JENRM, Vol. 1, No. 3, 176-181, 2014
Research Article

The Impact of Insect Infestation on Stored Purpled Cocoa Beans

E. Tettey[1]*, W.A Jonfia-Essien[2],D. Obeng-Ofori[3]

Abstract
Under-fermentation of cocoa beans produces purple beans. The fermentation period is 6 to 7 days but some cocoa farmers under-ferment their cocoa beans leading to the development of purple cocoa beans. This study determined the impact of insect infestation on stored purple cocoa beans. Wet cocoa beans were fermented for 1, 2, 3, 4 and 5 days to produce the purple beans. *Ephestia cautella* and *Tribolium castaneum,* both singly and in combination, were introduced into the cocoa beans and stored for different (30, 60, 90 and 120 days) period. Insect population, percentage weight loss and the contaminants produced by these insects were determined. Cocoa beans infested with *E. cautella* alone had the highest population of 297.0 $\pm$ 22.7. Beans fermented for 3 days had the lowest insect population both singly and in combination after 120 days of storage. The highest percentage weight loss was recorded in cocoa beans fermented for one day (10.1 $\pm$ 1.87%) and 4 days (10.1 $\pm$ 8.74%). *T. castaneum* did not cause much damage to the cocoa beans but *E. cautella* alone caused significant damage to stored cocoa beans. Insect infestation and poor fermentation contribute significantly to the reduction in quality of cocoa beans.

Keywords
Damage—Insect infestation—Purple cocoa beans—Storage—Under-fermentation

[1]*African Regional Postgraduate Programme in Insect Science (ARPPIS), University of Ghana, Legon, Ghana*
[2]*Quality Control Company Limited (COCOBOD), Accra, Ghana*
[3]*University of Energy and Natural Resources, Sunyani, Ghana*
***Corresponding author**: elimbahi@yahoo.com

Contents

1. INTRODUCTION

Fully ripened, properly fermented and thoroughly dried cocoa beans are of a brown to dark red in colour and have a very fragile shell with a pure, bitter flavour [9]. Poorly fermented cocoa beans are purple in colour when under-fermented or very dark in colour when over-fermented [13]. Purple beans occur when the fermentation has been terminated prematurely. The best fermentation period is 6-7 days [4].For example, [14] reported a high percentage of purple beans in cocoa beans fermented for 4days than cocoa beans fermented for 6days.

Cocoa beans are susceptible to attack by several species of beetles and moths. Insect infestation can start from the farm but mostly from the drying mats. At the end of a season, the mats are usually rolled up and stored but they often carry the eggs and pupae of insects which may emerge to infest the next crop. Similarly the area around artificial dryers can provide a breeding site for pests [17]. Infestation by insects can also occur during transportation to the warehouse for storage or shipment. Storage beetles are attracted to cocoa beans and cause damage by boring holes into the beans or feeding on the nib. Storage moths, causes damage by larval feeding, in addition to producing silken threads, which builds up into dense webbing that binds the cocoa beans [18]. Insect feeding causes loss of weight of the cocoa beans thus reducing it commercial and nutritional value [11]. [10], reported that cocoa beans infested with *E. cautella*, *T. castaneum* and *L. serricorne* reduced the weight quality of the cocoa beans.

The quality of dry cocoa beans in international trade is assessed by the percentage level of total mould, slaty,

purple, insect infestation, flat, and germinated beans [6]. It has been observed through personal interaction with cocoa farmers that, some farmers being under pressure from the buyers of cocoa beans do not allow their beans to undergo adequate fermentation. Some of the cocoa farmers allow a few days fermentation while a few do not ferment the beans at all which results in the production of purple cocoa beans [2]. Thus purple cocoa bean is caused mainly by improper fermentation [2]. This study therefore aimed at determining the impact of insect infestation on stored purple cocoa beans.

2. MATERIALS AND METHOD

2.1 Culturing of insects

The adults of *E. cautella* and *T. castaneum* were reared separately at a temperature of 30ś2 ^{0}C and relative humidity of 70ś5% [17]. These insects were selected because they are among the major insect pests attacking cocoa beans. *Ephestia cautella* was reared on a mixture of ground maize, wheat bran and glycerol in a ratio of 8:8:1 (W/W) and *T. castaneum* on crushed dry cocoa beans, [16]. Males of *E. cautella* were distinguished from the females by a dark patch (testes) on the back, which is visible at the fifth instar larva [15]. The males of *T. castaneum* were distinguished from the female by their aggregation behaviour and have a setiferous patch on the posterior side of the fore femur [20].

2.2 Fermentation and drying

Matured and fully ripe cocoa pods were harvested from cocoa plantation at Cocoa Research Institute of Ghana (CRIG). The beans were separated from the placenta and any black or diseased beans, germinated beans, placenta fragments or pieces of shell were removed. The wet cocoa beans were grouped into five samples. Heap fermentation method was used and each sample contained 50 kg of the wet cocoa beans. To produce purple beans, the cocoa beans were fermented for either 1, 2, 3, 4 or 5 days with consecutive openings and turning after every 2 days except for beans fermented for one and two days. After each fermentation period, the cocoa beans were sun-dried. Each sample of the fermented cocoa beans was dried to 6.9% moisture content.

2.3 Estimation of insect population

Ten (10) fifth instar larvae of *E. cautella* and 10 adult *T. castaneum* were introduced using aspirator into the jute sacks containing 2 kg of cocoa beans that had been fermented at various fermentation days separately and in combination. Each of the jute sacks was inserted into gray baft before storage to prevent migration of insects from one bag of the dry cocoa beans to another. The fifth instar larvae of *E. cautella* were used because it is very easy to distinguish the males and the females at this stage [15] and also because the fifth instar (last larval instars) feed vigorously before pupating [5]. The temperature of the store room was 30 ś 2 °C and relative humidity of 70 ś 2% and also free from insects. On monthly basis, each sample was sieved using a wooden sieve and the numbers of both live and dead insects (larva, pupa and adult) in each sack was counted to determine the changes in insect populations. The dead insects were counted because they were assumed to have completed their life cycles and therefore contributed to the percentage weight loss of the beans. The live insects were returned into their respective sack.

2.4 Determination of contaminants

On monthly basis, each sample was sieved using a wooden sieve, the live insect found in the residue were picked using an aspirator. The contaminants which were obtained after sieving and removing the live insects were observed, weighed and recorded monthly for a period of four months. Each treatment was replicated four times.

2.5 Damage and loss assessment of dry cocoa beans

Count and weigh method [12] was used to determine the weight loss in the various samples of dry cocoa beans. From each sack 100 g of cocoa beans was sampled, and sorted into damaged and undamaged. The damaged beans were those with holes or physical defects. Both the damaged and undamaged beans were counted and weighed separately. Each treatment was replicated four times. The percentage weight loss was calculated as follows:

$$\textbf{\% Weight loss} = ((\mathrm{UNd}) - (\mathrm{DNu}) / U(\mathrm{Nd} + \mathrm{Nu}))X100$$

U = Weight of undamaged beans
Nd = Number of damaged beans
D = Weight of damaged beans
Nu = Number of undamaged beans

2.6 Data analysis

Data were subjected to Analysis of Variance (ANOVA) using Genstat 9th edition. Least significant difference (LSD) was used to separate the means at 5% level of significant.

3. RESULTS AND DISCUSSION

3.1 Population estimate of *E. cautella* and *T. castaneum* in stored purple cocoa beans

Generally the population of *E. cautella* in the cocoa beans increased during the storage period and that of *T. castaneum* decreased with increasing storage period but only increased at 120 days of storage for beans fermented for 2 and 5 days (Table 1). *Ephestia cautella* alone recorded the highest mean population of 297.0 for cocoa beans fermented for one day and stored for 120 days (Table 1) whilst *T. castaneum* recorded the lowest mean population (1.5) both singly and in combination for cocoa beans fermented for one day and two days (Table 1). Cocoa beans

fermented for 3 days recorded the lowest mean population of both insects, either singly or in combination at the end of the 120 days storage (Table 1).

The population of insect pests are said to increase in the absence of predators, availability of food and favourable environmental conditions [7]. [19], reported that the populations of *E. cautella and T. castaneum* increase significantly with duration of storage in conventional storage system. Moreover, there were no predators and parasitoids to affect the pest population negatively. Another factor that affects the population of insects in cocoa beans is fermentation. According to [11] properly fermented beans had lower population of *E. cautellla* than unfermented and under-fermented beans.

The increase in population of *E. cautella* with storage period, both in single and mixed infestation could be attributed to the larvae of *E. cautella* which are internal feeders and they can move and feed on the cocoa beans [11]. Their short life-span, availability of cocoa beans and favourable environmental conditions also contributed to their multiplication, compared to *T. castaneum* which are secondary insects [1] and the newly hatched larvae of *T. castaneum* survive only when suitable food is readily available. Consequently, the population of *T. castaneum* in single infestation decreased during the storage because the dry cocoa beans were whole grains. However, populations of *T. castaneum* in combination with *E. cautella* were relatively higher, because the presence of the latter's larvae fed on the whole beans thus making them suitable for *T. castaneum* to also feed and increase in number. In contrast of [10], it was reported that the population *T. castaneum* in single infestation increases after 180 days of storage probably because brown cocoa beans was used (fully fermented) while purple cocoa beans was used in this study.

Table 1. Population trends of *E. cautella* and *T. castaneum* in cocoa beans fermented and stored for different periods

	Mean number of insect after days of storage			
Fermentation period	30	60	90	120
1 day				
E. cautella	8.5±1.2	48.3±3.1	158.0±12.0	297.0±22.7
T. castaneum	8.3±1.6	3.8±1.8	2.8±1.8	1.5±0.3
EC + TC	2.8±0.8, 4.5±2.0	2.0±1.0, 1.5±0.3	21.3±20.6, 2.0±1.2	29.5±17.1, 1.5±0.6
LSD(p<0.05)	4.7	5.8	36.9	43.9
2 days				
E. cautella	5.5±1.6	30.5±14.1	78.5±35.1	181.5±52.4
T. castaneum	11.8±2.8	4.3±2.5	1.0±0.4	1.5±0.9
EC + TC	13.5±12.5, 8.3±2.9	23.0±11.9, 8.5±5.5	59.5±42.8, 15.8±10.6	71.0±41.4, 14.3±8.4
LSD(p<0.05)	20.4	29.9	86.8	103.7
3 days				
E. cautella	5.8±1.5	13.5±5.0	27.3±13.2	75.5±41.9
T. castaneum	16.0±2.8	4.3±0.8	4.5±1.6	3.5±1.4
EC + TC	9.3±5.7, 3.3±0.9	16.5±8.7, 4.8±1.5	60.0±48.1, 1.0±0.7	46.8±21.6, 6.5±3.9
LSD(p<0.05)	10.2	15.8	76.9	72.9
4 days				
E. cautella	11.0±2.7	29.3±11.6	72.8±8.3	137.0±42.0
T. castaneum	17.3±3.0	4.8±1.5	3.5±1.5	2.8±2.8
EC + TC	14.8±4.2, 3.3±0.6	48.5±12.8, 5.8±2.3	96.3±19.6, 11.8±4.0	206.5±39.2, 11.3±3.9
LSD(p<0.05)	9	27	33.4	88.9
5 days				
E. cautella	23.3±7.4	58.0±11.0	111.0±9.0	143.3±48.6
T. castaneum	14.8±3.3	6.0±1.6	1.5±1.0	2.8±1.6
EC + TC	31.8±18.4, 40.0±11.2	23.3±10.9, 6.3±0.6	32.5±19.6, 5.0±2.8	45.3±17.8, 7.0±4.0
LSD(p<0.05)	35.4	24	33.5	80

EC + TC = combination of E. cautella *and* T. castaneum

3.2 Contaminants produced by *E. cautella and T. castaneum* on dry stored cocoa beans.

The contaminants consisted of pupal cases, frass, fragment of cocoa, silken threads and dead insects. All the treatments with *E. cautella* had dead insects, faeces and silken threads as major components of the contaminants. Cocoa beans infested with *E. cautella* had the highest mean weight of contaminants (21.34±8.12g) (Fig. 1).

The weight of contaminants in the treated cocoa beans were significantly higher ($p<0.05$) than that produced in the control throughout the storage period except for beans that were fermented for 3 days (Fig. 2).

The major contaminants found in cocoa beans infested with *T. castaneum* were frass, pupal cases and fragment of cocoa beans. The weights of the contaminants were generally low; this is as a result of low numbers of the insects found in the cocoa beans. The observed low contaminant in cocoa beans infested with *T. castaneum* confirms the finding of [10]. The highest weight of contaminant in cocoa beans infested with both insects was recorded in beans fermented for 4 days and stored for 120 days (15.6 ± 4.9g) (Fig. 3).

The larvae of *E. cautella* mainly produced large number of webbed galleries which bind the beans together and they also wander about leaving silken tunnels behind [5] thus contaminating the cocoa beans. Dead insects (especially adult) were the major component of the contaminants probably because the adults of *E. cautella* do not feed but lay eggs and die [3]. As the storage period increased the weights of the contaminants also increased probably due to increase in the insect biological activities. Therefore cocoa beans stored for more than 30 days contained more contaminants as a result of insect infestation.

For this reason, good quality cocoa meant for export must be free from live or dead insect especially *E. cautella*. In cocoa beans fermented for three days (Fig. 2), the weight of the contaminants was low because of low population of insects found in the beans.

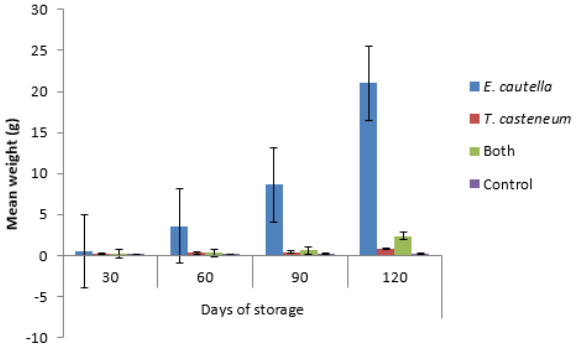

Figure 1. Mean weight (g) of contaminants for cocoa beans fermented for in 1 day (LSD, $p<0.05$)

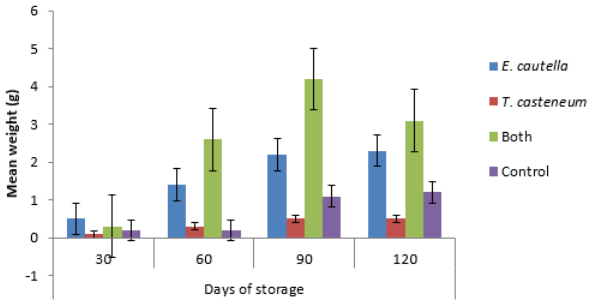

Figure 2. Mean weight (g) of contaminants for cocoa beans fermented for 3 days (LSD, $p<0.05$)

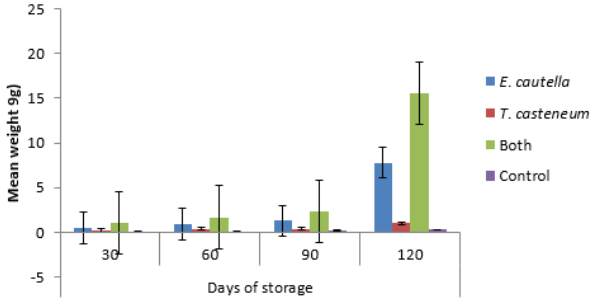

Figure 3. Mean weight (g) of contaminants of beans that underwent fermentation in 4 days (LSD, $p<0.05$)

3.3 Damage caused by *E. cautella* and *T. castaneum* on stored dry cocoa beans

Generally, the percentage weight loss increased with storage period and it varied significantly irrespective of whether the two insect pests occurred separately or in combinations on the stored cocoa beans. Cocoa beans infested with *E. cautella* produced the highest weight losses ranging from 1.56 ± 0.6% at the start of storage to 10.1 ± 1.87% at the end of the 120 days storage period (Fig. 4).The highest weight losses of *10.1±1.87%* and *10.14±8.74%* (Fig 4 and 5) were recorded in cocoa beans fermented for one day and four days respectively and these were caused mainly by *E. cautella*. The percentage weight loss that resulted from infestation by *E. cautella* alone for 120 days of storage was significantly higher than that caused by *T. castaneum* alone, and also the two insects in combination, except for beans fermented for four days (Fig. 5).

Insect infestation is one of the most important causes of deterioration of stored grains [11]. Insect feeding caused loss of weight to the cocoa beans thus reducing their nutritional and commercial value. Cocoa beans infested with *E. cautella* gave the highest percentage weight loss after 120 days of storage consistent with their higher numbers in the cocoa beans. The larvae of *E. cautella* caused more damage than *T. castaneum* and the increase in weight loss correlated with the number of insects that

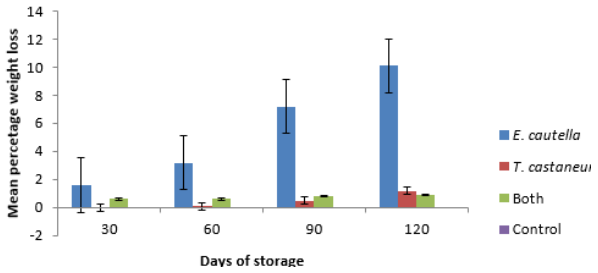

Figure 4. Mean percentage weight loss of dry cocoa beans fermented for 1 day (LSD, $p<0.05$)

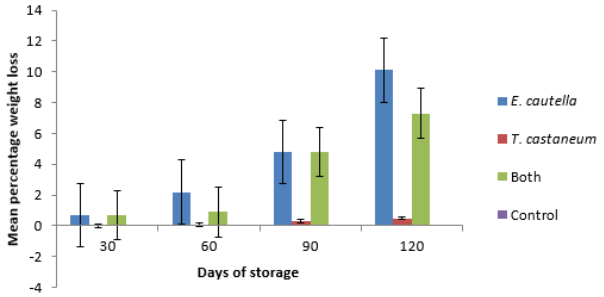

Figure 5. Mean percentage weight loss of dry cocoa beans fermented for 4 days

infested the cocoa beans. This is in agreement with [10], who also reported that infestation by *E. cautella* on cocoa beans stored for 180 days caused more damage than *T. castaneum*. Therefore special attention should be given to *E. cautella* in terms of control as it can cause greater loss of exportable cocoa.

Both the highest and the least weight loss was found in cocoa beans fermented for four days. Cocoa beans fermented for four days gave relatively higher percentage weight loss than those fermented for five days. Cocoa beans fermented for four days are considered as under-fermented cocoa. However, previous study showed that damage caused on fermented cocoa beans stored for 6 months (180 days) was lower than the damage on under-fermented beans [11]. [8], also reported that the percentage of damage beans on fermented cocoa beans was lower than that of unfermented beans. This shows that properly fermented cocoa beans could be stored for a longer period with less insect infestation.

3.4 CONCLUSION

The study was conducted using grade II cocoa beans but the cocoa beans deteriorated over the storage period to sub-standard due to high levels of defects especially insect infested beans. High insect infestation contributed significantly to the reduction in quality of the purple cocoa beans. The tropical warehouse moth (*E. cautella*) alone caused significant damage to the stored cocoa beans. It has been shown in this study that poor fermentation and insect infestation pose a great threat to the quality of cocoa beans. These factors deserve attention in order to maintain quality of cocoa beans during storage.

4. ACKNOWLEDGMENT

Deutsher Akademischer Austsuschidient (DAAD) for funding this project as part of my MPhil (Entomology) thesis at the University of Ghana

References

[1] C. Karunakaran, and D.S. Jayas.2004. Identification of wheat kernels damaged by the red flour beetle using x-ray images. *Biosystems Engineering 87(3)*, 267-274.

[2] D.K. Adzaho. 2007.*Studies of occurrence of purple beans in cocoa produced in Ghana.* Master of Philosophy dissertation, Crop Science Department, University of Cape coast, Ghana,.

[3] D. Obeng-Ofori.2008. Major stored product arthropod pests in E.W. Cornelius, and D. Obeng-Ofori, (Eds.), *Post harvests Science and Technology*, (Smartline Publicating limited, Accra, 2008) 67-91

[4] F. Aneani, and M. Asamoah.2004. Socio-economic survey on cocoa fermentation in Ghana. *Journal of the Ghana Science Association 6(2)*, 92-93.

[5] G. Chandra.2006. *Ephestia cautella* Tropical Warehouse Moth. The Fig moth `http://www.iaszoology.com/ephestia-cautella/` , Assessed 20/11/2012

[6] Ghana Cocoa Board News.2011. (COCOBOD).

[7] J.M. Fischer.2002. Population dynamics. `http://www.encyclopaedia.com`. Assessed on 12/3/ 2013

[8] K.F. Kresnowati.1999. Kualitas biji kakao akibat fermentasi dan serangan *Araecerus fasciculatus* De Geer (Coleoptera: Anthribidae) selama penyimpanan. (Cocoa beans quality affected by fermentation and *Araecerus fasciculatus* De Geer (Coleoptera: Anthribidae) infestation during storage). Department of Biology, Faculty of Mathematics and Natural Sciences, Bogor Agricultural University, Bogor, Indonesian, 1999.

[9] N. Camu, T. De Winter, S.K. Addo, J.S. Takrama, H. Bernaert, and L. De Vuyst.2008. Fermentation of cocoa beans: influence of microbial activities and polyphenol concentrations on the flavour of chocolate. *Journal of the Science of Food and Agriculture 88*, 2288–2297

[10] O.O. Obeng.2010. *Relative abundance of Three Major Insect Pests of Dry Cocoa Beans in Storage and Their Response to Selected Insecticides.* M.Phil dissertation, African Regional Postgraduate Programme in Insect Science, University of Ghana, Legon, 2010.

[11] O.S. Dharmaputra, A.M. Sunjaya, I. Retnowati, and S. Ambarwati.2000. Stored cocoa beans quality affected by fermentation and *Ephestia cautella* walker (lepidoptera: phycitidae) infestation. *Biotropia 15*, 58 – 75.

[12] R.A. Boxall.1986. A critical review of the method of assessing farm-level grain losses after harvest. Report of the tropical Development and Research Institute, 139pp.

[13] S.J. Misnawi, B. Jamilah and S. Nazamid. 2003. Effects of incubation and polyphenol oxidase enrichment on colour, fermentation index, procyanidins and astringency of unfermented and partly fermented cocoa beans. *International Journal of Food Science Technology 38*,285–295.

[14] S.T. Guehi, T.D. Adje´hi, P.B.K. Kouadio, D. Soumai¨la, L. Ban-Koffi, D.K. Kedjebo, and J.N. Gnopo. 2010. Performance of different fermentation methods and the effect of their duration on the quality of raw cocoa beans. *International Journal of Food Science and Technology 45*, 2508–2514.

[15] T. Sasaki, T. Kubo, and H. Ishikawa. 2002. Interspecific Transfer of Wolbachia Between Two Lepidopteran Insects Expressing Cytoplasmic Incompatibility: A Wolbachia Variant Naturally Infecting *Cadra cautella* Causes Male Killing in *Ephestia kuehniella*. *Genetics 162*,1313–1319.

[16] W.A. Jonfia-Essien.2001. The effect of storage on the quality of cocoa beans. Internal Report, Ghana Cocoa Board, 2001.

[17] W.A. Jonfia-Essien, Cocoa storage in Ghana, in R.J. Hodges, G. Farrell (Eds).2004. *Crop Post-harvest: Science and Technology* Volume 2: (Durables. Blackwell Science Ltd. Oxford, UK 2004), 218-224.

[18] W.A. Jonfia-Essien, P.G. Alderson, G. Tucker, R. Linforth, and G. West. 2007. Behavioural responses of *Tribolium castaneum* (Herbst) to volatiles identified from dry cocoa beans. *Pakistan Journal of Biological Sciences 10 (20)*, 3549-3556.

[19] W.A. Jonfia-Essien, S. Navarro, and J.V. Dator. 2008. Effectiveness of hermetic storage in insect control and quality preservation of cocoa beans in Ghana. In: G. Daolin, S. Navarro, Y. Jian, T. Cheng, J. Zuxun, L. Yue, W. Haipeng, (Eds) *Proceedings of Eight International Conference on Controlled Atmosphere and Fumigation in Stored Products,* Chengdu, China, 305-310.

[20] Y. Bousquet. 1990. *Beetles associated with stored products in Canada: An identification guide* (Agriculture and Agri-Food Canada, 1990).