that over the infested grain was large, the greater the amount of food available. Our results are those of simmilaires Farjan (1983) and Bekon (1984) in Kouassi (1991), which using *Sitophilus* reported that the weight of the latter was higher than on grain whose grain size was sufficiently great.

The difference in weight depending on the support food for both insects would be lower in *T. castaneum* because the larvae of the latter move freely in the food, allowing them access to other grains in contrast to *Sitophilus* whose development was hypogeous.

Apart from the influence of food availability, nutritional quality of these grains may also play a role on the fate of the weight of insects. The carbon / protein that express indirectly the carbon / nitrogen ratio are 5.03 for corn and 3.74 for millet (Kouassi, 1991). Unlike carbon-nitrogen composition was the cause of the weight difference between insects that thrive on different food support.

Regarding the sex ratio, it was broadly in favor of males on each support food despite variations in favor of one sex or the other depending on the nature of the substrate. A variation of this ratio in favor of either sex would have resulted in greater variation in reproductive success in some than in others.

In addition, for *S. zeamais*, the average development relative humidity ranging from 41 to 67% and a temperature ranging from 28.5 to 31 ° C (relative humidity and temperature of the experimental room) was 35.33 ± 5.6 days in corn kernels. Our results are similar to those Delobel & Tran (1993), reported that the optimum development of *S. zeamais* between 27 and 31 ° C for 70% humidity was 36 days. There was no spawning in the grains of millet. Indeed, the morphology of the rostrum of *S. zeamais* does not facilitate the drilled grain size very small as the millet. In addition, the bark of millet grain was more resistant than corn. According Philogène et al., (1989), the female of *S. zeamais* lays her eggs, placing each in a small hole in the grain and sealing it with a mucilaginous plug of saliva. Delobel & Tran (1993) reported that the development of *S. zeamais* was only possible on grains having high water content. This could explain the non-development of the insect into the grains of millet seed coats was very resistant there by reducing moisture in the grain. It could also be due to the fact that *Sitophilus* used are derived from corn and may struggle to adapt on target. The increase in moisture during grain maturation allows the insect to infest cereals like corn before the harvest. The low water content about 13% in the grains of millet (Codex Stan, 1989) would protect him against *S. zeamais*. However, it was noted by some authors in millet, there was much more than that of *S. oryzae* as *S. zeamais*. The latter was more suited to large grain size and less resistant barrier.

The average weight of the insect was 2.37 ± 0.15 days in the corn kernels. The development of *S. zeamais* was performed inside the grain. This observation allows us to think it that if development of the insect into the grains of millet, the weight of those that developed in the grains of corn would be more important than those who completed their round on target?

The sex ratio of *S. zeamais* was in favor of males in the corn kernels. Would it be the same in the grains of millet?

The results obtained on corn flour and millet show that the average number of larvae of *T. castaneum* was substantially the same in the first days of occurrence (7.33 and 7.57). It decreases until the second and third days will be canceled as of the fourth day in corn. While, on target average number of larvae that settles between the third and fourth day increasing to 1.8 at the end of the fifth day.The egg-pupal period of *T. castaneum* was longer in millet flour (25.22 ± 0.83 days) than in corn (21.25 ± 0.71 days). This confirms that the elimination of its causes slower development of *T. castaneum*. Thus, the duration of pupal-adult *T. castaneum* was substantially the same in corn flour and millet respectively 6.25 ± 0.71 days and 6.09 ± 1.51 days. Indeed, during the moult the nymph does not nourished and this influx no development of *T. castaneum*.

The average duration of development of *T. castaneum* in flour was 30.33 ± 0.87 days in the millet and 26.25 ± 0.46 days in corn. It appears that the average duration of the development cycle of *T. castaneum* depend both of humidity, the nature of the food support and protection of the grain. The transformation of grain into flour would reduce the moisture content low was a limiting factor for the development of this insect. Protection of the grain was highlighted by Seck et al. (1992), which according to them, broken on the millet grains promote the development of *T. castaneum*. Unlike the average duration of development of *T. castaneum* between these two foods could also be due to a difference in nutritional value between them. Indeed, the two grains are processed differently in flour to consumers. For corn that was the whole grain into flour which was contrary to millet where the sound was removed during processing. This would lead to a decrease in the nutritive value of millet flour, thus slowing the development of the insect from cornmeal where development was faster. This could be confirmed by Green Africa & INRAN (2007), who argue that the flour was a product intended for human consumption which was obtained from grains of millet (candle) by a process of grinding industrial (commercial) in which the seed was largely eliminated and the endosperm reduced sufficiently fine powder.

The average duration of development *T.castaneum* was longer on corn (36.3 ± 1.42 days) than on corn meal (26.25 ± 0.46 days). The reverse was true for millet: 29.38 ± 1.45 days on grain and 30.33 ± 0.87 days on flour. The average duration of insect development on millet grains intact was slightly higher than that found on broken grains of the same cereal (Seck et al., 1992).

Thus, the corn into flour has no means of resistance against *T. castaneum* in addition; the germ was not removed during this transformation, which would accelerate its development. However, *T. castaneum* are fewer obstacles in flour unlike grains whose envelope was a barrier to the development of the latter. By cons, on target, development was faster in the grains into flour, which was the elimination of the germ of grains during processing.

It is important to prevent the passage of *T. castaneum* from corn grains to corn flour.

The weight of the insect *T. Castaneum* was larger in absolute value in grains than in the millet flour. What we can say that the transformation of millet flour was unfavorable for the growth of the insect. By cons, in corn the average values of weight of the insect on grain and flour are substantially the same. Flour and corn have the same influence on weight gains of the insect.

The sex ratio towards males of *T. Castaneum* as well as on grain flour.This enables us there to say that the sex ratio was always in favor of males regardless of the type of cereal?

These results allow saying that the transformation of grain into flour affects the development of *T. castaneum* and *S. zeamais*. Thus, to protect corn against *S. zeamais*, it was best to store after processing into meal but short periods. Millet seems to hold more attacks *S. zeamais* when stored as grain processing into flour but slowed the development of *T. castaneum* and prevents that of *S. zeamais*.

Moreover, for a better understanding of biodemography of these two insects, more complete life tables can be established by calculating the following parameters:

The lifespan of the adult, the number of eggs laid by females, the fertility rate, larval survival rate (S), the rate of emergence, and the rate of increase per individual (RM), the generation time and the doubling time of the population (TD).

Acknowledgements

This publication was produced with financial support of the project WAAPP/2011 (West African Agricultural Productivity Programme) coordinated by Dr. Cheikh THIAW. We thank all laboratory technicians CBGP IRD Bel-Air for the help received during experiments.

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