A novel approach to the protection of cocoa beans by preventing free fatty acid formation under hermetic storage

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Abstract

Hermetic storage has provided a successful storage method for the protection of dry cocoa beans by replacing fumigants for insect control and for quality preservation. Hermetic storage is achieved in specially constructed flexible plastic structures and is based on the principle of generation of an oxygen-depleted, carbon dioxide-enriched interstitial atmosphere caused by the respiration of the living organisms in the ecological system of a sealed storage. An increase in free fatty acids (FFA) content in dry cocoa beans is a significant factor that determines its quality preservation. After fermentation of the beans, moisture content (m.c.) is usually high that poses a risk for the rise of FFA in the beans. Tests were carried out to study the effects of hermetic storage of dry cocoa beans under aerobic and hermetically sealed conditions on the development of FFA's in the beans at 7.0%, 7.5%, and 8.0% m.c. for periods of 90 and 160 d at 30°C. The beans under hermetic conditions responded by creating progressive depleted oxygen conditions that were accompanied by the increased carbon dioxide due to the respiration of the beans. The lowest oxygen concentration took place at 7.0% m.c. after 35 d, at 7.5% m.c. after 29 d, at 8.0% m.c. after 26 d of storage and thereafter, no significant increase in oxygen concentration was observed. The FFA content of cocoa beans at 7.0%, 7.5%, and 8.0% m.c. under hermetic conditions of 30°C remained below or close to 1.0% after 90 and 160 d of storage. This was more comparable to the results obtained when the beans were stored at 4°C rather than the controls. In comparison, the aerated control stored at 30°C showed marked increase in FFA levels of up to 1.48%.

Keywords: Hermetic storage, Modified Atmospheres, Cocoa beans, Quality preservation, Storage insect control, Flexible storage structures.

1. Introduction

The practice of producing cocoa beans is through a process of fermentation, which encourages yeast fermentation due to the partial anaerobic conditions (Schwan and Wheals, 2004). This process is necessary to moderate its initially bitter flavour and to develop the typical flavour of cocoa. After fermentation, infestation of cocoa beans starts from the drying mats and continues in storage. Climatic conditions in the tropics are characterized by high humidity levels of 70 to 90% r.h. and temperatures around 30°C which are ideal for storage insects and moulds to develop on cocoa beans.

Surface contamination is a major source of fungi in fermented and dried cocoa beans. According to Pitt and Hocking (1997), species of *Aspergillus* are the predominant spoilage fungi in tropical areas and *Penicillium* spp. occur in more temperate zones. Properties of fungal lipases and mycotoxin-producing abilities of fungi isolated from raw cocoa beans showed good evidence to support their potential toxicogenic abilities and the free fatty acids (FFA) content (Guehi et al., 2007). The cocoa butter is defined as the fat obtained from the cocoa beans which should not contain more then 1.75% FFA (expressed as oleic acid) (FAO/WHO, 1999).

Storage beetles are attracted to cocoa beans and cause damage by boring holes in the beans or feeding on the nib (Jonfia-Essien et al., 2007). A couple of methods are applied today to achieve a low FFA content of the cocoa beans: storing the beans at low temperature (4°C) or drying the beans. Hermetic storage has provided a successful storage method for the protection of dry cocoa beans by replacing fumigants for insect control and for quality preservation (Navarro et al., 2007). Hermetic storage is achieved in specially constructed flexible plastic structures and is based on the principle of generation of an oxygen-

depleted, carbon dioxide-enriched interstitial atmosphere caused by the respiration of the living organisms in the sealed storage.

The present paper is intended to study the effects of storage of cocoa beans with 7.0 to 8.0% m.c. under aerobic and hermetically sealed conditions on the development of FFA's in the beans.

2. Materials and methods

2.1 Moisture content

Cocoa beans imported from Ghana were used and their m.c. levels were checked at the outset of the storage and following 90 and 160 d of storage by electronic sensors that measures water activity (Rotronic, Instrument Ltd., Crawley, UK) converted to m.c. (wet basis). The tested cocoa beans had an initial equilibrium relative humidity (ERH) of 69% equivalent to a moisture content (m.c.) of 7.2%. To raise the moisture content, the total quantity of water needed to attain given m.c. was calculated and applied in successive small aliquots on the beans spread out in a single layer on a polyethylene liner. Time was allowed for the added water to be absorbed, and this procedure was repeated until the calculated amount of water had been added and absorbed. After moisture adjustment these samples were allowed to equilibrate at least 4 wks at 4°±1°C.

2.2. Storage conditions

The cocoa beans were tested at approximately 7.0%, 7.5% and 8.0% m.c. At each moisture content., about 0.56 kg of cocoa beans was placed in 0.9-L mason jars. Aerobic and hermetic storage at three moisture contents were replicated four times. Cocoa beans were stored at a controlled temperature of 30±1°C for 90 and 160 d. In addition to controls kept at 30°C, another group of jars were kept at 4°C in two replicates.

2.3. Testing methods

2.3.1. Respiration rate of cocoa beans

The respiration rate was determined based on the oxygen consumption and the carbon dioxide evolved from the cocoa beans using the oxygen monitor (Emproco Ltd., HGA11-PB, Israel) equipped with inlet and outlet gas ports that enabled gas circulation by a closed loop gas flow system using flexible tubes connected with the two copper tubes soldered to the jar lid. The top end of each copper tube was equipped with T-type two-way valves from outside the jars situated between each flexible and copper tube. Similar to oxygen concentration the carbon dioxide evolved from the beans was measured using a Gow-Mac carbon dioxide analyzer model 20-600 using a thermal conductivity detector.

2.3.2. FFA content

At the outset of storage as well as following 90 and 160 d of storage the FFA content of the cocoa beans was tested according to the method of the International Office of Cocoa, Chocolates and Sugar Confection (IOCCC 1996). In this method the percentage FFA was calculated as percentage of oleic acid.

3. Results

Figures 1, 2 and 3 show the average gas concentrations of the four replicates that reflect the changes in oxygen and carbon dioxide concentration of 7%, 7.5% and 8% m.c. of the cocoa beans stored under hermetic conditions for 160 d at 30°C, respectively. The progressive depletion in oxygen concentrations were accompanied by the increased carbon dioxide that evolved from the living organisms prevailing on the tested beans. The lowest oxygen concentration (<0.5%) was recorded at 7.0% m.c. after 35 d, at 7.5% m.c. after 29 d and at 8.0% m.c. after 26 d of storage and thereafter no significant increase in oxygen concentration was observed. The highest carbon dioxide concentration at 7.0%, 7.5% and 8% m.c. was 20.2, 25.3 and 25.8%, respectively.

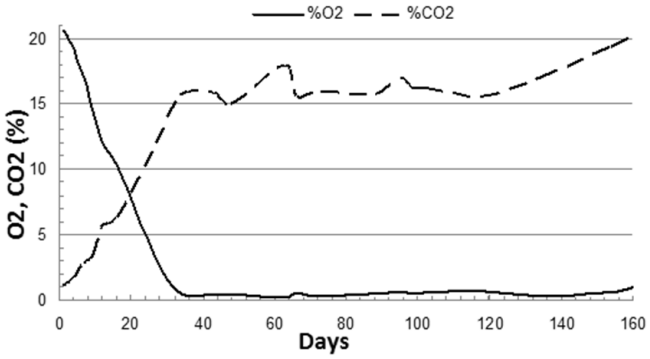

Figure 1 Changes in oxygen and carbon dioxide concentration of 7.0% moisture content cocoa beans stored under hermetic conditions for 160 d at 30°C. Results are averages of four replicates.

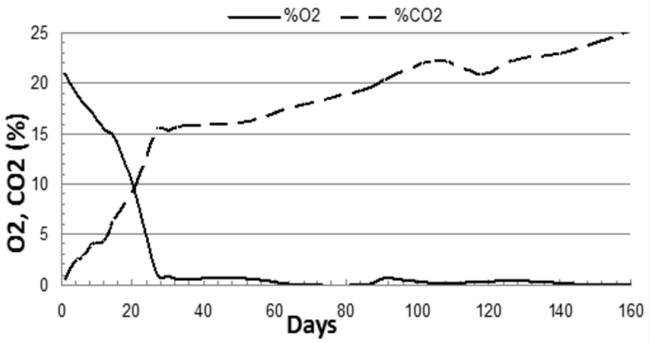

Figure 2 Changes in oxygen and carbon dioxide concentration of 7.5% moisture content cocoa beans stored under hermetic conditions for 160 d at 30°C. Results are averages of four replicates.

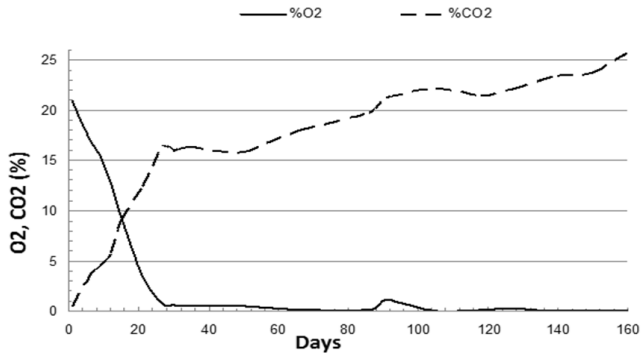

Figure 3 Changes in oxygen and carbon dioxide concentration of 8.0% moisture content cocoa beans stored under hermetic conditions for 160 d at 30°C. Results are averages of four replicates.

Figures 4, 5 and 6 show the average gas concentrations of the four replicates that reflect the changes in oxygen and carbon dioxide concentration of 7%, 7.5% and 8% m.c. of the cocoa beans stored under aerated conditions for 160 d at 30°C, respectively. There were slight changes in the oxygen and carbon dioxide concentration at 7.0%, 7.5% and 8.0% m.c. of the cocoa beans stored under aerated conditions for 160 d at 30°C. They maintained approximately the level of 20% oxygen as at start and with the highest percent of 2.8, 5.0 and 4.9 carbon dioxide respectively (Figures 4, 5 and 6).

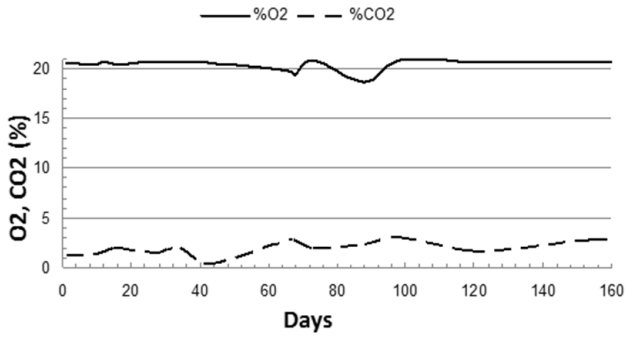

Figure 4 Changes in oxygen and carbon dioxide concentration of 7.0% moisture content cocoa beans stored under aereated conditions for 160 d at 30°C. Results are averages of four replicates.

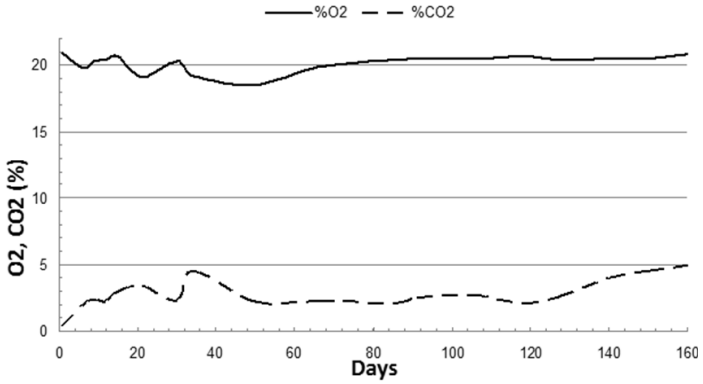

Figure 5 Changes in oxygen and carbon dioxide concentration of 7.5% moisture content cocoa beans stored under aerated conditions for 160 d at 30°C. Results are averages of four replicates.

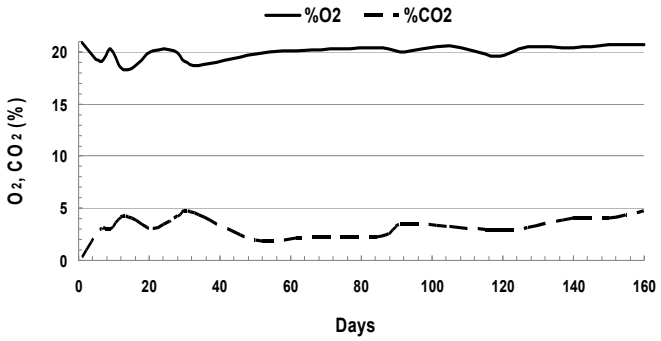

Figure 6 Changes in oxygen and carbon dioxide concentration of 8.0% moisture content cocoa beans stored under aerated conditions for 160 d at 30°C. Results are averages of four replicates.

Table 1 shows the FFA (% oleic acid) of cocoa beans at 7.0%, 7.5% and 8.0% m.c. stored under hermetic condition at 30ºC, in aerated conditions of 30°C and 4°C at 0 d, 90 d and 160 d of storage. Results were reported as average of four replicates and the calculated standard deviation for each set. Results in Table 1 clearly indicate that FFA levels under hermetic conditions of the 7.0% m.c. after 90 d storage are more comparable to the results obtained when the beans were at 4°C rather than the controls for which there was a significant and marked increase of FFA levels from 0.70% up to average of 0.95%.

Table 1 FFA (%) (± SD) level of 7.0, 7.5 and 8.0% moisture content cocoa beans stored under both hermetic and aerated conditions at 30°C and at 4°C at the start of storage, after 90 d and after 160 d of storage.

		After 90 d storage			After 160 d storage		
M.C. (%)	**Initial FFA (%)**	**Hermetic 30°C**	**Control 30°C**	**Control 4°C**	**Hermetic 30°C**	**Control 30°C**	**Control 4°C**
7.00	0.70±0.100	0.74±0.118	0.95±0.232	0.70±0.000	0.91±0.062	1.03±0.126	0.54±0.000
7.50	0.69±0.070	0.85±0.070	1.13±0.287	0.69±0.120	0.98±0.085	0.94±0.043	0.93±0.106
8.00	0.70±0.000	0.83±0.047	1.13±0.386	0.72±0.113	1.09±0.160	1.48±0.222	0.83±0.127

After 160 d of storage FFA results did not differ significantly compared to the control, but at 8.0% m.c. there was a marked increase of the FFA content in the control (1.48% FFA). Because of the moderate increase in FFA, and additional test for infestation and broken kernels revealed that the beans were sound and of good quality with percentage of broken kernels less than 1%.

4. Discussion

Among the potentially mycotoxigenic filamentous fungi on bean samples found by Rahmadi et al. (2008) the main species were *Aspergillus flavus* Link (Trichocomaceae), *A. niger* Tieghem, *A. wentii* Wehmer, *A. clavatus* Desmazières, *Penicillium citrinum* Thom (Trichocomaceae), and *P. spinulosum* Thom. *Aspergillus* spp. require higher temperature but lower water activity compared with *Penicillium* spp., and it grows more rapidly as well (Hocking, 2006). Although *Penicillium* spp. produce more chemical resistant spores (Hocking, 2006; Pitt, 2006), Guehi et al. (2007) found that FFA accumulation in raw cocoa beans could be attributed mainly to the presence and the action of *Rhizopus oryzae* Went & Prins. Geerl. (Mucoraceae) and *Absidia corymbifera* (Cohn) Sacc. & Trotter (Mucoraceae).

During storage, beetles and moths cause damage to dry cocoa beans by boring into the beans. The beans then become naked from their natural defence mechanism attracting moths' larva (Jonfia-Essien, 2004) and allowing fungi to penetrate the beans. Increased levels of broken beans and fragments in a consignment can significantly increase the average FFA content of the fat extracted. The greater the initial FFA content of the raw cocoa beans, or the lower the quality of the beans, the greater is the increase in FFA. Moulds could produce lipase (Wood and Lass, 1985) which in contact with cocoa butter of broken cocoa nibs releases FFA from triglycerides. Guehi et al. (2008) showed that on artificially broken cocoa beans FFA content increased substantially regardless of cocoa beans initial quality. Their low FFA content in whole healthy beans increased from 0.48 to 0.78% and did not exhibit an appreciable change during over 12 wks' storage. The present work was carried out using high quality cocoa beans imported from Ghana that contained very low fragmented or broken beans percent (<1%) and consequently the initial FFA was at 0.7%. According to cocoa bean grading and marketing rules (India Government, 1997), the percent of broken beans should not exceed 3% for grade A quality.

In previous work using biogenerated atmospheres of stored cocoa commodity for quality preservation and insect control, where the respiration of cocoa beans depleted oxygen concentration to <1% and increased carbon dioxide concentration up to 23%, no insects survived and the quality of the beans was preserved (Navarro et al., 2007, Jonfia-Essien et al., 2008 a, b).

In conclusion, storing cocoa beans in hermetically sealed structures inhibits activity of insect pests and mould development; as a consequence the FFA deriving from microflora development was inhibited. Most possible that the toxicogenic mycotoxins are also inhibited, though this requires further research for extended period of time in hermetically sealed structures with a higher percent of fragmented beans or a low quality cocoa beans

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