International Journal of Environment, Agriculture and Biotechnology, 5(3)
May-Jun, 2020 | Available: https://ijeab.com/

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

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Abstract*— *This 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 labelled 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 evaluated. Sensory evaluation revealed that washed beans scored 70% chocolate colour for both drying methods, 80% aroma, 90% texture for all washed beans. When graded, solar dried beans scored 70% of grade 1 while sun dried scored 80% of grade 1. Also, the weight of unwashed solar dried beans recorded 9.61 kg while sun dried beans scored 10.09 kg. The pH of all washed beans were high with maximum value of 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 (*Theobroma cacao*) 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 used by chocolate manufacturing industries [2]. The plant is grown mostly in the wet tropical forest climate which is within 20ºF of latitude of the equator

at countries such as, Ivory Coast, Ghana, Nigeria, Cameroon, Brazil, Ecuador 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 of Sierra Leone. This served as the first research station of 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 cocoa. Today, cocoa is currently one of the most important export crops in Sierra Leone, commanding a very high price at international markets in Europe, Asia and America.

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

In Sierra Leone, cocoa is produced in the Eastern and Southern Provinces, with most of the crops 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.

Its 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 is said to be a producing cocoa belt but very little as compared to the other districts mentioned above.

During the war, most of the cocoa 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 rainy season. Based on this, most of the cocoa beans processed in most areas fall in to 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 buildings that are highly infested with insect pests (weevils) which makes 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] shows 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 have led to the 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) of 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 was 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 to 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 and ineffective especially in the rainy season and this involves human drudgery.

This research intended 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 between 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 produce from grade three (3) or two (2) to one or premium and

The research will also serve as a baseline 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 authors of this work 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 were 4 m length, 2.55 m width and 3 m height. The dryer constituted 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 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 weighing 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 48 hours to ensure uniformity during the processing. Beans labelled C and D were washed twice immediately after pod opening and placed into boxes labelled C and D and fermented from the 19th-25th January, 2016. While beans with labels A and B were unwashed and placed into boxes labelled A and B and fermented on the same date as mentioned above.

2.4.4 Basket Fermentation Method

Cocoa beans weighing 5.5 kg, 5.6 kg, 5.2 kg and 5.5 kg were put into baskets labelled E, F, G and H respectively and fermented on the same date with beans in the boxes, turned every 48 hours to ensure uniformity during fermentation. Beans labelled G and H were unwashed, put into baskets labelled G and H, while beans labelled E and F were washed, put into baskets labelled 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 labelleded A, D, F and H weighing 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 for drying to commence until the moisture content of the dried cocoa beans reached 7%. The temperature of the dryer was recorded from morning onto 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 labelled B, C, E and G weighing 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 period. 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 below. The sun drying was performed on the same date with solar drying method.

2.6 Data Collection

Data were 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 paper sheets, 2 washed and 2 unwashed for baskets and 2 washed and 2 unwashed for boxes. The procedure was done by dropping 4 labelled papers in the first box and 1 was chosen and assigned, 3 labelled papers to the second box, 2 labelled papers to the third and 1 to the last box, The same procedure was also done to the 4 baskets.

Also, capital letters labelled A-D for boxes and E-H for baskets were assigned. Four (4) labelled 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 labelled 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.

2.10Equations

$D_g = \sqrt[3]{(L \times T \times W}$ ---------- (1)

D_g = Geometric Mean Diameter in (mm)

Where L = Major diameter in (mm)

T = Intermediate diameter in (mm) and

W = Minor diameter in (mm)

$A_m = \frac{L+T+W}{3}$ ---------- ---------- (2)

A_m= Arithmetic mean diameter in (mm)

$S_m = [(\frac{(L\times T)+(T\times W)+(L\times W)}{3})]^{\wedge}1/2$ ---------- (3)

S_m= Mean Square Diameter in (mm^2)

$D_e = \frac{D_g+A_m+S_m}{3}$ ---------- (4)

D_e = Equivalent diameter in (mm)

$S = \frac{(L*T*W)}{L}\ ^{\wedge}1/3$ ---------- (5)

E = L/T ---------- (6)

E = Elongation

V = 4/3 π LTW ---------- (7)

Where V = Volume in (cm^3)

$A = \frac{\pi BL^2}{(2L-B)}$ ---------- (8)

B = (WT) ^1/2

A = Area in (mm^2)

III. RESULTS

3.1Figures and Tables

3.1.1 Sensory Evaluation

3.1.1.1 Colour of Dried Cocoa Beans

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

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
		Unwashed	0	0	0	0

	Basket	Washed	0	0	0	0
		Unwashed	3	30	0	0
Sun	Box	Washed	2	20	0	0
		Unwashed	1	10	1	0
	Basket	Washed	1	10	0	0
		Unwashed	1	10	0	0

3.3 Aroma of Dried Cocoa Beans

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
		Unwashed	3	30
Sun	Box	Washed	0	0
		Unwashed	2	20
	Basket	Washed	0	0
		Unwashed	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

Result shows 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 showed 90% good, in box fermented, 80% good, in basket fermented. Also washed beans showed 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

Sun	Box	Washed	1	10	8	80
		Unwashed	1	10	6	60
	Basket	Washed	8	80	2	20
		Unwashed	6	60	4	40

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
	Basket	Washed	1	10
		Unwashed	7	70
Sun	Box	Washed	1	10
		Unwashed	3	30
	Basket	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	0	0	0
		Unwashed	20	100	0	0	0	0
	Basket	Washed	16	80	2	10	2	10
		Unwashed	18	90	0	0	2	10
Sun	Box	Washed	10	50	2	10	8	40
		Unwashed	20	100	0	0	0	0
	Basket	Washed	14	70	2	10	4	20
		Unwashed	20	100	0	0	0	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
	Basket	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
	Basket	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	A_m (mm)	Stdv	D_g (mm)	Stdv	S_m (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
	Basket	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
	Basket	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	d_e (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
	Basket	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

		Unwashed	226.2	6.21	2.92	0.02	57.26	0.10
	Basket	Washed	265.4	6.87	2.74	0.08	58.35	0.25
		Unwashed	256.2	3.78	2.71	0.09	60.09	0.83
Mean			244.8		2.9		57.57	

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

Drying method	Fermentation	Treatment	V (cm^3)	Stdv	A (mm^2)	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	7.2	7.06	0.15
		Unwashed	6.5	6.5	6.5	6.50	0.24
	Basket	Washed	6.9	7.3	7.2	7.13	0.20
		Unwashed	6.5	6.6	6.6	6.56	0.19
Sun	Box	Washed	7.2	7.1	7.1	7.13	0.20
		Unwashed	6.3	6.3	7.1	6.56	0.19
	Basket	Washed	7.3	7.2	7.3	7.26	0.30
		Unwashed	6.5	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	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	18.5	19	18.83	0.162	0.153
		Unwashed	18	19	19	18.66	0.103	0.097
	Basket	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 basket 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.

ACKNOWLEDGEMENTS

I am most grateful to the Almighty God for the grace and strength he provided each day to make this publication with success.

My utmost appreciation goes to my former Supervisors and Lectures: Dr. Joseph Sherman-Kamara and Mr. John Victor Bangura for their great interest, corrections, guidance and also to the staff of Kenema Forestry and Tree Crops Research Centre (KFTCRC) especially Amara Kamara who harvested the cocoa pods for this publication.

I am also greatly indebted to all lecturers of the Department of Agricultural Engineering, Njala University, Njala Campus.

My appreciation also goes to my brothers: Mr. Ibrahim N. Kanu and Hassan G. Kanu, lovely wife Vivian Aminata Sesay and sons, Momoh Fovian Turay and Frederick G. M Lamin and wonderful Turay Family and others in Magbeni, Koya Chiefdom, Port Loko District and the people of Mayekson for the emotional support

I also appreciate the contributions and encouragements from my course mates especially Philip P. Bangura, Nabieu Y. Kamara, Dominic Musa Ibrahim-Sayo, Emmanuel Kangoma and Gareth J. Saffa.

My special thanks go to the technicians at the Agricultural Engineering, Njala University, Njala Campus especially Ernest Lissah for his technical support.

And, my sincere thanks to all those diverse ways have contributed to the successful completion of this publication.

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