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Production of Clay Containers for Curbing Plantain Post-Harvest Losses in Ghana

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Abstract

In Ghana, most farmers are peasants and at times foodstuffs produced get rotten either through transportation or market places. This normally affects the meager income that farmers earn through hard work. Available statistics indicate that each year, food crops worth several hundreds of dollars go waste in the country due to poor harvest losses and it represents 70% of total food production in Ghana. Again, in the country, there is abundant of clay as a natural resource. Geological study has revealed that it is found in almost every part of the country. As a means of finding solution to the rate at which local foodstuffs especially plantain rot, the study sought to design and compose clay container purposefully for storing plantain to prolong its lifespan. The study focused on 5 clay body compositions (C_1 to C_5) and fired at 950˚C. Composition $\mathbf{C_1}$ consisted of 50% of Abonko clay and 50% of Daboase clay. Composition $\mathbf{C_2}$ was made up of 40% Abonko clay, 50% Daboase clay and 10% of smooth sawdust. Composition $\mathbf{C_3}$ composed of 45% of Abonko clay, 45% of Daboase clay and 10% of smooth sawdust. Composition $\mathbf{C_4}$ was made up of 90% Daboase clay and 10% rough sawdust. The last composition $\mathbf{C_5}$ comprised mainly 100% Abonko clay. Fresh plantains obtained from Takoradi market circle were stored in the containers and weekly recordings of states of plantain for five consecutive weeks were carried out. It was revealed that $\mathbf{C_4}$ was successful in storing fresh plantains to ripe stage after the five weeks. It is recommended among others that, the technique should be made available to stakeholders such as Ministry of Food and Agriculture (MOFA), plantain farmers and market plantain sellers through seminars, public education and symposia in order to minimize post-harvest losses.

Keywords

Clay, Containers, Plantain, Storage

1. Introduction

In Ghana, the loss of foods in the post-harvest system has been a problem, and there is the exigency to do a better job of conserving or expanding the shelf-life of food supply in order to ease hunger and undernourishment. The agricultural sector responsible for food production supplies the majority of crops including fruits and vegetables that are seasonal crops and perishable in nature. Available statistics indicate that each year, food crops worth Seven Hundred Thousand Dollars ($700,000.00) go waste in the country due to poor harvest losses and it represents 70% of total food production in Ghana [1]. A good number of studies on post-harvest technology have been undertaken and concentrated on grains and other durable products, which are generally stored dry, and a considerable technology has been developed to deal with these problems. On the other hand, little work has been conducted on the perishable food crops, yet they are of great importance and contribute portions of the diets in developing countries such as Ghana. According to a Food and Agriculture Organization (FAO) survey in 2006, plantain contributed about 13.1% of the agricultural gross domestic product (AGDP) and per capita annual consumption of 101.8 kg per head in Ghana [2]. There are crops of great economic value with a hope of local consumption, export market, and play a big role in food security and poverty reduction. They are also essential sources of nutrients, minerals, and vitamins for human health and wellbeing [3]. During good seasons, there may be pumper harvest, especially plantain, but due to lack of good roads, inadequate transport facilities and poor availability of packing materials, the surplus cannot be conveyed quickly to the markets in urban centres. In addition, the surplus production often cannot be stored for sale during off-seasons because of insufficient local storage facilities [4]. In other words, the farmers and foodstuff sellers do not achieve good prices for their produce because of the pumper harvest and most of the crops get spoilt resulting in complete loss of income. According to Asarewaa [5], fresh plantains take less than two weeks to get rotten at the Ghanaian market centres and it is a big challenge for plantain sellers. In effect, the ultimate aim of preserving food is to reduce the growth of microorganisms during the storage stage, thus facilitating longer shelf life and minimizing hazard from eating the food [6]. According to Hagan [6], some modern preservation methods of food include: 1) canning—process of preserving food by heating and sealing it in containers for storage; 2) dehydration—longer storage through sundry, room dry and dehydrators; 3) freezing and freeze-drying—creating environment where bacteria cannot grow. Freeze-dried foods lust months to years. For example, sea food and fruit juice; and 4) irradiation—food is exposed to a controlled amount of radiation to destroy organisms responsible for spoilage.

1.1. Objectives of the Study

1) To investigate possibilities of composing clay bodies to manufacture clay containers for storing plantain.

2) To determine whether the manufactured clay containers can increase the

life-span of plantain.

3) To provide local plantain farmers and sellers alternative means of storing plantain.

1.2. Importance of the Study

The study will be useful to peasant farmers and market dealers especially plantain sellers, in order to maximize profit or income.

1.3. Research Question

To what extent can composed clay containers store and prolong shelf-life of plantains as foodstuff?

1.4. Delimitation (Scope)

The study is limited to the use of composed clay bodies to manufacture clay containers that will be used to store plantain.

1.5. Brief Overview of Food Storage

Foods are materials, raw, processed, or formulated, that are consumed orally by humans or animals for growth, health, pleasure, satisfaction, and satisfying social needs [7]. Food by its nature starts to deteriorate the moment it is harvested. Physical, chemical, mechanical, and microbial effects are the leading causes of food deterioration and spoilage. Rahman [7] argues that damage can start at the initial point by mishandling of foods during harvesting, processing and distribution; and may lead to ultimate reduction of shelf life. Rahman [7] outlines other instances of deterioration as follows: 1) bruising of fruits and vegetables during harvesting and postharvest handling, leading to the development of rot, 2) tuberous and leafy vegetables lose water when kept in atmospheres with low humidity and, subsequently, wilt, and 3) dried foods kept in high humidity may pick up moisture and become soggy. Food storage involves the action taken to maintain foods with the desired properties or nature for as long as possible [7]. In Ghana, it is a common practice to see different containers such as wood box, plastic materials, baskets, and sacks used in collecting various farm produce during harvesting with inadequate handling that enhances level of produce damage. Food scientists have described that absence of farm storage facility and proper packing systems results in perishable produce being marketed immediately after harvesting without primary processing and adequate packaging [8]. According to Brummell [9], the main reasons for storing food are to overcome inappropriate planning in agriculture, produce value-added products, and provide variation in diet. In ancient times, farmers used the sun and wind to naturally dry food. Evidence proved that Middle East and oriental cultures actively dried foods in hot suns as early as 12,000 B.C. [10]. Freezing was also an obvious preservation method to the appropriate climates. People who lived in geographic areas that had freezing temperatures for some part of a year made use of the temperature to store foods [11]. Another method termed fermentation was also used in some parts of the world. It was not invented but rather discovered when first beer was outlined as a result of few grains of barely were left in the rain and microorganisms fermented the starch-derived sugars into alcohols [10]. In another development, majority of studies have shown that the most common causes of post-harvest losses include lack of sorting to eliminate defects before storage and the use of inadequate packaging materials, rough handling and inadequate cooling and temperature maintenance [12].

Local Storage of Plantain

In Ghana, the bumper harvest of plantain in the food growing areas such as Agogo, Maame Krobo in the Afram Plains, Hwediem and Gaoso as well as several plantain growing areas make it difficult for farmers to store plantain before transporting them to market. Post-harvest loss assessment of plantains were carried out in Market Circle, Takoradi and the result revealed that there were greater post-harvest losses of 53.3% due to poor handling during transportation and the use of poor marketing structures to sell their plantains [13]. Some sellers adopted crude methods by covering their foodstuffs with fabric and also sold in the open space being exposed to direct sunlight; leaving them at the mercy of the weather as demonstrated in **Figure 1**. These outmoded methods of trying to store plantains rather worsen the situation thereby making the plantain foodstuffs ripe or get rotten in no time. This situation becomes serious for plantain farming, especially during bumper harvest and requires urgent attention. The short shelf-life of plantain makes it difficult to manage easily post-harvest period unlike that of dry grains [14]. Hence, the attempt by the researchers to experiment and find if possible, an enduring solution to plantain getting rotten by adopting the use of clay containers as a method of storing fresh plantain to expand its shelf-life.

1.6. Clay Deposits in Ghana

Clay deposits are located in all regions of Ghana. According to Kesse [15], work has been done on the occurrence of clay deposits in Ghana, including the location, reserves in metric tonnes, approximate expected life span of the clay deposit in years and the possible usage of the deposits. **Table 1** and **Table 2** represent the location, area and reserve of the clay deposits in Ghana.

Figure 1. Methods of storing plantain at the mercy of the weather in Market Circle, Takoradi.

Table 1. Clay deposits in the greater Accra, Brong Ahafo, Upper, Central regions of Ghana (Kesse, 1985).

Greater Accra Region					
Area	**Location**	**Reserve (tonnes)**	**Area**	**Location**	**Reserve (tonnes)**
Accra	Alajo	48,600			
	Ashiaman	18,677,165		Afienya East	24,194,681
	Prampram A	21,779,929	Tema	Afienya West	5,514,894
	Prampram B	74,350		Mobole	15,000,000
	Prampram C	43,771	Ada	Kasseh/Bedaku	42,661,830
	Kpone	10,960,115		Big Ada	51,242,553
	Oyibi	6735			
	Kwabenya	2,326,596			
Brong Ahafo Region			**Upper Region**		
Area	**Location**	**Reserve (tonnes)**	**Area**	**Location**	**Reserve (tonnes)**
Sunyani	Susan Valley	661,188		Gambibigo	12,419,998
	Tanoso	16,200,200	Bolgatanga/ Navrongo	Sumbrungu	4020
	Adantia	530,665		Tono	8,477,333
				Sobolo	649,997
Eastern Region					
Area	**Location**	**Reserve (tonnes)**	**Area**	**Location**	**Reserve (tonnes)**
			Asamankese	Asamankese	840.000
Nkawkaw	Adihima/Asuogya	2,240,099		Apinmang	2,801,250
	Abepotia	7,614,793	Akim Oda	Akim Swedru	33,173,335
	Framase	41,687		Akim Awisa	1,285,553
Kibi	Tamfoi	1,285,084		Akim Abonase	4,561,000
	Moseaso	444,000	Akwapim	Adawso	1,027,000
Anyinam	Abomosu	4,081,434	Somanya	Okwenya	34,862,223
Central Region					
Area	**Location**	**Reserve (tonnes)**	**Area**	**Location**	**Reserve (tonnes)**
Cape Coast	Nkuntraw	7,527,168	Winneba	Esuakyir No 2	1,800,000
	Kakum Valley	42,800		Simbrofo	3,100,000
	Atrankwa	12,000,000		Mprumen	35,877
	Ochiso	15,441,702		Kasua/Oduponkpehe	51,702,127
	Ampia Ajumaku	195,000		Nyanyanu	1,107,191
Ajumaku	Esuakyir No 1	6,800,000	Gomoa	Gomoa Brofo	268,968
Dunkwa	Subin Valley	162,000	Komenda	Domenase	3,952,551

Table 2. Clay deposits in the Northern, Western, Ashanti and Volta regions of Ghana (Kesse, 1985).

Northern Region					
Area	**Location**	**Reserve (tonnes)**	**Area**	**Location**	**Reserve (tonnes)**
Tamale	Koblimahago	9,455,892	Tamale	Kunkuo	234,502
	Kpaliga	259,200		Yapei	38,694
	Nyankpala	48,600			
Western Region					
Area	**Location**	**Reserve (tonnes)**	**Area**	**Location**	**Reserve (tonnes)**

Continued

	AlendaWharf	2,956,522		Inchanban	2,668,600
	Aluku	17,860,944	Sekondi	Shama	7,163,082
	Esiama-Kakam	113,550,239	Takoradi	Dixcove (Mfruma)	9,469,979
Nzima	Teleku-Bokaso	74,456,122		Wasa-Akropong	614,249
	Nimzimirim	9,343,117	Wasa	Asankragwa	8,629,200
	Bao-Bamakpolo	31,493,879		Enchi	226,330
	Bokazo	221,600,000	Amanfi	Manso-Amanfi	597,780
	Nzima East	241,190,133			
			Ashanti Region		
Area	**Location**	**Reserve (tonnes)**	**Area**	**Location**	**Reserve (tonnes)**
	Womasi	164,570			
	Kaasi (Tuantem)	1,086,993			
	Sisai	113,400		Asokwa	33,865,955
	Kokobriko	21,061		Mfensi	396,548
Kumasi	Dichemso-Valley	81,000	Obuasi	Afari	2,055,900
	Aboabo	162,017	Nkawie	Jankoba	139,999
	Dichemso-Aprapong	162,017		Ahatawsu-(Mpasatia)	100,560
	Satang No 1	32,400		Awrenfena	268,801
	Satang No 2	162,017			
	Subin Valley	162,900			
			Volta Region		
Area	**Location**	**Reserve (tonnes)**	**Area**	**Location**	**Reserve (tonnes)**
	Adidome No1	7,755,319			
	Adidome No2	469,800	Bowiri	Kalapka	501,440
Ho	Tangidome	7614		Tuwotsive	1944
Anfoega	Nuzeme	10,083		Amanfro/Anyinase	2,000,000
	Toga	42,163	Dayi	Dayi River Basin	997,900
Gbefi-Hoeme	Kpetoe	29,160	Ketekrachi	Woroto	7,027,707
	Aveyiboe	27,540		Adankpe	2,273,361
	Valexo	16,300	Hohoe	Adutor	35,854,085
Kudzra	Aklamapata	6318		Kpolo	9,413,582
	Have	6430	Kadjebi	Kadjebi	97,742,979
	Agbeditive	12,961			

2. Materials and Methods

2.1. Materials

Basically, clay was the major material used to manufacture the clay containers. Two types of clay deposits were adopted for the study namely; Abonko clay and Daboase clay as shown in Figure 2 and Figure 3 respectively. Small quantity of smooth and rough sawdust shown in Figure 4(a) and Figure 4(b) was also used in the composition.

2.2. Methods

Samples of clay materials were processed into finer particles and aged for two weeks. The purpose of the aging was to enhance the plasticity of the clay as demonstrated in Figure 5. After aging, samples were weighed on a scale to compose clay bodies for the manufacturing of the clay containers as shown in Table 3.

Figure 2. Daboase clay.

Figure 3. Abonko clay.

(a) (b)

Figure 4. (a) Smooth sawdust; (b) Rough sawdust.

Figure 5. Aging of clay.

Table 3. Composition of Abonko clay, Daboase clay, and sawdust.

Composition number	Abonko Clay weight %	Daboase clay weight %	Sawdust weight %	Total %
C_1	50	50	-	100
C_2	40	50	10 (smooth)	100
C_3	45	45	10 (smooth)	100
C_4	-	90	10 (rough)	100
C_5	100	-	-	100

From **Table 3**, five (5) clay bodies were composed as means of experimentation to ascertain which composition would be suitable for the clay container. Composition $\mathbf{C_1}$ consisted of 50% of Abonko clay and 50% of Daboase clay. Composition $\mathbf{C_2}$ was made up of 40% Abonko clay, 50% Daboase clay and 10% of smooth sawdust summing up to 100%. Composition $\mathbf{C_3}$ composed of 45% of Abonko clay, 45% of Daboase clay and 10% of smooth sawdust giving a total of 100%. Composition $\mathbf{C_4}$ was made up of 90% Daboase clay and 10% rough sawdust adding up to 100%. The choice of the rough sawdust became necessary because Daboase clay appeared to be too plastic, hence the need to use rough sawdust in order to miminise, shrinkage and increase the porosity of the container. The last composition $\mathbf{C_5}$ comprised mainly 100% Abonko clay.

2.2.1. Processing of Weighed Materials

The weighed materials were thoroughly mixed and kneaded to remove air bubbles and unwanted materials from the composition as captured in **Figure 6**. It was then rolled into slabs with the aid of sack board and rolling pin as highlighted in **Figure 7**. Afterwards, the slabs were cut into rectangular shapes to suit the shape of containers.

In order to prevent the constructed slabs in **Figure 8** from warping during leather hard stage, the slabs were packed on flat boards with little load on top as displayed in **Figure 9** and turned intermittently to ensure slow and uniform drying at that state.

Figure 6. Kneading of clay.

Figure 7. Cutting of slab into shape.

Figure 8. Drying of constructed slabs.

Figure 9. Packed slabs with load on top.

2.2.2. Construction of Clay Containers

After the leather hard stage, the slabs were measured to the required height of 55 cm and base of 30 cm (55 cm × 30 cm), scored and joined together with the help of clay slip to form clay containers with lids (Figures 10-12). The joining was well executed especially at the joints otherwise; there could be break off after drying or firing of the containers.

The same procedures were repeated to produce all the five clay containers (C_1 to C_5). After construction, the clay containers were allowed to dry gradually. The essence of slow drying was to avoid cracking and warping of the wares as rapid drying could result in these deformities.

Composition C_5 was purposefully perforated as shown in Figure 13 to allow fresh air to enter the container. It was to find out if allowing air to penetrate the container could play major role in assisting foodstuff to get rotten quickly in the experiment (Figure 14).

3. Results and Discussions

Observation Made after Firing of Containers

The dried containers were successfully fired in a gas kiln. The maturing temperature of the containers was 980˚C determined by the pyrometer of the kiln. It was observed that even though the containers were initially of the same heights, after firing the rate of shrinkage differed from one container to another. This was attributed to varied body compositions of the containers (Figure 15).

The set up was carried out to experiment on the abilities of the containers to store plantains and extend its lifespan. The bunch of plantain was purchased from a plantain seller in the Takoradi Market Circle where the plantain sellers also find it difficult to preserve their foodstuffs. The plantains were carefully packed and sealed in the containers (C_1 to C_5) as shown in Figure 16 and Figure 17 respectively.

Figure 10. Applying slip and joining of parts of container.

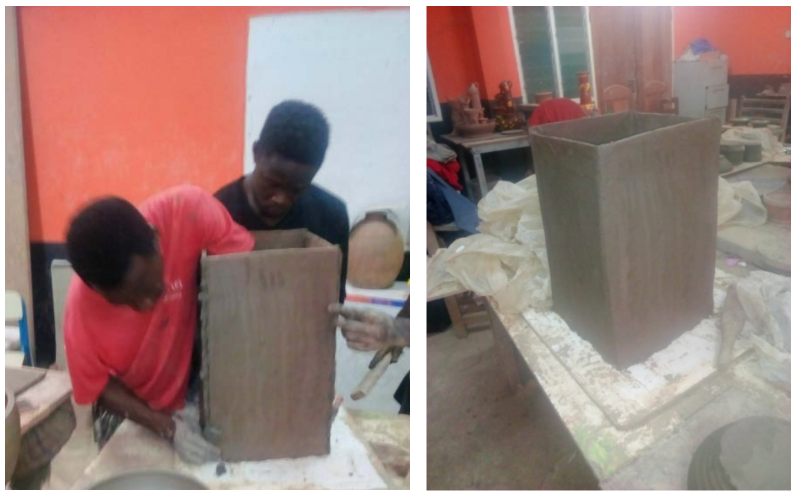


Figure 11. Assembling parts of container.

Figure 12. Constructing lids of container.

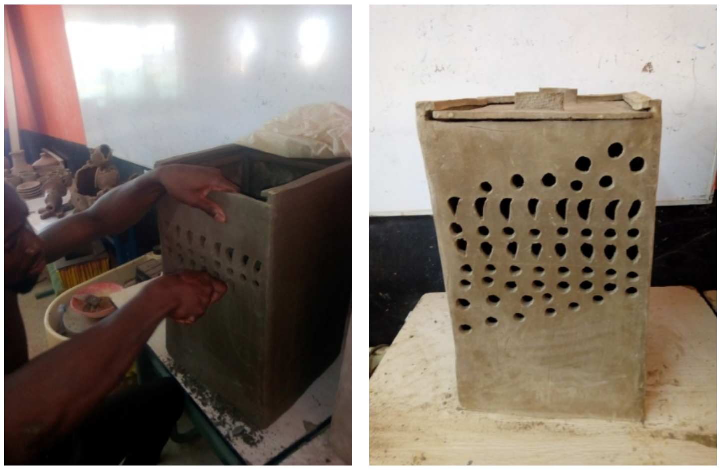


Figure 13. Perforated holes on container C_5 for air penetration.

Figure 14. Gradual drying of clay containers (C_1 to C_5).

Figure 15. Fired clay containers (C_1 to C_5).

(a) (b)

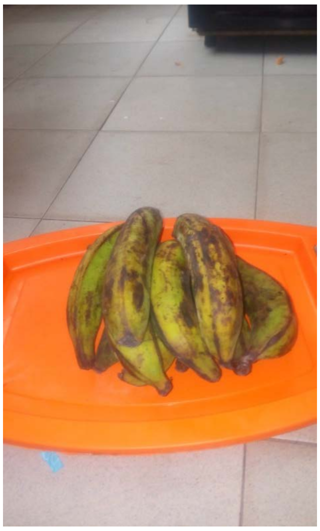
Figure 16. (a) Fresh plantains; (b) Packing of plantains into containers.

(a) (b)

Figure 17. (a) Closing of clay containers; (b) Sealed clay containers of fresh plantains.

A control experiment (uncovered plantains) was also set up in an open space to ripe in order to compare it with the ones in the containers. It was realized that the uncovered plantains took seven (7) days to ripe as its states have been shown in **Figure 18(a)** and **Figure 18(b)** respectively. This confirms Asarewaa's [5] assertion that, fresh plantains take less than two weeks to get rotten at the Ghanaian market centres.

From **Table 4**, the analysis of weekly recordings of storage/state of plantain in containers was carried out. It was revealed that the plantains were fresh in all the containers for day one. The state of plantains in week two (2) for container C_1 was partially fresh, C_2 was also partially fresh, C_3 was fresh, C_4 was also fresh and C_5 was ripped. Recordings for week three (3) indicated C_1 as ripped, C_2 was also ripped, C_3 as partially ripped, C_4 as still fresh and C_5 as very ripped. In week four (4), the recordings of state of plantains were very ripped in both C_1 and C_2, ripped in C_3, partially fresh in C_4 and over ripped in C_5. The last recordings of state of plantains in containers were in week five (5). It came to light that C_1, C_2 and C_5 were over ripped; C_3 was much ripped while C_4 was ripped at the end of the recordings of states of plantains. It was realized that plantains in C_5 started ripping in week two (2) and could be attributed to perforation of holes in the container. It implied that circulation of air in the container affected the plantains to ripe early. The state of plantains in the various manufactured clay containers after the five (5) week recordings had been shown in Figure 19.



(a)

(b)

Figures 18. (a) and (b) States of control experiment (uncovered plantains) for day 4 and day 7. (a) Day 4; (b) Day 7.

Figure 19. State of plantains in the containers after the period of recordings.

Table 4. Weekly recordings of storage/state of plantain in containers.

Composition	Storage/state of plantain per week 1	Storage/state of plantain per week 2	Storage/state of plantain per week 3	Storage/state of plantain per week 4	Storage/state of plantain per week 5
C_1	F	PF	R	VR	OR
C_2	F	PF	R	VR	OR
C_3	F	F	PR	R	VR
C_4	F	F	F	PF	R
C_5	F	R	VR	OR	OR

Note: F = Fresh, PF = Partially Fresh, R = Ripped, VR = Very Ripped, OR = Over Ripped.

4. Conclusions

It has emerged from the study that it took only seven (7) days for the control experiment (uncovered plantains) to get ripped while in all the five containers (C_1 to C_5), it was container C_3 composed of 45% Abonko clay, 45% Daboase clay and 10% smooth sawdust that had very ripped plantains; and C_4 made up of 90% Daboase clay and 10% rough sawdust had ripped plantain at the end of five (5) week recordings of states of plantains in the manufactured clay containers. It can therefore be concluded that container C_4 became successful by extending the shelf-life of fresh plantains to ripe state in five conservative weeks instead of normal period of less than two weeks for fresh plantains to ripe.

Based on the above conclusion, the following recommendations are made:

1) The technique should be made available to stakeholders such as Ministry of Food and Agriculture (MOFA), plantain farmers and market plantain sellers through seminars, public education and symposia in order to minimize post harvest losses.

2) Other perishable crops such as banana should be experimented to find out if the composed clay container can expand their potential shelf-life.

3) The researchers should improve on the study by enlarging the size of the manufactured container to accommodate plenty of plantains in order to ascertain its dependability.

4) Further studies should be scientifically conducted to find out the chemical properties of Daboase clay and be related to other clays to facilitate their usage in the manufacturing of clay containers. Additionally, preserved plantains in clay containers should be investigated if they have any health hazards on human consumption.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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