Effect of storage management on free fatty acid content in dry cocoa beans

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Abstract

Though not a quality parameter, it is expected that the free fatty acids (FFA) content must be less than 1.0% to meet the acceptable level of 1.75% in cocoa butter extracted from the dry cocoa beans. This study therefore investigates the FFA content of stored dry cocoa beans from Ghana that was generally low compared to that of Côte d'Ivoire. The FFA content of dry cocoa beans increases with storage time and this was evident for both countries. The mean FFA of Ghana's cocoa beans was 2.03% in 1999 and 0.90% in 2008 while that of Cote d'Ivoire's cocoa beans was 2.57% in 2002 and 1.43% in 2008. The low mean moisture content of 6.5% of Ghana cocoa beans and the mean moisture content 8.0% of Côte d'Ivoire cocoa beans might have influenced the differences in mean FFA levels. To evaluate the effect of insect infestation on increase of FFA, dry cocoa beans were infested with ten young adults of *Lasioderma serricorne* (Fabricus), *Tribolium castaneum* (Herbst), *Cryptolestes ferrugineus* (Stephens) and stored for 9 mo under dry condition at 30±2°C. The mean FFA of the insect-infested dry cocoa beans increased from 0.76% at the time of storage to 1.81% after 9 mo of storage. However, the mean FFA of the control dry cocoa beans increased from 0.79% at the time of storage to 0.93% after 9 mo of storage. It could therefore be inferred conclusively that FFA content in dry cocoa beans increases with insect infestation.

Keywords: Cocoa beans, Free fatty acids, Storage management, Quality preservation, Insect infestation.

1. Introduction

Quality of dry cocoa beans in international trade is assessed on the percentage level of total mould, slaty, purple, insect infested, flat, and germinated beans. Recent cocoa trade has assumed a scientific dimension and emphasis is placed on the content of free fatty acids (FFA) which is influenced by many factors such as humidity, oxygen and insect infestation. For these reasons hermetic storage has been considered as a successful storage method for the management of FFA, insect control and quality preservation.

Ghana is the world's second biggest producer of cocoa *Theobroma cacao* L. after neighbouring Côte d'Ivoire (Sarpong, 2002). Under the climatic conditions of these countries, output is sometimes affected significantly by infestation. Infestation of dry cocoa beans in the post harvest sector starts from the drying mats and continues during storage. At the farm, insects in drying mats are an important source of infestation. At the end of the season they are usually rolled up and stored under the eaves but they often carry pupae from which *Ephestia cautella* (Walker) may emerge to infest the new crop. Similarly, the area around mechanical dryers can provide a breeding ground for pests (Wood and Lass 1985, Jonfia-Essien, 2004). This incidence of pests is a worldwide phenomenon which cannot be completely eradicated but can be curbed through pragmatic measures. Unless storage is properly carried out there is a risk of dry cocoa beans becoming damaged from insect infestation, mould and foreign odours (Jonfia-Essien, 2001).

1.1. Infestation of cocoa

All cocoa is susceptible to insect infestation and both beetles and moths infest cocoa beans. Some of the common beetles are *Lasioderma serricorne* (F.) (the cigarette beetle) and *Araecerus fasciculatus* (Degeer) (the coffee bean weevil), which can pierce the shell of the bean thereby providing an entrance for moths such as tropical warehouse moth (*Ephestia cautella*) (Walker) and for moulds (Jonfia-Essien, 2001; 2004). In Ghana, dry cocoa beans were monitored for insect pests associated with the cocoa in storage from 1995 to 2000 and eleven species identified including *Tribolium castaneum* (Herbst),

Cryptolestes ferrugineus (Stephens)*, E. cautella, L. serricorne* and *A. fasciculatus* (Jonfia-Essien, 2001; 2004).

Insect pests inflict their damage on stored products mainly by direct feeding, but their very presence in foodstuffs is a nuisance. In many species both larvae and adults cause damage, which may be devastating at times. Several factors may be responsible for insect infestation in storage and of special importance is the number of flying insects searching for food (Hodges et al., 2002). Studies in Ghana, with experimental and real stores, have shown that the number of flying beetles during the period of storage is directly correlated with the probability that the produce in any given store will become infested (Birkinshaw et al., 2002).

1.2. Mould infection of dry cocoa

It is a known fact that high moisture content result in mould infection. Microflora, particularly moulds, has been associated with FFA occurrence in stored cocoa beans (Wood and Lass, 1985; Pontillon, 1998). Increase in FFA during storage could be attributed to the activities of the enzyme lipase, which is naturally present in raw cocoa (Minifie, 1989). The enzymes become active due to the changes in moisture content of the beans and high temperatures of storage environment.

1.3. Standards of cocoa trade

Various cocoa standards that apply relate to flavour and purity or wholesomeness. The most important of these standards are the ISO standards (ISO, 1973) and those in the contracts of various trade associations such as Cocoa Association of London, the Association Française du Commerce des Cacao, and the US Cocoa Merchants Association (Jonfia-Essien, 2004). The grade standards are based on the cut test that allows certain gross flavour defects to be identified by cutting open the beans to reveal the colour of the dried nib (Anon., 1996).

1.4. New dimension of cocoa standards

Recently, the cocoa trade has assumed a more scientific position and a lot of emphasis is placed on the content of free fatty acids (FFA) which is influenced by many factors including humidity, moulds and oxygen. Though the use of pesticide in the control of insect infestation in cocoa beans has been associated with residue and Maximum Residue Levels (MRLs) determination has now become a requirement, FFA level has ushered in an additional standard that will enhance the production of superior quality of cocoa beans, which should have a positive impact on cocoa trade in the future.

1.5. Justification

It was observed that some cocoa beans with low moisture content of 6.5% were found to contain high FFA levels. Incidentally, the cocoa beans were infested with insects. However there is no scientific data on the relationship between insect infestation and FFA. This study therefore, aims at determining the impact of insect infestation on FFA formation in raw cocoa beans in storage and the role of storage management on FFA content.

2. Materials and methods

A total of 195 samples of dry cocoa beans were used for this study out of which 54 were Cote d'Ivoire's beans and the rest (141) from Ghana. 24 samples of Ghana's cocoa beans were used for the categorization studies in storage, 9 for insect studies in storage and the rest (108) for yearly comparison studies. All the 54 samples from Cote d'Ivoire were used for the yearly comparison studies. Data collected from the studies were subjected to statistical analysis using GenStat 7.22 DE (Discovery Edition).

2.1. Infestation experiments

Laboratory reared storage insect pests of the species *L. serricorne*, *T. castaneum*, and *C. ferrugineus* were used to investigate the level of insect infestation on 500 g each of cocoa bean samples of different categories (super main crop, main crop, super light crop, light crop, small beans, type 4 and remnant) from Ghana in triplicates. Adult insect pests (10 unsexed each) were introduced into the dry cocoa beans using miniature prototype jute sacks and inserted into cotton cloth sacks to prevent insect migration from the cocoa beans and stored for 9 mo in a controlled environment at 30□2°C and relative humidity of 70□2%, based on the prevailing conditions at the cocoa warehouses in Ghana. A single insect species

per sample was used in the insect studies whereas all three species were used per sample for the categorization studies. The number of larvae, pupae and adults were assessed once every 3 mo for the period of 9 mo. The cocoa beans were also analysed for FFA content.

2.2. Sampling and preparation

Ghana exportable dry cocoa beans shipped in 1999, 2004, 2006 and 2008 were sampled from three different sites at SITOS warehouse in Amsterdam. Sampled from the same warehouse were Côte d'Ivoire exportable cocoa beans shipped in 2002 and 2008. All sampling was done in triplicates from each site. The cocoa beans were sieved and moisture content determined before subjecting the beans to any analysis.

Cocoa beans were bulked and reduced to the laboratory sample size before coding for analysis. Each sample (50 g) of cocoa beans was weighed in a Petri dish. The samples were roasted for about 2 h in the oven at 105°C, cooled and de-shelled to separate the nib from the shell. The de-shelled samples were milled (test samples) and moisture content of each was determined.

2.3. Free fatty acid analysis

Federation of Cocoa Commerce (FCC) recommended method was used for the FFA analysis and double extraction was carried out. Round bottomed flasks of 250 mL were dried in the oven at 105°C, cooled in the desiccator, weighed and 180 mL of hexane was measured into the round bottomed flasks. Each test sample of 10 g was measured into a thimble and was set up for extraction for two hours using the Soxhlet apparatus. The set up was allowed to cool and the solvent drained into the round bottomed flask.

Each sample was ground with sand and set up for two 2 h again. The solvent was concentrated into fat by evaporating the hexane using the rotary evaporator. The fat content was dried in the oven for 2 h and cooled in the desiccator. Weight of the extract and the flask were taken and recorded.

The weighed fat extract was dissolved in 50 mL ethanol/diethyl ether solution, 1/1 [v/v/]. About three drops of phenolphthalein indicator were added to the fat in 50 mL ethanol/diethyl ether. The mixture was titrated against 0.1 M sodium hydroxide in ethanol solution and the end point taken and recorded for the FFA calculation as follows.

$FFA = (282 \times V \times C) / 10xM$
$M = (M_2 - M_1)$
Where
282 = molecular mass of oleic acid
V = volume (mL) of standardised sodium hydroxide used for titration.
C = concentration (mol L^{-1}) of the standardised sodium hydroxide used for titration.
$C = Wp / (Mp \times Vp)$
Where
Mp = molecular weight of hydrogen phthalate
Vp = volume of sodium hydroxide solution
Wp = weight of sodium hydroxide phthalate
M = mass of extracted fat
M_1 = mass of conical flask and pumice stones before extraction
M_2 = mass of conical flask after extraction

3. Results

The mean moisture content of cocoa beans from Ghana was 6.5% and that of Côte d'Ivoire 8.0%. All the cocoa beans from both countries were infested with *T. castaneum, C. ferrugineus, E. cautella* and *A. fasciculatus*.

All three insect species that were introduced on the cocoa beans multiplied significantly ($P < 0.01$) over the storage period (Fig. 1) causing severe damage to the cocoa beans. The insect activity resulted in a significant ($P < 0.01$) increase in FFA content (Fig. 2) over the storage period. However, the control samples which were not infested with insects maintained a low FFA level throughout the storage period. The FFA content of insect infested cocoa beans increased by 138.2% whereas that of the control without insect infestation increased by 17.7% over the 9 mo storage period. In comparison, the FFA content of

cocoa beans from Ghana was significantly lower than that of Côte d'Ivoire (Fig. 3). The insect population in cocoa beans from Côte d'Ivoire was slightly higher than that of Ghana although not significant and the 8.0% moisture content of Côte d'Ivoire cocoa beans is just on the border line of FCC threshold. However, all the cocoa beans from Côte d'Ivoire contained more than 1.4% FFA while that of Ghana had FFA levels lower than 1.0%. Ghanaian cocoa beans stored between one year (2008 crop) and three years (2006 crop) had a FFA content lower than 1.0% while the cocoa beans stored for five years (2004 crop) higher than 1.0% though lower than the 1.75% threshold level (Table 1). The cocoa beans stored for ten years (1999 crop) contained more than 1.75% FFA. Differences in FFA content between the cocoa beans stored over the storage period and samples taken from different sites were significant ($P < 0.01$). Cocoa beans from Côte d'Ivoire stored for one year (2008 crop) had FFA content more than 1.4% and cocoa beans stored for seven years (2002 crop) contained more than 2.5% FFA (Table 2) which was higher than the internationally accepted level of 1.75%. The FFA content of 2008 crop differed significantly ($P < 0.01$) from that of 2002 crop although samples taken from the three sites were not significantly different ($P > 0.05$).

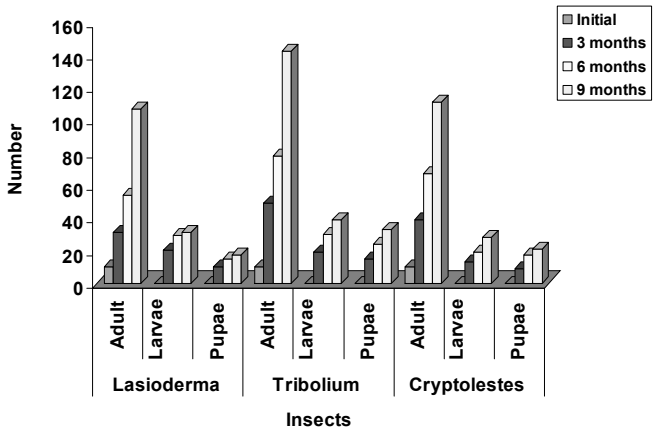

Figure 1 Number of insects found on 500 g of dry cocoa beans from Ghana after various months of storage (s.e. = 0.044).

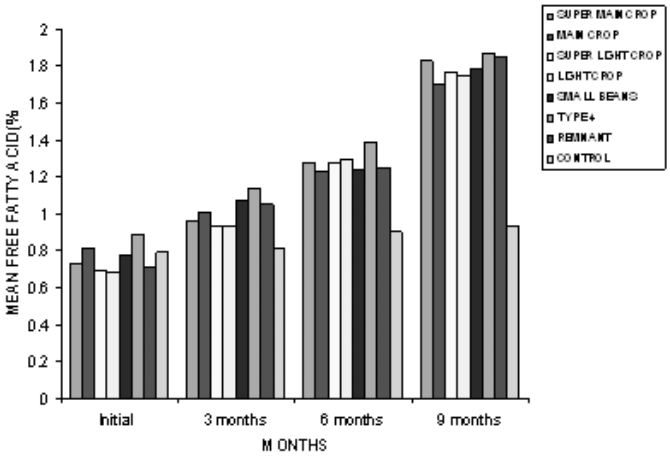

Figure 2 Free Fatty Acid (FFA) contents of various categories of dry cocoa beans from Ghana artificially infested with stored product insects and stored over different periods of time (s.e. = 0.006).

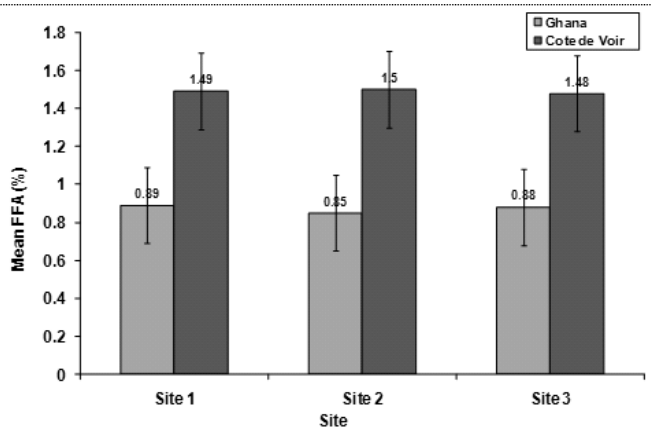

Figure 3 Free fatty acid (FFA) contents of 2008 crop year cocoa beans from Ghana and Cote d'Ivoire.

Table 1 FFA analysis of dry cocoa beans from Ghana stored over period of time (s.e. = 0.004).

	Mean FFA (%)							
	Sampling site 1			Sampling site 2			Sampling site 3	
Crop year	Site 1	Site 2	Site 3	Site 1	Site 2	Site 3	Site 1	Site 2
1999	2.08	2.06	2.09	2.06	2.04	2.03	1.96	1.94
2004	1.40	1.49	1.45	1.40	1.43	1.41	1.37	1.35
2006	1.25	1.24	1.27	1.18	1.17	1.15	1.11	1.14
2008	1.10	1.09	1.07	0.91	0.93	0.90	0.70	0.69

Table 2 FFA analysis of dry cocoa beans from Cote d' Ivoire stored over period of time (s.e. = 0.005).

	Mean FFA (%)							
	Sampling site 1			Sampling site 2			Sampling site 3	
Crop year	Site 1	Site 2	Site 3	Site 1	Site 2	Site 3	Site 1	Site 2
2002	2.63	2.60	2.58	2.53	2.51	2.55	2.57	2.60
2008	1.42	1.47	1.45	1.44	1.39	1.41	1.40	1.43

4. Discussion

4.1. Insect pest infestation

Storage management plays a vital role in maintaining the quality of cocoa beans in storage. Particularly dry and cool conditions should be preferred. Lower temperatures would result in maintaining better quality cocoa beans by inhibiting FFA and insect development. However, since cocoa beans are hygroscopic, sudden removal of the cocoa beans from cool to warm areas without sufficient temperature equilibration would cause moisture migration. A well managed cocoa bean warehouse would be free from insect infestation which causes devastating effect on the beans.

Some insects have been found not to be attracted to stored products at long range but to locate their food by making holes into (Hodges, 1994; Hodges et al., 1999) the cotyledon, causing much damage (Hodges, 1994; Hodges et al., 1999). The insects inflicted damage on the cocoa beans by direct feeding. Their multiplication on the cocoa beans is a nuisance, for example, members of the genus *T. castaneum* are known to produce toxic quinones (Mills and White, 1994).

4.2. Effect of insect pests on FFA content

Insect damage to the cocoa beans in storage resulted in mustiness, leading to mould formation and the breakdown of fat to free fatty acids in the beans. The significant increase in the level of FFA during storage suggests that insect infestation is one of the factors other than biochemical factors that may be

responsible for the increases in FFA levels in stored cocoa beans. Low moisture content can limit the increase in FFA, which are carboxylic acids released from triglycerides (Selamat et al., 1996) facilitated by a lipase (E.C. 3.1.1.3) or oxidation. Also the risks of oxidation are negligible in cocoa butter due to its low unsaturated fatty acid content (Whitefield, 2005) and high content of polyphenols, natural antioxidants, in cocoa beans (Nickless,1996). Under negligible biochemical activity, insect activity will breakdown cocoa butter, increasing the FFA level in the cocoa beans (Anon, 1970). The increase in the amount of FFA therefore has a direct impact on the fat content and causes a negative change in cocoa flavour (BCCCA, 1996). For reasons of quality therefore, the directive 73/241/EEC (EEC, 1973) limits the maximum FFA content to 1.75% oleic acid equivalent in cocoa butter.

In conclusion, this study showed that poor storage management resulting in insect infestation resulted in increased FFA content. Good storage management must be practiced to control insect pests and sustain the quality of the cocoa beans.

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