Effects of Fermentation Techniques on the Quality of Cocoa Beans

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Abstract**—**Fermentation as an important operation in the processing of cocoa beans is now affected by the recent climate change across the globe. The major requirement for effective fermentation is the ability of the material used to retain sufficient heat for the required microbial activities. Apart from the effects of climate on the rate of heat retention, the materials used for fermentation plays an important role. Most Farmers still restrict fermentation activities to the use of traditional methods. Improving on cocoa fermentation in this era of climate change makes it necessary to work on other materials that can be suitable for cocoa fermentation. Therefore, the objective of this study was to determine the effects of fermentation techniques on the quality of cocoa beans. The materials used in this fermentation research were heap-leaves (traditional), stainless steel, plastic tin, plastic basket and wooden box. The period of fermentation varies from zero days to 10 days. Physical and chemical tests were carried out for variables in quality determination in the samples. The weight per bean varied from 1.0-1.2 g after drying across the samples and the major color of the dry beans observed was brown except with the samples from stainless steel. The moisture content varied from 5.5-7%. The mineral content and the heavy metals decreased with increase in the fermentation period. A wooden box can conclusively be used as an alternative to heap-leaves as there was no significant difference in the physical features of the samples fermented with the two methods. The use of a wooden box as an alternative for cocoa fermentation is therefore recommended for cocoa farmers.

Keywords**—**Effects, fermentation, fermentation materials, period, quality.

I. Introduction

COCOA (*Theobroma cacao* L.), which literally means food of the gods [1], belongs to the Malvaceae family and is a tropical plant cultivated for its beans from which cocoa powder and butter are extracted. The cacao tree is indigenous to the tropical forests of Latin America. According to [2], Cocoa originated in the foothills of the Andes in the Amazon and Orinoco basins of South America (now Colombia and Venezuela and its bean was a common currency throughout Mesoamerica before the Spanish conquest.

Fermentation, as an essential process in cocoa production, differs from one to another, but all methods involve removal of the beans from the pods and piling them together in a confinement to allow the activities of micro-organisms to initiate the fermentation of the pulp surrounding the beans. The piles may be covered with banana leaves for the traditional method, or in a box or any other confined and air-tight environment. In anaerobic conditions, the alcohol converts to lactic acid and later acetic acid during the process of fermentation. The temperature is raised between 40ºC and 45 ºC during the first two days to three days. As a result of the increased temperature, cell walls break down and segregate substances to mix. Enzyme activity, oxidation and the breakdown of proteins into amino acids takes place also in the fermentation process (Fig. 1). These chemical reactions cause the chocolate flavor and color to develop [3], [4].

There have been many cocoa processing industries established in the country and abroad and many more are still springing up due to the increasing market force for cocoa products. The processing of cocoa includes the splitting of the pods; extraction, fermentation, drying, dehulling, and winnowing of the beans [5]. Reference [6] studied the performance of population dynamics, metabolite target, and chocolate production for seven independent spontaneous cocoa bean heaps fermentation in Ghana. Although the same microorganisms were involved in these heaps, carried out at different farms or in different seasons, heap temperature and microbial metabolite concentrations were different. This could be due to heterogeneity and size of the heaps, but was mainly ascribed to microbial variability. Indeed, differences in microbial activity could be linked with the favor of chocolate made from the corresponding dried, fermented cocoa beans. Fermentation is commonly carried out by the local farmer in Nigeria by the traditional way of using banana and cocoa yam leaves but there has been little research to improve on the traditional technique. To find an alternative fermentation system in cocoa production and processing that can improve quality of the beans as well as control pollution of agricultural soil and its environment, there is the need to comparatively study the effects of other suitable materials and techniques on the quality of cocoa beans. Therefore, the objective of this study was to comparatively determine the effects of fermentation techniques on the quality of cocoa beans.

II. Materials and Methods

A. Experiment Site

The experiment was conducted at the research farm of the Department of Agricultural and Bio-Environmental Engineering, Rufus Giwa Polytechnic, Owo, Nigeria (Latitude 7^0 15ˊ N Longitude 5^0 35 ˊE) and Elevation 210 m.

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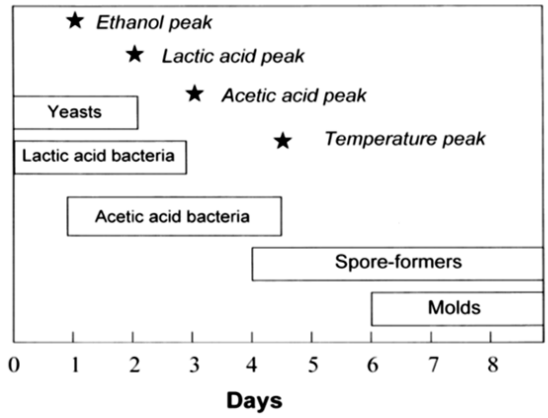

Fig. 1 Schematic of Microbial succession during Cocoa Bean Fermentation [7]

B. Experimentation Procedure

Cocoa pods were procured from farms from the Aladi farms settlement in Ose Local Government Ondo State. The cocoa pods were broken with the use of cutlass and the beans separated from the broken pods (Fig. 2). The wet beans were subjected to fermentation using a wooden box, plastic basket, plastic, stainless steel and heap leaves (Fig. 3) to know the influence of the material on the fermentation rate and quality of the cocoa beans after drying. The temperatures of the samples were taken daily at intervals using a thermometer. The fermentation period was varied from zero days, 2 days, 4 days, 6 days, and 8 days to 10 days, to determine the effect of fermentation period on the quality of the cocoa beans. The fermented beans were dried by sun-drying and physical evaluation was carried by cut test and weight test after drying to determine the effect of the materials on the quality of cocoa beans. The moisture content, nutritional and chemical analysis of each sample were carried out at Food Science Technology Laboratory.

Fig. 2 Manual Cocoa Pod Splitting

C. Physical Evaluation Test

1. Weight Test

The weight test is to know the various weights of the cocoa beans in the various materials and for different days after fermentation and drying. The weight test was carried at the crop processing laboratory of the Agricultural and Bio-Environmental Engineering Technology Department. The weights of the samples were taken using electronic weighing balance.

Fig. 3 An Aspect of the Fermentation Process Fermentation

2. The Cut Test

The cut test was carried at the crop processing laboratory of Agricultural and Bio-Environmental Engineering Technology Department. Fifty cocoa beans were selected as samples from each material with different days of fermentation. Each of the beans was laterally cut using a sharp knife for defect observation from its cotyledon. The defects observed varied from slaty, insect damaged, flat bean, over fermented and moldy beans.

D. Moisture Content Using Gravimetric Method

Dry samples of the beans were milled to powdery form. The powdery cocoa was measured inside the Petri dish and 2 kg of each of the samples was weighed using the digital weighing balance and then oven dried for about three hours at 110 °C. The dried sample cooled using a desiccator for 1 hour before reweighing to record the final weight after drying. The moisture content determine the moisture content using (1):

$$Moisture\ Content = \frac{M_W}{M_s} \times 100 \qquad (1)$$

where M_w is the mass of water and M_s for soil.

E. Chemical and Nutritional Analysis

Mineral analysis was carried out using [8] method with slight modification. About 0.5 g of the ground cocoa bean (sample) was weighed into a 250 ml beaker. To this, 25 ml of concentrated nitric acid was added and the beaker was covered with a watch glass. Each sample was carefully digested on a hot plate in a fume chamber until the solution turned pale yellow. The solution was cooled and 1 ml Chloric acid (70% HCL04) added. The digestion continued until the solution turned colorless. After the digestion process, the solution was slightly cooled and 30 ml of distilled water added. The mixture was boiled for about 10 minutes and filtered using a Whatman No. 4 filter paper. The solution was transferred to a 100 ml volumetric flask and mixed with distilled water. The concentrations of Ca, Mg, Zn, Fe, Na, and K were determined using spectral AA 220 FS Spectrophotometer (Varian Co., Musgrave, Australia) with an acetylene flame. Aliquots of 1 ml of the digest were used to determine the Ca, Mg, Zn, Fe, Cu, Na, and K content of each sample.

III. Results and Discussion

A. Results

The results of the comparative evaluation are presented in Figs. 4-6 and Tables I-V.

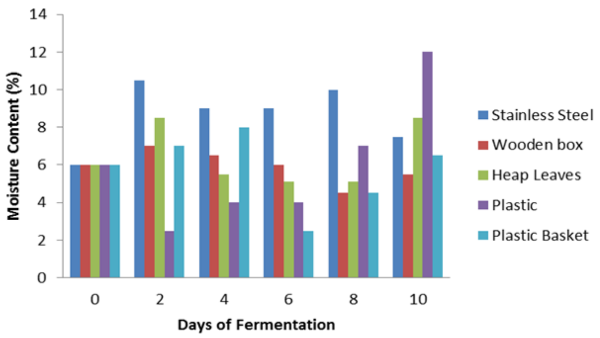

Fig. 4 Moisture Content Analysis of Cocoa Bean after Drying on Each Material

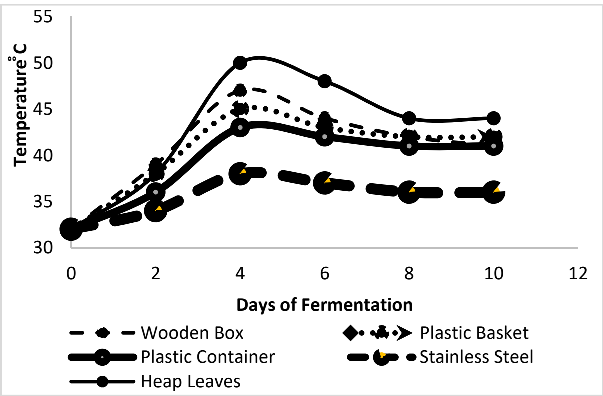

Fig. 5 Temperature of Cocoa at Fermentation

TABLE I
EFFECT OF FERMENTATION ON THE COLOR OF COCOA BEANS AFTER FERMENTATION

Materials	Color
Wooden Box	Brown
Plastic basket	Brown
Plastic	Brown
Stainless steel	Milk
Heap leaves	Brown

B. Discussion

1. Effects of Fermentation Material on the Physical Characteristic of Dry Cocoa Bean

As presented in Table I, the color of the beans after fermentation was majorly brown in all the fermentation materials, with the exception of the stainless steel in which a milk color was observed after fermentation. The percentage of brown beans in the cut test, as presented in Fig. 3, varies from 40% to 86%; heap leaves having the highest percentage of 86% and stainless steel with the least percentage of 40%.

From the results presented in Table II, it was observed that the weight per dry cocoa bean ranged from 1.0 g to 1.2 g for the fermented beans in the experiment, while the average weight of a bean without fermentation was recorded as 1.3 g. This is in conformity with [9] who reported that the average weight of dry and fermented cocoa bean was 1 g. It was observed that the weight of the dry cocoa bean decreases with the increase in the period of fermentation.

On the temperature of the beans at fermentation, it ranges from 34 to 50 °C, as presented in Fig. 5. This is in conformity with [10]. The temperature of cocoa beans without fermentation was recorded as 32 °C. The peak temperature was recorded at a fermentation period of 4 days. This is in conformity with [7].

Table III presents the results of the cut test after drying of the fermented cocoa beans. It was observed that the beans fermented with heap leaves gave out the optimum results, the observations range from violet, well fermented slightly over fermented except with period of fermentation period of 10 days, which shows that the beans were moldy and infested. The unfermented beans were slaty after drying. This is in conformity with [7] in his review work on microbiology of cocoa fermentation.

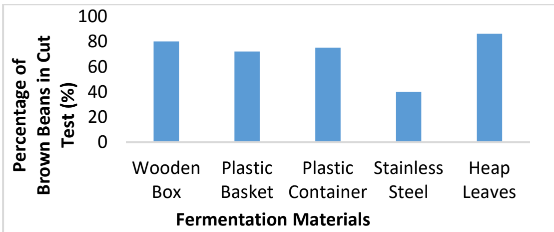

Fig. 6 Fermentation Materials vs. percentage of Brown Beans in Cut Test

TABLE II
EFFECTS FERMENTATION TECHNIQUES ON THE WEIGHT OF DRY COCOA BEANS

Materials \ Days	0	2	4	6	8	10
Wooden Box	1.3	1.1	1.1	1.1	1	1
Plastic basket	1.3	1.2	1.2	1.2	1.1	1
Plastic	1.3	1.1	1.2	1.1	1.1	1
Stainless steel	1.3	1.1	1	1	1	1.1
Heap leaves	1.3	1.2	1	1.2	1.2	1

2. Effects of Fermentation Period on the Moisture Content of Dry Cocoa Beans

It was observed from Fig. 4 that the moisture content of dry cocoa beans decreased with the increase in fermentation period, but later increased with time in all the fermentation materials. It was also observed that the moisture content later decreased with the increase in fermentation period at day 6 (Fig. 6). Maximum moisture content was 12% and was observed with the plastic container with a fermentation period of 10 days. This is not suitable as it was more than 7.5% maximum moisture content recommended by [11]. While the minimum moisture content of 2.5% was observed with the plastic container with fermentation period of two days. Optimum moisture contents of 5.5%, 6%, 6.5% and 7% were observed with heap leaves, the wooden box, the plastic container and the plastic basket with fermentation days varying from 2 days to 10 days. The moisture content of dry and unfermented cocoa beans was observed as 6%.

3. Effects of Fermentation Period on The Chemical Composition of Dry Cocoa Beans Fermented with Heap Leaves.

As presented in Tables IV and V, the mineral content and heavy metal decreased with the increase in the fermentation period in all the materials. This shows that the longer fermentation period is better for the health of cocoa consumers, as heavy metals are detrimental to humans.

TABLE III
EFFECTS OF FERMENTATION MATERIAL AND PERIOD ON THE PHYSICAL CHARACTERISTIC OF DRY COCOA BEAN

Materials \ No of Days	0	2	4	6	8	10
Wooden Box	Slaty and unfermented	Slaty and unfermented	Partly purple and partly brown	Violet	Well fermented pale	Slaty turning violet
Plastic basket	Slaty and unfermented	Violet turning brown	Slaty turning violet	Violet	Mold	Mold and infested
Plastic	Slaty and unfermented	Slaty and unfermented	Slaty turning violet	Well fermented	Slightly over fermented	Mold and infested
Stainless steel	Slaty and unfermented	Slaty and unfermented	Well fermented (pale)	Partly purple partly brown	Violet turning brown	Slightly over fermented
Heap leaves	Slaty and unfermented	Violet	Well fermented	Well fermented (Pale)	Slightly over fermented	Mold and infested

TABLE IV
MINERAL ANALYSIS OF DRY COCOA BEANS

No of Days	Na (ppm)	Ca (ppm)	K (ppm)	Fe (ppm)	Mg (ppm)	Zn (ppm)
0	18.400	106.000	30.460	1.080	5.960	1.860
2	16.800	94.000	41.000	0.970	4.080	1.510
4	10.560	71.700	29.500	0.900	4.010	1.300
6	9.450	69.300	23.600	0.850	3.960	1.480
8	6.290	69.100	21.000	0.720	3.520	1.360
10	5.440	66.000	29.100	0.50	2.920	1.220

TABLE V
CHEMICAL ANALYSIS OF HEAVY METAL IN DRY COCOA BEANS

Days	Cd (ppm)	Ni (ppm)	Pb (ppm)	Cr (ppm)
0	0.003	0.010	0.230	0.005
2	0.003	0.006	0.190	0.002
4	0.002	0.002	0.120	0.001
6	0.001	0.001	0.090	0.002
8	0.001	0.001	0.060	0.001
10	0.001	0.001	0.040	0.001

IV. CONCLUSIONS AND RECOMMENDATIONS

This study was carried to know if there could be alternatives to the traditional method of cocoa beans fermentation in which banana and cocoyam leaves are used. The other materials used for the experiment were wooden box, plastic basket, plastic and stainless steel. It was found that the traditional (heap leaves) method produced the best quality in terms of the acceptable standards. But wooden box had a very close range in quality performance with heap leaves.

The best quality of cocoa beans was achieved at a fermentation period of 6 days in all the materials used for the fermentation experiments.

There was a correlation between fermentation period and chemical composition. The longer the fermentation period, the better for the health of cocoa consumers as heavy metals reduced with an increase in the days of fermentation.

For mechanization, it is recommended that wooden box can be used as an alternative to the traditional (heap leaves) method. This will reduce the destruction of economic crops like plantain, banana and cocoyam as well as eliminate the pollution of agricultural soil and its environment.

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