Compare the Physical Quality of Dried Cocoa beans from drying methods in terms of Appearance, Structural Features, Shelf life and other Defects

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Abstract—The research was conducted to investigate the effect of drying methods on the drying properties on the quality of cocoa beans in Agricultural Engineering Department, Njala University, and Njala Campus, Sierra Leone. The pods were divided into 8 parts, 53 pods per sample and depodded. Four samples were washed and four unwashed from the 53 pods and fermented with box methods. Also, from these samples, four were solar dried and four sun dried. All samples were labeled with randomization, Samples A, D, F and H were solar dried while Samples B, C, E and G sun dried. Furthermore, laboratory investigations: pH test, sucrose test, bulk density, cutting test, physical properties and sensory evaluation: colour, taste, texture, aroma and grade were. Sensory evaluation revealed that washed bens scored 70% chocolate colour for both drying methods, 80% aroma, texture 90% for all washed. When graded, solar dried beans scored 70% grade 1 and sun dried scored 80% grade 1. Also, the weight of unwashed solar dried beans recorded 9.61 kg and 10.09 kg sun dried, the pH of all washed beans are high with maximum value 7.3 and the sucrose content of unwashed was reported high as 0.405% in box fermented beans.

Keywords—Beans, cocoa, defects, quality, shelf-life.

I. INTRODUCTION

1.1 Background to the Study

Cocoa (Theobromacacao) with family Malvaceae alternate Sterculiaceae is an ancient crop of the lowland tropical forest, which originated from the Southern and Central America [7] and originated from tropical rain forests of South America. Three domesticated groups are distinguished: Criollo, Forastero and a hybrid group, Trinitario [3]. Generally, fine flavour cocoa beans are produced from Criollo or Trinitario varieties, while bulk cocoa beans come from Forastero trees, but there are exceptions. Nacional trees in Ecuador considered to be Forastero by some, but with traits distinguishing them from all other groups [4] produce fine flavour cocoa, while Cameroon cocoa beans, which are produced by Trinitario trees and whose cocoa powder has a distinct and sought-after red colour, are classified as bulk cocoa beans [6].

In West Africa, cocoa is one of the most important cash crops. Studies show that the cocoa bean contains flavonoids with antioxidant properties that can reduce blood clot and the risk of stroke and cardiovascular attacks [5]. The crop is very low in cholesterol and a good source of protein, potassium, zinc, and dietary fibres.

Pods may contain 20–45 beans embedded in a mass of mucilaginous pulp within the pods. Cocoa bean is the principal raw material of chocolate manufacture [2]. The plant is grown mostly in the wet tropical forest climate which is within 20°F latitude of the equator at countries such as, Ivory Coast, Ghana, Nigeria, Cameroon, Brazil, Equador and Papua New Guinea.
The first cocoa plant brought in to Sierra Leone came from Ghana. These were established in Kpuwabu, Gaura Chiefdom in the Kenema District, Sierra Leone. This served as the first research centre in the Kenema Forestry and Tree Crops Research Centre (KFTCRC) for cocoa scientists and rural farmers in the Eastern Province. Through the use of extension techniques coupled with the full participation of traditional rulers, farmers developed high interest in the cultivation of cacao. Cocoa is currently the most important export crop in Sierra Leone, commanding a very high price at international markets in Europe, Asia and America.

The cultivated forms of cacao farms in Sierra Leone are Amazon (Ghana Cocoa), Trinitario and Amelonado (Mende Cocoa).

Cocoa is produced in the Eastern and Southern Provinces, with most of the crop coming from Kailahun and Kenema Districts. Cocoa production in Sierra Leone involves operations like harvesting, depodding (pod breaking), fermentation, drying, bagging transportation and storage.

After processing, the farmers take their processed consignment of dried cocoa beans directly to the produce buying agents at the various buying centres within the Provinces (Southern and Eastern Provinces). Sometimes farmers sell their produce to petty traders who in turn sell to the buying agents.

At the buying agent’s stores, produce inspectors or examiners inspect and grade all the produce intended for sale in sealed bags before the issuance of trade certificates.

These certificates indicate the fitness of the produce for the export market. Inspected and graded beans are packed in trucks for transporting to transit stores at or around the Port of Freetown.

Further checks are conducted at the port before a final certificate of fitness for export is issued. Certified beans are then shipped to their export destination overseas.

Cocoa export declined considerably during the war and was gradually increased over the last five years and presently the exports are estimated to have risen to about 18,000mt in 2008 which is quite below the export performance of the Ivory Coast and Ghana which export an average 1.5 million mt and 440,000mt respectively.

It production has long been the principal economic activity in Sierra Leone especially Kono and Kailahun. In the past Sierra Leone used to be the leading producer of cocoa in West Africa, alongside suppliers like Ghana. In those days the country was highly reputed in the world market for its high quality. This reputation was lost during the war years when legal exports were very low. In the pre-war era production level for cocoa was around 16,000 to 20,000mt from over 40,000ha. But another favourable area for cocoa production is in the belts that span the Moa River drainage basin, from north east of Kailahun to Barri and Makpele Chiefdoms in the Pujehun District.

Kenema District also said to be a producing cocoa but very little as compare to the other districts mentioned above.

During the war years most of the cacao farms were abandoned and became over grown with bush. This situation led to a major decline in the production levels and quality of cocoa produced in the country [1]. However, organic cocoa processing facilities have recently come into the scene and appear to be playing major roles in Sierra Leone’s cocoa subsector.

1.2 Statement of the Problem

Over the past years drying has been a serious problem in the processing of cocoa beans more especially in the raining season. Based on this most of the cocoa beans processed in most areas fall in some of the following defects such as mould, germinate or slate as a result of lack of proper drying technology.

Majority of farmers in Sierra Leone are believed to be facing difficulties with lack of proper drying floors and adequate storage facilities. Most of their crop (cocoa beans) is frequently reported to be dried on unpaved floors and stored in building that are highly infested with insect pests (weevils) which made the cocoa beans unfit for sale. Such reduction in the quality and quantity of cocoa beans eventually results in serious financial losses to the farmers. A previous investigation [1] shown that most farmers reported selling grades 2 and 3 cocoa beans to produce buyers; and this situation may have resulted in significant reduction in farmers’ potential incomes at that time.

That was supposed to abandoned state of the farms, poor field and post-harvest practices, low level of farmer’s participation following the end of the civil unrest and low levels of private sector participation in the national cocoa subsector could be responsible for such low quality outcomes at the time.

Recent reports indicated a vibrant private sector involvement in the cocoa industry resulting in significant improvement in the incentive system, farmer participation, better field and post-harvest practices, and a more active cocoa industry.
There are speculations that these improvements have led to major increase in the status of the quality system for low input (organic) cocoa production in the country. There is however, no scientific evidence to substantiate these speculations.

1.3 Aim of the Research

The ultimate aim of this research is to compare the physical quality of dried cocoa beans from drying methods in terms of appearance, structural features, shelf life and other defects in Sierra Leone.

1.4 Justification of the Research

Although several efforts have been made in different parts of the world to improve on cocoa drying processing, serious attention has to be paid on the fermentation and drying processes. Sierra Leone still relies on the natural sun drying, very few solar dryers are available in the country. The sun drying method is usually slow especially in the rainy season and ineffective, involves human drudgery.

This research intends to recognize some of the problems faced in cocoa drying processing and handling, therefore justifies the necessity to evaluate the performance of washed and unwashed beans, box and basket fermentation methods, solar and sun drying methods.

1.5 Hypothesis of the Research

The following hypothesis will be investigated:

Box Fermentation Method

$H_0$: There is no significant variation in the box fermentation method between washed and unwashed dried beans.

$H_1$: Box fermentation method varies significantly between washed and unwashed dried beans.

Basket Fermentation Method

$H_0$: There is no significant variation in the basket fermentation method between washed and unwashed dried beans.

$H_1$: Basket fermentation method varies significantly between washed and unwashed dried beans.

Sun Drying Method

$H_0$: There is no significant variation in the sun drying method with washed and unwashed dried beans.

$H_1$: Sun drying method varies significantly between washed and unwashed dried beans.

Solar Drying Method

$H_0$: There is no significant variation in the solar drying method with washed and unwashed dried beans.

$H_1$: Solar drying method varies significantly between washed and unwashed dried beans.

1.6 Significance of the Research

The significance of the research is discussed as thus below:

To investigate the most effective method of cocoa drying for producers.

Create employment for local fabricators of drying structures.

This research introduced appropriate drying technology to upgrade cocoa product from grade three (3) or two (2) to one or premium and

The research was also serve as a base line for future researchers in post-harvest technology of cocoa processing.

II. MATERIALS AND METHODS

2.1 Study Area

The research was conducted between Pendembu Research Station in Pendembu, Upper Bambara Chiefdom, in the Kailahun District and Agricultural Engineering Department, Njala University, Kori Chiefdom, Moyamba District, Sierra Leone.

2.2 Materials

2.2.1 Sample Preparation

Samples of mixed hybrid varieties of ripe cocoa pods were harvested from the Pendembu Research Station of Kenema Forestry and Tree Crops Research Centre (KFTCRC) of the Sierra Leone Agricultural Research Institute (SLARI).

2.3 Methods

The research involved fermentation and drying of cocoa beans performed by the researcher at the Agricultural Engineering Department, School of Technology, Njala University, and Njala Campus. The methods involved design, construction, fermentation and drying chronologically.

2.3.1 Design and Construction

The design and construction involved 12 fermentation boxes and 1 solar dryer at the Agricultural Engineering Department, Njala University, and Njala Campus.

2.3.1.1 Fermentation Box

12 fermentation boxes with dimensions 60.96 cm length, 45.72 cm width, 20.32 cm depth and leg-height 30.48 cm
each was constructed for the experiment in the above mentioned department.

2.3.1.2 Solar Dryer

A solar dryer was constructed at the Agricultural Engineering Department, Njala University, and Njala Campus with local materials. The dimensions are 4 m length, 2.55 m width and 3 m height. The dryer constitute three drying chambers and a passage, the two opposite chambers and one adjacent.

2.3.1.3 Basket

The 8 baskets used during the fermentation for the experiment were obtained from the local fabricators in a nearby village.

2.4 Cocoa Processing

2.4.1 Harvesting

424 ripe cocoa pods were harvested on the 17th January, 2016 from the Clonal Garden of the Pendembu Research Station of Kenema Forestry and Tree Crops Research Centre (KFTCRC).

2.4.2 Pod Opening

The pods were divided into eight (8) portions, 53 per portion with labelled A-H and were opened (depodded) on the 19th January, 2016 in the above mentioned department and prepared for fermentation and drying.

2.4.3 Box Fermentation Method

Cocoa beans with weight 4.5 kg, 5.5 kg, 5.0 kg and 6.0 kg were put into boxes A, B, C and D respectively and fermented at the Agricultural Engineering Department, turned every two days to ensure uniformity during the processing. Beans with labeled C and D were washed twice immediately after pod opening and put into boxes labeled C and D and fermented from the 19th-25th January, 2016. While beans with labels A and B were unwashed and put into boxes labeled A and B and fermented on the same date as mentioned above.

2.4.4 Basket Fermentation Method

Cocoa beans with weight 5.5 kg, 5.6 kg, 5.2 kg and 5.5 kg were put into baskets labeled E, F, G and H respectively and fermented on the same date with beans in the boxes, turned every two days to ensure uniformity during fermentation. Beans labeled G and H were unwashed, put into baskets labeled G and H, while beans labeled E and F were washed, put into baskets labeled E and F and fermented. A scheme below shows the Basket Method of Fermentation conducted.

2.4.5 Drying Methods

Two different drying methods were conducted for the experiment, solar and sun drying.

2.4.5.1 Solar Drying Method

Samples labeled A, D, F and H with weight 4.0 kg, 5.0 kg, 4.5 kg and 4.5 kg respectively were placed in the solar dryer with thin layer drying performed from 10:00 AM to 5:00 PM each day drying was commenced until the moisture content of the dried cocoa beans reached to 7%. The temperature of the dryer was recorded from morning down to evening each day. The drying started on the 25th-28th January, 2016 and scheme sample of dried cocoa beans in the solar dryer is shown below.

2.4.5.2 Sun Drying Method

Fermented cocoa beans with sample labeled B, C, E and G with weight 4.0 kg, 4.0 kg, 4.0 kg and 4.0 kg were respectively exposed under the sun on a tarpaulin from 10:00 AM to 5:00 PM which is considered the standard drying time. The beans were mixed every two hours during drying period to ensure uniformity, collected, stored and dried the next day until the beans attained moisture content of 7%. Samples of dried cocoa beans with sun drying are shown in the table. The sun drying was performed on the same date with solar drying method.

2.6 Data Collection

Data was collected during the drying process of cocoa beans from two drying methods conducted.

2.7 Experimental Design

The design was a 3 factorial experiment conducted with sun and solar drying methods, using box and basket fermentation methods, treatment washed and unwashed cocoa beans with tap water.

2.7.1 Randomization

A random selection was made after labeling on A4 papers, 2 washed and 2 unwashed for baskets and 2 washed and 2 unwashed for boxes, the procedure was done by dropping 4 labels papers in the first box and 1 was chosen and assigned, 3 labels papers to the second box, 2 labels to the third and 1 to the last box. The same procedure was also done to the 4 baskets. Also capital letters labeled A-D for boxes and E-H for baskets were assigned. 4 labeled capital letters were dropped in the first box 1 was picked to assign a label, 3 in the second, 2 in the third and 1 in the last box, the same
procedure was also done to the baskets where 4 labels were dropped in the first basket and 1 was chosen, 3 in the second, 2 in the third and 1 in the last basket. These selections were used to labeled baskets and boxes used during fermentation. The same procedure was also carried out for sun and solar drying samples.

2.9 Data Analysis

Data obtained were processed using computer software Statistical Package for Social Science (SPSS 16.0), Microsoft excel, presented in tabular form and were analyzed.

2.10 Equations

\[ D_g = \sqrt[3]{L \times T \times W} \]  \hspace{1cm} \text{(1)}

\[ D_m = \frac{L+T+W}{3} \]  \hspace{1cm} \text{(2)}

\[ A_m = \frac{L+T+W}{3} \hspace{1cm} \text{Arithmetic mean diameter in (mm)} \]

\[ S_m = \frac{1}{3} \left[ \frac{(L+T+W)^3}{L} \right]^{1/3} \]  \hspace{1cm} \text{(3)}

\[ S_e = D_g + A_m + S_m \]  \hspace{1cm} \text{(4)}

\[ D_e = \frac{D_g + A_m + S_m}{3} \]  \hspace{1cm} \text{Equivalent diameter in (mm)}

\[ S = \frac{(L-T+W)^{1/3}}{L} \]  \hspace{1cm} \text{(5)}

\[ E = \frac{L}{T} \]  \hspace{1cm} \text{Elongation}

\[ V = \frac{4}{3} \pi L T W \]  \hspace{1cm} \text{(7)}

\[ A = \pi B \left( \frac{2L-B}{2} \right) \]  \hspace{1cm} \text{(8)}

\[ B = (WT)^{1/2} \]

\[ A = \text{Area in (mm}^2) \]

III. RESULTS

3.1 Figures and Tables

3.1.1 Sensory Evaluation

3.1.1.1 Colour of Dried Cocoa Beans

\textbf{Table 3.1: A distribution of various colours of dried cocoa beans during the evaluation}

| Drying method | Fermentation | Treatment | Fully brown | Percent (%) | Partly-purple brown | Percent (%) |
|---------------|--------------|-----------|-------------|--------------|---------------------|-------------|
| Solar Box     | Washed       | 6         | 60          | 3            | 30                  |             |
|               | Unwashed     | 3         | 30          | 7            | 70                  |             |
| Basket        | Washed       | 7         | 70          | 3            | 30                  |             |
|               | Unwashed     | 3         | 30          | 4            | 40                  |             |
| Sun Box       | Washed       | 4         | 40          | 4            | 40                  |             |
|               | Unwashed     | 1         | 10          | 7            | 70                  |             |
| Basket        | Washed       | 8         | 80          | 1            | 10                  |             |
|               | Unwashed     | 5         | 50          | 4            | 40                  |             |

\textbf{Table 3.2: A distribution of various colours of dried cocoa beans during the evaluation}

| Drying method | Fermentation | Treatment | Fully-purple | Percent (%) | Black | Percent (%) |
|---------------|--------------|-----------|--------------|-------------|-------|-------------|
| Solar Box     | Washed       | 1         | 10           | 0           | 0     | 0           |
|               | Unwashed     | 0         | 0            | 0           | 0     | 0           |

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### Table 4.20: A distribution of various aromas of dried cocoa beans during the evaluation

| Drying method | Fermentation | Treatment | Chocolate | Percent (%) | Fine smell | Percent (%) |
|---------------|--------------|-----------|-----------|-------------|------------|-------------|
| Solar Box     | Washed       | 5         | 50        | 4           | 40         |             |
|               | Unwashed     | 4         | 40        | 5           | 50         |             |
| Basket Washed | 6            | 60        | 4         | 40          |            |             |
| Unwashed      | 5            | 50        | 2         | 20          |            |             |
| Sun Box       | Washed       | 4         | 40        | 6           | 60         |             |
|               | Unwashed     | 5         | 50        | 3           | 50         |             |
| Basket Washed | 7            | 70        | 3         | 30          |            |             |
| Unwashed      | 7            | 70        | 3         | 30          |            |             |

### Table 4.21: A distribution of various aromas of dried cocoa beans during the evaluation

| Drying method | Fermentation | Treatment | Bad smell | Percent (%) |
|---------------|--------------|-----------|-----------|-------------|
| Solar Box     | Washed       | 1         | 10        |             |
|               | Unwashed     | 1         | 10        |             |
| Basket Washed | 0            | 0         | 0         |             |
| Unwashed      | 3            | 30        | 30        |             |
| Sun Box       | Washed       | 0         | 0         |             |
|               | Unwashed     | 2         | 20        |             |
| Basket Washed | 0            | 0         | 0         |             |
| Unwashed      | 0            | 0         | 0         |             |
4.5.3 Texture of Dried Cocoa Beans

Table 4.22: A distribution of various textures of dried cocoa beans during the evaluation

| Drying method | Fermentation | Treatment | Smooth | Percent (%) | Coarse | Percent (%) |
|---------------|--------------|-----------|--------|-------------|--------|-------------|
| Solar         | Box          | Washed    | 9      | 90          | 1      | 10          |
|               |              | Unwashed  | 3      | 30          | 7      | 70          |
|               | Basket       | Washed    | 8      | 80          | 2      | 20          |
|               |              | Unwashed  | 2      | 20          | 8      | 80          |
| Sun           | Box          | Washed    | 6      | 60          | 4      | 40          |
|               |              | Unwashed  | 4      | 40          | 6      | 60          |
|               | Basket       | Washed    | 10     | 100         | 0      | 0           |
|               |              | Unwashed  | 5      | 50          | 5      | 50          |

4.5.4 Taste of Dried Cocoa Beans

Table 4.23: A distribution of various taste of dried cocoa beans during the evaluation

| Drying method | Fermentation | Treatment | Good | Percent (%) | Bad | Percent (%) |
|---------------|--------------|-----------|------|-------------|-----|-------------|
| Solar         | Box          | Washed    | 9    | 90          | 1   | 10          |
|               |              | Unwashed  | 2    | 20          | 8   | 80          |
|               | Basket       | Washed    | 8    | 80          | 2   | 20          |
|               |              | Unwashed  | 4    | 40          | 6   | 60          |
| Sun           | Box          | Washed    | 5    | 50          | 5   | 50          |
|               |              | Unwashed  | 5    | 50          | 5   | 50          |
|               | Basket       | Washed    | 8    | 80          | 2   | 20          |
|               |              | Unwashed  | 10   | 100         | 0   | 0           |

Results shown that, unwashed beans scored the highest percentage of good tasted beans by the evaluators with 100% of basket fermented and sun dried. However, solar dried beans shown 90% good, in box fermented, 80% good, in basket fermented. Also washed beans shown 50% and 80% respectively in box and basket fermented and solar dried.

4.5.5 Grade of Dried Cocoa Beans

Table 4.24: A distribution of various grades of dried cocoa beans during the evaluation

| Drying method | Fermentation | Treatment | Grade 1 | Percent (%) | Grade 2 | Percent (%) |
|---------------|--------------|-----------|---------|-------------|---------|-------------|
| Solar         | Box          | Washed    | 4       | 40          | 6       | 60          |
|               |              | Unwashed  | 2       | 20          | 1       | 10          |
|               | Basket       | Washed    | 7       | 70          | 2       | 20          |
|               |              | Unwashed  | 1       | 10          | 2       | 20          |
### Table 4.25: A distribution of various grades of dried cocoa beans during the evaluation

| Drying method | Fermentation | Treatment | Grade 3 | Percent (%) |
|---------------|--------------|-----------|---------|-------------|
| Solar Box     | Washed       |           | 0       | 0           |
|               | Unwashed     |           | 7       | 70          |
|              | Washed       |           | 1       | 10          |
|              | Unwashed     |           | 7       | 70          |
| Sun Basket    | Washed       |           | 1       | 10          |
|               | Unwashed     |           | 3       | 30          |
|              | Washed       |           | 0       | 0           |
|              | Unwashed     |           | 0       | 0           |

### 4.1 Cutting Test

#### Table 4.1: Shows a distribution of cutting test during the experiment

| Drying Method | Fermentation | Treatment | Brown Percentage (%) | Violet Percentage (%) | Mould Percentage (%) |
|---------------|--------------|-----------|-----------------------|-----------------------|----------------------|
| Solar Box     | Washed       |           | 20                    | 100                   | 0                    |
|               | Unwashed     |           | 20                    | 100                   | 0                    |
| Basket        | Washed       |           | 16                    | 80                    | 2                    |
|               | Unwashed     |           | 18                    | 90                    | 0                    |
| Sun Box       | Washed       |           | 10                    | 50                    | 0                    |
|               | Unwashed     |           | 20                    | 100                   | 0                    |
| Basket        | Washed       |           | 14                    | 70                    | 2                    |
|               | Unwashed     |           | 20                    | 100                   | 0                    |

### 4.3 Physical Properties of Dried Cocoa Beans

#### 4.3.1 Axial Dimension of Cocoa Samples
### Table 4.6: A distribution of some physical properties of dried cocoa beans

| Drying method | Fermentation | Treatment | Length (L) (mm)  | Stdv | Width (W) (mm) | Stdv | Thickness (T) (mm) | Stdv |
|---------------|--------------|-----------|------------------|------|----------------|------|-------------------|------|
| Solar Box     | Washed       | 21.89     | 0.12             | 10.95| 0.22           | 7.14 | 0.39              |      |
|               | Unwashed     | 21.01     | 0.42             | 12.16| 0.17           | 7.17 | 0.38              |      |
|               | Washed       | 23.15     | 0.29             | 12.73| 0.36           | 8.76 | 0.38              |      |
|               | Unwashed     | 22.43     | 0.05             | 11.85| 0.07           | 7.56 | 0.25              |      |
| Sun Box       | Washed       | 22.85     | 0.19             | 12.31| 0.22           | 8.23 | 0.02              |      |
|               | Unwashed     | 21.78     | 0.16             | 7.469| 1.38           | 11.92| 1.20              |      |
|               | Washed       | 23.42     | 0.38             | 12.82| 0.39           | 7.71 | 0.20              |      |
|               | Unwashed     | 21.69     | 0.19             | 12.73| 0.36           | 8.02 | 0.09              |      |
| Mean          |              | 22.28     |                  | 11.63|               | 8.31 |                   |      |

### Table 4.7: A distribution of some physical properties of dried cocoa beans

| Drying method | Fermentation | Treatment | Am (mm) | Stdv | De (mm) | Stdv | Sm (mm) | Stdv |
|---------------|--------------|-----------|---------|------|---------|------|---------|------|
| Solar Box     | Washed       | 13.3      | 0.24    | 570.5| 44.42   |      | 17.73   | 0.14 |
|               | Unwashed     | 13.4      | 0.20    | 610.5| 31.09   |      | 17.97   | 0.06 |
|               | Washed       | 14.8      | 0.27    | 860.5| 52.25   |      | 17.35   | 0.27 |
|               | Unwashed     | 13.9      | 0.03    | 669.8| 11.32   |      | 18.65   | 0.15 |
| Sun Box       | Washed       | 14.6      | 0.19    | 771.6| 22.62   |      | 19.48   | 0.43 |
|               | Unwashed     | 13.7      | 0.11    | 646.5| 19.09   |      | 18.39   | 0.07 |
|               | Washed       | 14.3      | 0.10    | 762.5| 19.59   |      | 19.49   | 0.43 |
|               | Unwashed     | 14.1      | 0.02    | 738.1| 11.45   |      | 16.31   | 0.62 |
| Mean          |              | 14.0      |         | 703.7|         |      | 18.17   |      |

### Table 4.8: A distribution of some physical properties of dried cocoa beans

| Drying method | Fermentation | Treatment | dc (mm) | Stdv | E       | Stdv | S (%)  | Stdv |
|---------------|--------------|-----------|---------|------|---------|------|--------|------|
| Solar Box     | Washed       | 200.5     | 14.77   | 3.07 | 0.02    | 54.64| 0.97   |      |
|               | Unwashed     | 209.9     | 11.62   | 2.93 | 0.02    | 58.23| 0.21   |      |
|               | Washed       | 297.5     | 17.58   | 2.97 | 0.01    | 59.26| 0.56   |      |
|               | Unwashed     | 234.1     | 3.56    | 2.97 | 0.01    | 56.26| 0.43   |      |
| Sun Box       | Washed       | 268.5     | 7.91    | 3.64 | 0.21    | 56.48| 0.36   |      |

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717
Table 4.9: A distribution of some physical properties of dried cocoa beans

| Drying method | Fermentation | Treatment | V (cm³) | Stdv | A (mm²) | Stdv |
|---------------|--------------|-----------|---------|------|---------|------|
| Solar Box     | Washed       | 7.17      | 0.56    | 380.91 | 18.84   |
|               | Unwashed     | 7.73      | 0.37    | 396.39 | 13.68   |
| Basket        | Washed       | 10.86     | 0.66    | 497.53 | 20.02   |
|               | Unwashed     | 8.49      | 0.12    | 442.43 | 1.65    |
| Sun Box       | Washed       | 9.66      | 0.26    | 461.73 | 8.09    |
|               | Unwashed     | 8.15      | 0.23    | 412.35 | 8.36    |
| Basket        | Washed       | 9.55      | 0.23    | 459.73 | 7.42    |
|               | Unwashed     | 9.24      | 0.12    | 448.60 | 3.71    |
| Mean          |              | 8.85      |         | 437.45 |         |

4.7 Laboratory Test of Cocoa Samples

4.7.1 pH Test

Table 4.34: A distribution of pH Test of dried cocoa samples

| Drying Method | Fermentation | Treatment | Replication | Average | Stdv |
|---------------|--------------|-----------|-------------|---------|------|
| Solar Box     | Washed       | 6.9       | 7.1         | 7.06    | 0.15 |
|               | Unwashed     | 6.5       | 6.5         | 6.50    | 0.24 |
| Basket        | Washed       | 6.9       | 7.3         | 7.13    | 0.20 |
|               | Unwashed     | 6.5       | 6.6         | 6.56    | 0.19 |
| Sun Box       | Washed       | 7.2       | 7.1         | 7.13    | 0.20 |
|               | Unwashed     | 6.3       | 6.3         | 6.56    | 0.19 |
| Basket        | Washed       | 7.3       | 7.2         | 7.26    | 0.30 |
|               | Unwashed     | 6.5       | 6.5         | 6.50    | 0.24 |
| Mean          |              |           |             | 6.84    |      |
4.7.2 Sucrose Test

Table 4.35: A distribution of sucrose test of dried cocoa samples

| Drying Method | Fermentation | Treatment | Replication | Average | Stdv | Total sugar (%) |
|---------------|--------------|-----------|-------------|---------|------|-----------------|
| Solar Box     | Washed       | 17        | 18          | 19      | 18.00| 0.132           | 0.125 |
|               | Unwashed     | 17.5      | 15          | 19      | 17.16| 0.427           | 0.405 |
| Basket Box    | Washed       | 17        | 19          | 18.5    | 18.16| 0.073           | 0.069 |
|               | Unwashed     | 19        | 19          | 18      | 18.66| 0.103           | 0.097 |
| Sun Box       | Washed       | 19        | 18          | 19      | 18.83| 0.162           | 0.153 |
|               | Unwashed     | 18        | 19          | 19      | 18.66| 0.103           | 0.097 |
| Basket Box    | Washed       | 19        | 19          | 18.5    | 18.83| 0.162           | 0.153 |
|               | Unwashed     | 18.5      | 18.5        | 19      | 18.66| 0.103           | 0.097 |
| Mean          |              |           |             |         | 18.37|                 |      |

IV. CONCLUSION

1: Assessment of Some Drying Parameters of Dried cocoa Beans of Solar and Sun Drying Methods

In terms of cutting test, it can be concluded that box fermented beans have the highest brown colour with 100% for treatments washed and unwashed. Also the box fermented beans have the highest thickness of 3.07 mm and 3.64 mm for solar and sun dried respectively. The Sphericity of washed beans for sun dried beans reported the highest value of 60.06% during the research. However, the volume of washed beans for both drying methods and fermentation methods reported the highest values with 10.86 cm$^3$ for solar dried with box fermented.

From the results obtained in Chapter Four, it can also be concluded that the bulk densities of the unwashed, solar dried, box and basket fermented beans reported to be the highest in the research conducted with values of 532.24 kg/m$^3$ and 472.80 kg/m$^3$ respectively. However, washed, solar dried, box and basket fermented beans scored similar values.

1. Drying Curves of Dried Cocoa Samples

From the research conducted, it can be conclude that sun dried Samples B, C and E attained a constant weight at 24 hours of drying with a corresponding moisture content of 0.01 ddb, while Sample G attained constant weight at 32 hours with a corresponding moisture content of 0.01 ddb.

But however, solar dried Samples, A and F reported constant weight and moisture content with Samples B, C and E while Samples D and H attained similar conditions with sun dried Sample G.

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