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EFFECT OF FERMENTATION ON THE PROXIMATE COMPOSITION OF DIFFERENT CLONES OF COCOA BEANS AND ITS SUSCEPTIBILITY TO INFESTATION BY *EPHESTIA CAUTELLA* POPULATION

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ABSTRACT
Fermentation, an important process in the processing of cocoa beans had hitherto affected the physiology, quality and chemical composition of dried cocoa beans in store. The present study attempts to investigate the effect of fermentation on the proximate composition of different clones of cocoa beans ant its susceptibility to infestation by Ephestia cautella population. Thirty (30) ripped and mature cocoa pods were harvested from different clones at Tree Crop Unit of the Ondo State Ministry of Agriculture, Akure, Ondo State. Morphometric measurements of the pods were determined with the aid of vernier caliper. The cocoa beans were fermented and later sundried for 8 days to achieve desirable moisture content. Proximate analysis was carried out following established protocols. Susceptibility of different clones to infestation by Ephestia cautella was also carried out. Population of Ephestia cautella on fermented cocoa beans was lower than the unfermented pods. The population of Ephestia cautella increased with storage period. Insect pest inflicted damage caused drastic reduction in weight. Findings revealed that insect infestation is an important indicator of deterioration of stored grains leading to drastic reduction in weight thereby affecting their nutritional and commercial value.
KEY WORDS*: clones; deterioration; Ephestia cautella; fermentation; susceptibility*

INTRODUCTION

Theobroma cacao (Cocoa) is a crop that has been in the consciousness of Nigerians long before independence and one that is capable of stimulating agricultural growth. Among the comity of nations in Africa, the number one producer on the continent is Coted'ivoire with 1, 980 millions tons followed by Ghana (950 thousand tons), Cameroun and Nigeria with 240 and 220 thousand tons respectively (Abdelrahim *et al*., 2002). It is the major component used in the production of chocolate, cocoa butter and mucilage, cocoa wine and beverages, cosmetics and many other products (Soldani *et al*., 2001; Opeke, 2005). The fruit, known as a 'pod' is a

type of indehiscent berry, varying in weight depending on the clones, and averaging around 500 g. It contains 30–60 seeds surrounded by sweet mucilage. Once fermented and dried, seeds ('beans'), constitute the fermented dried cocoa on which the chocolate industry is based (Misnawi, 2003; 2004; Lachenand, 2007). Insect pest infestation had become a recurring decimal decimating and constraining the production of cocoa on the field and in the store. Fermentation is an essential post-harvest processing of freshly harvested cocoa beans which precedes drying in order to attain the desired flavor, physicochemical and/or industrial properties for its acceptability by consumers (Wollgast, 2000; Hi *et al*., 2009). Insect infestation and chemical residues in cocoa beans portends a greater challenge confronting the cocoa industry in Nigeria. The beans are susceptible to attacks by numerous insect pests which can cause serious economic and nutritional loss. Insect feeding results in loss of weight of cocoa beans, hence reducing its commercial and nutritional value (Harrigan *et al*., 1993; AOAC, 1990)

MATERIALS AND METHODS

Collections of different clones of cocoa beans. Thirty (30) riped and matured cocoa pods were harvested from different clones at Tree Crop Section of the Ondo State Ministry of Agriculture, Akure, Ondo State, Nigeria.

Morphometric measurement of the pods. Morphometric measurements of the pods length, width and thickness respectively were carried out with the aid of venier caliper. The pods were broken and the beans and pulp collected. The number of beans per pods was counted and average number of beans contained in 30 pods was determined as followed.

$$\text{Average No of Beans per pod} = \frac{\text{Number of bean in 30 pods}}{\text{Total number of pods (30)}}$$

Fermentation of cocoa beans. The cocoa beans were harvested and the beans and pulp are placed into wooden boxes enclosed with banana leaves to initiate the fermentation process for five days. As the temperature rises in the box, fermentation process increases. The beans were then sundried for 8 days to achieve a desirable moisture content of 70%.

Morphometric measurement of bean. Morphometric measurement of the cocoa beans lengthy, width and thickness of the beans coat were determined with the aid of micrometer screw guage.

Determination of moisture content and weight of the cocoa beans. The moisture content of each clone of cocoa beans was determined by oven drying method (Ianovici, 2015; Datcu *et al*, 2018). Fifty dried beans were selected at random from each clone and place on sensitive weighing balance (model 373) and the weight determined.

Proximate analysis of different clones of cocoa beans. Proximate analysis of the different clones of cocoa beans was carried out following the method of (AOAC, 1990). Samples were taken from fermented and unfermented cocoa beans and subjected to proximate analysis (moisture content, crude protein content, crude fibre content, crude fat, ash content and carbohydrate content) mineral analysis; free fatty acid and pH test were also carried out.

Extraction of oil from cocoa bean. The dried cocoa bean was grinded to powder and a previously dried filter paper was weighed (W_1), a quantity of the cocoa powder was wrapped with the filter paper and weighed (W_2). The filter paper with the sample was then put inside an extractor and plugged with defatted cotton wool. A previously weighed dry 500ml round bottom flask was then filled with the solvent (petroleum ether) up to about 2/3. The extractor was fitted with a reflux condenser and attached to the flask. The flask was then heated in an electro thermal heating mantle so that the solvent boiled gently and allowed to siphon over the sample several time for about 3hrs for a complete extraction. After extraction, the condenser was detached and the fitter paper was removed. The mixture (Oil and solvent) in the flask was heated at 100^0C temperature at which only the solvent will be evaporated and condensed inside the extractor for recovery leaving the oil in the flask. The heating was continued until there is a very small amount of petroleum ether (solvent) present with the oil after which the heating was stopped and the flask was allowed to cool and left in order for the remaining solvent to evaporate at room temperature. The extracted oil was then stored in an airtight container with screw capped lid and stored at room temperature.

Acid value determination**:** 25ml diethyl ether was mixed with 25ml ethanol. 1ml of 1% phenolphthalein solution was added and neutralized with sodium hydroxide solution. 1.20g of the oil was dissolved in the neutralized solvent mixture and titrated with 0.1M sodium hydroxide solution.

$$\text{Acid value} = \frac{\text{Titre value x } 5.61}{\text{Weight of sample}}$$

Saponification value determination. 1g of the oil was weighed into a clean flask. 12.5ml alcoholic potassium hydroxide solution was pipetted into it. The flask was attached to a reflux condenser and heated for one hour with occasional shaking 1ml of phenolphthalein solution was added and the solution was titrated while hot with standard 0.1M HCl. The colour change was from pink to milky colour. A blank determination was also carried out and this determination was carried out for all the samples (Amoo *et al*., 2004)

$$\text{Saponification value} = \frac{\text{(b-a) } 28.05}{\text{Weight of sample}}$$

Where b = blank titre value,
a = titre value (titration sample)

Iodine value determination. 0.20-0.30g of oil was weighed into a 250ml conical flask. 10ml of carbon tetrachloride was added to dissolve the oil. 20ml of the solution was added and a stopper, which has been moistened with potassium iodide solution, was inserted. The mixture was shaken and allowed to stand in the dark for 30 minutes. 15ml potassium iodide solution and 100ml distilled water was added to the solution. The solution was mixed and titrated with 0.1M sodium thiosulphate using starch as an indicator.

$$\text{Iodine value} = \frac{(b-a)\ 1.269}{\text{Weight of sample}}$$

Where a = titre value (i.e titration with ample),
b = blank titre value

Peroxide value determination. 1g of oil was weighed into a clean flask. 1g of powdered potassium iodide and 20ml solvent mixture (2 volume acetic acid and one volume of chloroform) was added to the oil. The flask was then placed inside boiling water bath for few seconds. The content was then poured into a titration flask containing 20ml potassium iodide solution. The tube was washed with 25ml portion of water and the water was added to the titration flask. The solution was then titrated with 0.002M thiosulphate solution using starch as indicator. This determination was carried out for all the samples (Amoo *et al*., 2004)

Free fatty acid determination. The titre values obtained from the acid value determination were used for the determination of free fatty acid for all the samples.

1ml 0.1M NaOH = 0.282g Oleic acid

$$\text{Free fatty acid (FFA) (as \% Oleic acid)} = \frac{0.282 \times \text{titre value}}{\text{Weight of sample}}$$

$$\text{Peroxide value} = \frac{V \times 0.002 \times 1000}{\text{Weight of sample}}$$

Where V = titre value

Susceptibility of different clones of cocoa beans to infestation by Ephestia cautella. Twenty five grams of uninfested cocoa beans of different clones were weighed into a plastic container measuring 12.50 cm diameter and 13.50 cm deep and were replicated thrice. Four copulating pairs of freshly emerged (0 – 24 h old) adult *E.cautella* were introduced. The plastic containers were then kept for 45 days in insect breeding wire mesh cage measuring (50 x 60 x 70) cm in Storage Research Laboratory of the Department of Biology, Federal University of Technology, Akure. At the end of 45 days, the final weights of the cocoa sample in each clone were determined using high sensitive electric weighting balance (model 373). The percentage weight loss was determined according to Odeyemi *et al*. (2000) using the formula

$$\%\ \text{weight loss} = \frac{\text{weight of frass}}{\text{weight of sample}} \times \frac{100}{1}$$

Determination of the effects of fermented and unfermented dried cocoa beans on Ephestia cautella population. Twenty-five grams of uninfected fermented and unfermented dried cocoa beans at different moisture content (6, 7,8,9,10 and 12%) were weighed into a plastic container 12.50 cm diameter and 13.50 cm depth and replicated three times. Ten copulating pairs of teneral adult moths (0 – 24h old) were introduced into each plastic container and covered with perforated lid and sealed with muslin cloth for aeration. The plastic containers were kept inside the insect breeding wire mesh cage measuring (50 x 60 x 70) cm for 6 months. The number of adult emerged at F1, F_2 and F_3 were counted and the mean of the three replicates were calculated for the 6months and this was expressed as population. After six months of insect infestation percentage insect damage was calculated according to the method described by

Determinations of percentage of fermented and unfermented cocoa bean infected by mould after 6 months of storage. Twenty-five grams of dried cocoa beans, fermented and unfermented at different moisture content were kept inside separate new jute bag of dimension (30 x 30) cm obtained from Baclem Iynol Nigeria Limited Sabo, Ondo. The bags were disinfected in oven (Gallenkamp BS 250) at 60^{o}C for 3 hrs before the cocoa beans were bagged. The jute bag with each sample of cocoa beans was replicates 3 times and kept inside insect breeding wire mesh cages. After 6 months, samples were taken from each replicate and percentage mouldness was determined according to the method described by (Odeyemi *et al*., 2000).

RESULTS AND DISCUSSIONS

Morphometric measurement of cocoa pods. The morphometric measurement of different clones of cocoa pods is presented in Table 1. Clones C_{78}, C_{73} C_{64} and C_{75} recorded the highest pod length 22.4cm, 22.2cm, 21.7cm and 20.4cm respectively. The least pod length 15.6cm, 15.7cm, 18.5cm and 18.9c m were obtained from C_{76}, C_{20}, C_{70}, and C_{74}. Clone C_{78}, C_{71} and C_{73} recorded the highest pod width of 32.2cm, 30.3cm, 30.2cm and 30.1cm respectively while the lowest pod width 13.4cm, 13.6cm, 25.1cm and 25.1cm was obtained. The highest pod thickness 1.7mm, 1.6cm, 13cm was obtained from clone C_{73}, C_{71}, & C_{74} respectively whereas the least pod thickness was obtained from clone C_{76}, C_{20} C_{64} and C_{79} (Table 1). Clone C_{71} (53.5), C_{75} (49.2), C_{64} (48.7) and C_{78} (45.9) recorded the highest number of beans per pod while the least number of beans per pod were obtained from C_{70} (37.9), C_{69} (39.4), C_{79} (40.2), C_{70} (40.8), (Table 1). The beans length is highest in clone C_{64} (22.9mm), C_{78} (22.2mm), C_{64} (21.9mm) and C_{69} (21.8mm) and lowest in clone C_{70} (20.4mm), C_{76}. (20.8mm), C_{74} (20.0mm) and C_{75} (21.5mm) (Table 2).

The highest beans width 14.2mm and lowest bean with 0.23mm was obtained in clone C_{73} and C_{78} respectively ranged between 0.2m to 0.4mm a crossed all clones (Table 2). The clone C_{75} and C_{20} recorded the highest and the lowest moisture content

respectively. (Table 3). The highest weight of 50 beans selected at random for clone C_{79} (61.4g); C_{64} (60.9g) and C_{74} (57.1g) and the least was recorded for clone C_{73} (44.4g); C_{20} (47.6g); and C_{76} (47.3g). The highest weight of the seed coat was obtained in clone C_{73} and the least was obtained from C_{64} (Table 3). The bean size ranged between 0.8g - 1.23g. Clone C_{79} (1.23g), C_{64} (1.21g), C_{70} (1.13g), C_{75} (1.09g) and C_{69} (1.01) were the highest beans size while C_{73}, C_{76}, C_{78} and C_{71} recorded the least beans size (Table 3)

TABLE 1. Morphometric Measurement of Pods (M±SD)

Clones	Pod Length (cm)	Pod Width (cm)	Pod Thickness (mm)
C 20	15.7^{a}±0.4	13.6^{b}±0.0	0.7000^{a}±0.2
C 64	21.7^{f}±0.2	30.3^{h}±0.0	1.2633^{ef}±0.0
C 67	19.0^{c}±0.0	25.6^{d}±0.0	1.0400^{b}±0.0
C 69	20.1^{d}± 0.0	26.9^{f}±0.0	1.2467^{def}±0.0
C 73	22.2^{g}±0.1	30.1^{g}±0.0	$1,6467^{g}$±0.0
C 74	18.9^{c}±0.0	25.6^{d} ± 0.0	1.2700^{f} ± 0.0
C 75	20.4^{e}± 0.0	26.3^{c} ± 0.0	1.2033^{dc} ± 0.0
C 76	15.6^{a} ± 0.0	13.4^{a} ± 0.0	0.6933^{a}± 0.0
C 78	22.4^{g} ± 0.0	32.2^{i} ± 0.0	1.1167^{ef} ± 0.0
C 79	20.2^{dc} ± 0.0	26.3^{e} ± 0.0	1.11667^{c}±0.0
C 70	18.5^{b}±0.0	25.1^{c}± 0.0	1.2467^{def}± 0.0
C 71	19.1^{b}± 0.0	30.2^{h} ±0.0	1.6267^{g}± 0.0

Mean followed by the same letter (s) are not significantly different) $p < 0.05$) by New Duncan's Multiple Range Test

TABLE 2. Average Number of beans per per pod and Morphometric measurement of the Beans (M±SD)

Clones	No of Beans per pod	Beans Length (mm)	Beans width A (mm)	Beans width B (mm)	Thickness of bean coat (mm)
C 20	40.3^{bc}±.0	21.6^{abc}±.1	11.3^{de}±.2	6.9^{abc}±.4	0.3^{ab}±.03
C 64	48.7^{g}±.1	22.9^{c}±.4	7.3^{a}±.0	12.4^{de}±.3	0.2^{a}±.0
C 67	42.5^{e}±.1	21.9^{bc}±.5	7.7^{a}±.1	12.0^{d}±.3	0.3^{ab}±.0
C 69	39.4^{b}±.3	21.8^{abc}±.4	12.8^{g}±.2	7.1^{abc}±.0	0.3^{ab}±.0
C 73	43.3^{c}±.3	20.9^{b}±.5	14.2^{h}±.3	6.7^{ab}±.1	0.3^{ab}±.0
C 74	41.5^{d}±.6	21.8^{bc}±.4	12.5^{fg}±.2	7.5^{c}±.4	0.3^{ab}±.0
C 75	49.2^{g}±.1	21.5^{abc}±.3	7.6^{a}± .3	12.8^{c}±.3	0.3^{ab}±.0
C 76	40.8^{cd}±.6	20.8^{ab}± .4	10.3^{c}±.3	6.5^{a}±.0	0.3^{ab}±.0
C 78	45.9^{f}±.4	222.0^{bc} ±.6	7.5^{a}±.3	7.3^{bc}±.1	0.4^{b}±.1
C 79	40.2^{bc}±.0	21.7^{abc}±.9	11.4^{c}±.3	7.3^{bc}±.2	0.3^{ab}±.0
C 70	37.9^{a}±.5	20.4^{a}±.3	11.8^{ef}±.4	7.6^{c}±.1	0.2^{a}±.0
C 71	53.5^{h}±.3	21.7^{abc}±.4	9.5^{b}±.3	12.4^{dc}±.1	0.3^{ab}±.0

Amount of water loss during fermentation and drying of cocoa beans and percentage damage due to E. cautella in different clones of cocoa beans. The dried weight of the cocoa bean across all clones ranged between 1.2 -1.5kg /30 pods and the wet weight ranged between 2.3kg - to 4.0kg/30 pod and the loss in weight across all clones ranged from 1.0 to 2.6kg/30 pod (Table 3). The development cycle and number of adult emergence per clone of cocoa bean is presented in Table 16. The development

cycle of *E. cautella* ranged from 40.0 days to 48days across all clones but found to be highest in clone C_{74} (48days) and lowest in clone C_{79} (40.0 days). Percentage weight loss due to *E. cautella* was highest in clone C_{79} (30.0%); C_{76} (25.0%); C_{78} (20.5%) and C_{70} (20.5%) and lowest in clone $_{C69}$ (8.8%); C_{71} (9.9%) and C_{74} (11.9%). (Table 4).

TABLE 3. Moisture Content and Mean Weight of 50 beans selected at random (M±SD)

Clone	% Moisture content	Weight of 50 beans selected at random (g)	% Beans Coat	Beans size (g)
C 20	5.6^{a}±.3	47.6^{a}±.3	14.1^{abc}±.0	0.95
C 64	6.1^{b}±0.2	60.9^{k}±.0	13.6^{a}±.0	1.21
C 67	6.2^{bc}±0.0	49.4^{f}±.2	14.0^{abc}±.4	0.99
C 69	6.2^{bc}±.1	50.5^{g}±.2	14.7^{c}±.4	1.01
C 73	6.2^{bc}±0.0	44.4^{a} ±.1	16.0^{e}±.2	0.89
C 74	6.2^{bc}±0.0	57.1^{j}±.0	15.8^{de}±.5	1.14
C 75	6.3^{bc}±0.0	54.6^{h}±.1	13.9^{abc}±.3	1.09
C 76	6.1^{b}±0.0	47.3^{d}±1	14.9^{cd}±7	0.95
C 78	6.1^{b} ± 0.0	45.5^{b}±.1	15.0^{cd}±.3	0.91
C 79	6.1^{b} ± 0.0	61.4^{l}±.1	14.7^{bc}±.1	1.23
C 70	6.1^{b}±0.0	56.3^{i}±.1	13.7^{ab}±.0	1.13
C 71	6.2^{bc}±.2	48.6^{e}±.0	14.1^{abc}±.0	0.97

Mean followed by the same letter(s) on a column are not significantly different P > 0.05 from each other by Duncan's New Multiple Range Test

TABLE 4. Amount of water loss during Fermentation and Drying of Cocoa beans obtained from different cones (M±SD)

Clones	Wet weight of beans from 30 pods/ clone (Kg)	Dry weight of cocoa bean from 30 pods/clone (Kg)	Loss in weight of cocoa beans from 30 pods/clone Kg)
C 20	2.3^{a}±0.1	1.2^{a}±0.0	1.1^{a}±0.0
C 64	3.5^{a}±0.2	1.5^{e}±0.0	2.0^{e}±0.0
C 67	4.0^{e}±0.6	1.4^{d}±0.0	2.6^{d}±0.0
C 69	3.2^{cd}±0.0	1.4^{d}±0.0	1.8^{bc}±0.0
C 73	2.5^{ab}±0.0	1.5^{e}±0.6	1.0^{a}±0.0
C 74	3.3^{cd}±0.1	1.4^{d}±0.0	1.9^{bc}±0.0
C 75	3.5^{de}±0.0	1.5^{e}±0.0	2.0^{e}± 0.0
C 76	2.6^{ab}±0.0	1.4^{d}±0.0	1.2^{a}±0.0
C 78	3.4^{cd}±0.0	1.5^{e}±0.0	1.9^{bc} ± 0.0
C 79	3.3^{cd}±0.0	1.3^{c}±0.0	1.9^{bc}±0.0
C 70	2.9^{bc}±0.0	1.5^{d}±0.0	1.5^{b}±0.0
C 71	3.5^{de}±0.0	1.5^{d}±0.0	2.1^{de}±0.0

Mean followed by the same letter(s) on a column are not significantly different P > 0.05 from each other by Duncan's New Multiple Range Test

TABLE 5: Percentage damage due to *E. cautella* on different clones of cocoa beans (M±SD) after 40 days

Clone	Initial weight g)	Final weight (g)	% percentage weight Loss
C 20	30.1^{bc}±0.9	25.9^{c}±0.6	14.0^{abc}±2.0
C 64	30.2^{bc}±0.05	26.1^{c}±0.6	13.4^{abc}±2.0
C 67	30.1^{bc}±0.0	26.6^{c}±0.2	11.6^{abc}±0.75
C 69	30.2^{bc}±0.0	27.5^{c}±0.4	8.8^{a}±1.3
C 73	30.3^{d}±0.0	27.3^{c} ±0.5	9.9^{abc}±0.7
C 74	30.2^{cd}±0.0	26.6^{c}±0.2	11.9^{abc}±1.0
C 75	30.1^{b}±0.0	26.7^{c}±0.1	11.3^{abc}±6.6
C 76	20.0^{a}±0.0	15.0^{a}±1.3	25.0^{de}±6.6

C 78	$20.0^{a} \pm 0.0$	$15.9^{ab} \pm 0.6$	$20.5^{cd} \pm 2.9$
C 79	$20.1^{a} \pm 0.0$	$14.1^{a} \pm 1.6$	$30.0^{e} \pm 7.3$
C 70	$20.0^{a} \pm 0.0$	$15.9^{ab} \pm 0.3$	$20.5^{cd} \pm 1.6$
C 71	$20.0^{a} \pm 0.0$	$18.1^{b} \pm 0.1$	$9.5^{ab} \pm 0.6$

Mean followed by the same letter(s) on a column are not significantly different P > 0.05 from each other by Duncan's New Multiple Range Test

After 6 months of storage, the percentage of insect damaged beans on fermented cocoa beans was different from the unfermented ones. The population of *Ephestia cautella* on fermented cocoa beans was lower than that of unfermented cocoa beans (Jayas *et al*., 2004). The population of *Ephestia cautella* increased with storage period probably due to their short life span, availability of cocoa beans and favourable environmental conditions which contributed to their multiplication (Dharmaputra, 2000). Insect infestation had constantly being touted as an important cause of deterioration of stored grains ecosystem (Dharmaputra, 2000; Brunneto *et al*., 2007). Insect pest inflicted damage caused weight loss to the cocoa beans thus reducing their nutritional and commercial value. Previous study showed that damage caused by fermented cocoa beans stored for 180 days was lower than the damage of unfermented beans (Kresnawati, 1997; Mazarudin *et al*., 1987). The significant reduction ($P<0.05$) in the fat content during storage could be linked to the lipase enzyme activities which is naturally present in raw cocoa (Minife, 1989). The enzyme could be activated due to changes in moisture content of the beans and the high temperature of the storage environment. According to Gueli *et al*. (2004), the moisture content of cocoa beans should be between 6 and 7%. Storage in a well managed controlled environment allowed gradual drying resulting in a reduction in moisture content to the acceptable limit and eliminating any problem of mould development. The fat content of the cocoa beans decreased significantly ($p>0.05$) with increase in fermentation period which may be attributed to microbial activities present in the cocoa pulp (Gueli *et al*., 2004). Variation in the proximate and mineral composition of the cocoa beans was probably influenced by levels of fermentation of the beans which notwithstanding affected the development of *Ephestia cautella* on the cocoa beans stored over a period of 180 days. Valemir (2001) revealed that chemicals do not only contribute to the location of host by prey but could be predicated on certain factors such as attractants, deterrents, and differences in chemical composition and biochemical changes. The insect inflicted damage on clones 64, 69, 74 and 75 in this study results into mustiness leading to mould formation and the breakdown of fats to fatty acid in the beans. The significant reduction ($p<0.05$) in the moisture content during storage could be attributed to the enzymatic activities of lipase naturally present in raw cocoa (Jonifa-Essien, 2004). The enzyme could have been activated due to changes in the moisture content of the beans and the high temperature of the storage environment thereby contributing to this phenomenon. Due to safety, the moisture content of cocoa beans should be between 6

and 7%. There is palpable danger and mould development if the moisture content is greater than 8%. However, below 5%, the beans will be very brittle (Gueli *et al*., 2004) and disintegrate. Reduction in moisture content probably accounted for reduction in weight per bean. Storage in a controlled environment for four months result in a reduction in moisture content to the acceptable limit and eliminating any problem of mould development.

CONCLUSIONS

The findings of this study revealed that the population of *Ephestia cautella* in fermented cocoa beans was lower than that of the unfermented cocoa beans. It also showed that insect infestation is an important indicator of deterioration of stored grains leading to drastic reduction in weight thereby affecting their nutritional and commercial value.

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