Assessment of Some Production Practices on the Quality of Cocoa Beans (*Theobroma cacao*): A Case Study of Forest Savanna Transition and Semi-Deciduous Rainforest Zones of Ghana

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Authors' contributions

This work was carried out in collaboration between all authors. All authors read and approved the final manuscript.

| *Original Research Article* |

ABSTRACT

Cocoa from Ghana is of premium quality but non-recommended farmer practices could impact negatively on the quality of cocoa beans. Therefore, this study sought to determine the effect of some agricultural practices that could affect the quality of cocoa beans from four districts in two ecological zones. Treatments included samples of cocoa beans from the two ecological zones produced using either recommended or non-recommended practice. Offinso and Tepa in the Ashanti region as well as Goaso and Sankore districts in Brong Ahafo region were purposively selected from each of the ecological zones for more accurate results. The study was both field survey and laboratory work. The survey involved the use of structured questionnaire to obtain primary data from the farmers and purchasing clerks. The laboratory work was a 4×3 factorial experiment in completely randomized design with three replications. Results from the survey were

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analysed with SPSS and showed that majority of the farmers practiced harvesting at correct interval, fermentation, drying, disease and pest control which affected the quality of cocoa beans. However, majority of farmers did not practice pruning, fertilisation, proper storage, hence affecting quality. The laboratory results indicated that practices in Offinso and Tepa in the Forest Transition Zone of Ashanti Region had significantly (P≤ 0.05) better influence on the physical, chemical, and microbial quality of cocoa beans than Goaso and Sankore in the Deciduous Forest Zone of Brong Ahafo region. Also, there were significant differences (P≤ 0.05) in the four districts for percentage mouldy beans, slaty, pH, fat content, mould count and faecal coliform. Moreover, recommended farmer practices had a significant effect on the final quality of beans than non-recommended farmer practices at the various districts. It is, therefore, concluded that fermentation, drying, harvesting and Disease and pest control, which were the key practices, significantly influenced the physical, chemical and microbial quality of cocoa beans irrespective of the ecological zones.

1. INTRODUCTION

Cocoa belongs to the family *Steculiaceae* which is a tree crop and is scientifically well-known as *Theobroma cacao.* More than twenty species take place in the genus, but the cocoa tree is the one that is generally cultivated [1].

Wood and Lass [1] acknowledged that the lower level of the evergreen rainforest is the natural environment of the genus *Theobroma*. Such habitats usually give a confirmation of high rainfall, which favours good growth of the crop with temperature comparatively uniform all over the year; there is also stable high moisture and the shade is impenetrable Wood and Lass [2].

In countries with serious cocoa production, harvesting of cocoa is done over several months and not restricted to a particular time of the year like in some crops [2]. Cocoa like many crops has its fair share of diseases and pests and as such require the regular use of pesticides to combat capsid bugs and fungicides to control black pod disease [3].

Undeveloped cocoa pods have varied colours, but are usually green, red, or purple. As the pods mature, however, their colour changes to yellow or orange, predominantly in the creases. [2,4]. During harvesting, care must be taken to avoid damage to the junction of the stem as this is where future flowers and pods will emerge ([2,4]). A total of 650 pods can be harvested per day per person [3,5].

Processing of cocoa beans through a traditional method is desirable and responsible for the much-loved taste and flavour of Ghanaian cocoa beans [6]. As such the proportion of beans processed locally has also soared from 20 to 35% with plans on-going to ensure that the percentage reaches 50% target in the near future. It is also the target of the government that alongside increased cocoa production, there is also an increase in the processing of cocoa into desirable products for the local Ghanaian market and eventually into the international market [6].

Cocoa from Ghana is rated as the best in the international market due mainly to its premium quality; however, non-recommended farmer practices could have negative impact on the quality of cocoa beans [7]. Non recommended agricultural practices such as poor fertilisation, improper spacing of plants, poor weeds control, improper pruning as well as poor disease and pest control strategies could contribute negatively to the growth and development of the plant which could eventually affect the quality of the beans. Additionally, rainfall regime and nature of the soil could also significantly affect the growth and quality of the cocoa beans. Also poor harvesting techniques, as well as postharvest handling strategies, could have a negative impact on the cocoa beans quality. The repercussion is that it affects the market price of the commodity.

Therefore, the main objective of this study was to determine the effect of some Agricultural practices on the quality of cocoa beans in Forest transition Zone and Deciduous Forests.

The specific objectives of the research were to: Identify through field survey key agricultural practices of cocoa farmers that could affect the quality of cocoa beans. Determine the effect of some agricultural practices on the physical bean quality characteristics of cocoa beans through cut tests. Determine the effect of some agricultural practices on the chemical bean quality characteristics of cocoa beans through laboratory test. Determine the effect of some

agricultural practices on the microbial bean quality characteristics of cocoa beans.

2. MATERIALS AND METHODS

2.1 Survey

The cocoa districts were purposively selected due to their high production for accuracy.

The study was conducted at Goaso and Sankore cocoa districts in Deciduous Forest of Brong Ahafo region and Offinso and Tepa districts in Forest Transition Zone of the Ashanti Region due to the quality of beans produced in those areas to ascertain the impact of farmer practices in those areas.

2.2 Stakeholders (Population)

Random sampling technique was used to select the respondents. The population consisted of one hundred and twenty (120) respondents comprising one hundred (100) cocoa farmers and twenty (20) cocoa purchasing clerks. The population chosen depended upon the number of farmers and purchasing clerks within the community chosen from the districts.

Formular for calculating sample size

$$ss = \frac{Z^2 \times (P) \times (1-P)}{C^2}$$

ss= sample size
Z= z value (1.96 for 95% confidence level)
P= percentage picking a choice, expressed as decimal
C= confidence interval, expressed as decimal

They were then segregated into two farmer groups, purchasing clerks based on interview, for those who follow recommended and non-recommended practices and also physical observation on the field.

2.3 Sampling Techniques

The data from the field was collected using a structured questionnaire to obtain primary data from the respondents. Four (4) cocoa growing districts were selected for the study. Thirty (30) respondents were interviewed from five (5) different communities within each of the districts. Thus five (5) farmers and one (1) cocoa purchasing clerk, constituting six (6) respondents per community. A total one hundred and twenty (120) respondents from the four (4) districts were studied.

2.4 Sample Collection Procedure

Based on the survey, it was realised that there were group of farmers and a purchasing clerk that undertook recommended practice for pre-harvest, harvest and post-harvest practices and those who undertook non-recommended practices. The final conclusion was drawn after the laboratory test was carried out on the cocoa beans to confirm results from survey.

Samples of dried cocoa beans were randomly selected from two (2) of the five (5) selected farmers from the communities to represent recommended farmer practices and non-recommended farmer practices based on responses of farmers from the survey as well as physical observations on farmers field and one purchasing clerk for the laboratory analysis. This would enable us know those farmers who performed good as well as bad practices. Samples were collected from ten (10) farmers and five (5) Purchasing Clerks from the five (5) selected communities. These samples from the two (2) groups were bulked and quartered together as well as purchasing clerks to give a final three (3) samples for each district. Where five (5) farmers were summed to give recommended farmer group and the other five (5) farmers were summed to give non-recommended farmer group. Therefore a total of twelve (12) samples were collected for the four (4) districts that constituted the two (2) regions. Replication was done three times to give a total of thirty six (36) samples for the study.

2.5 Research Design

The research design used was 4×3 factorial experiment which was laid in Completely Randomised Design (CRD). These comprised of four (4) districts and farmer group one (Recommended), farmer group two (non-recommended) and purchasing clerks (3).

2.6 Determination of Microbial Qualities of Cocoa Beans

Hundred grams (100 g) of hybrid cocoa beans were taken to the department of biological science laboratory at the Kwame Nkrumah University of Science and Technology for microbial analysis such as Mould count, Faecal coliform and *Escherichia coli.*

2.6.1 Mould (fungi) count

Mould were secluded and enumerated by pour plate method and grown on potato Dextrose Agar

(PDA). Serial dilutions of 10^{-1} to 10^{-4} were prepared by diluting 1g of the sample into 9ml of sterilised distilled water. One millilitre aliquots from each of the dilutions were inoculated into the Petri dishes with already prepared PDA. The plates were then incubated at $25^{o}C$ for 24hrs. After incubation all white spot or multiply were counted and recorded as mould using the colony counter [8].

2.6.2 Faecal coliforms

The Most Probable Number (MPN) method was used to determine total and faecal coliforms in the samples. Serial dilutions of 10^{-1} to 10^{-4} were prepared by picking 1g of the sample into 9ml sterilised distilled water. One millilitre aliquots from each of the dilutions were inoculated into 5ml of macConkey broth with inverted Durham tubes and incubated at $35^{o}C$ for total coliforms and $44°C$ faecal Coliforms for 18-24 hours. Tubes showing colour change from purple to yellow and gas collected in the Durham tubes after 24 hours were identified as positive for both total and faecal coliforms. Counts per 100ml were calculated from Most Probable Number (MPN) tables [8,9].

2.6.3 *Escherichia coli*

From each of the positive tubes identified a drop was transferred into a 5 ml test tube of tryptone water and incubated at $44°C$ for 24 hours. A drop of Kovacs' reagent was then added to the tube of tryptone water. All tubes showing a red ring colour development after gentle agitation denoted the presence of indole and recorded as presumptive for thermo-tolerant coliforms (*Escherichia coli)*. Counts per 100 ml were calculated from Most Probable Number (MPN) tables [9].

2.7 Data Analysis

The field survey result was analysed with SPSS version 21, whilst the cut test and laboratory results were analysed with student statistic software version 9. Where significant differences exist treatment means were separated with LSD at 1% probability level (P≤ 0.01).

3. RESULTS AND DISCUSSION

3.1 Pre-harvest Practices

3.1.1 Pruning activity by cocoa farmers

The table showed that majority of farmers practice pruning. In the case of respondent in

Goaso district, 92% practice pruning but 8% do not practice whilst for Sankore 84% practice pruning but 16% do not undertake pruning. Furthermore, 92% of Tepa respondents practice pruning but 8% do not practice pruning whilst 96% of Offinso practice pruning and 4% do not engage in pruning activity. Moreover, removal of pods affected by viral and fungal diseases helped to improve quality of cocoa beans. Pruning also facilitates the entrance of sunlight which is essential for pollination [10]. It also strengthens the formation of new leaves and production areas. Fewer number of farmers did not practice pruning due to long time for regrowth of branches and the assumption that tress will die.

3.1.2 Effect of fertiliser application on quality of cocoa beans

The table presents the percentage respondents view on the quality of cocoa beans. 64% of farmers from Sankore indicated that fertilisation had effect on the quality of cocoa beans whilst 96% of farmers from Tepa also showed that fertilisation had effect on bean quality. 68% of farmers in Goaso indicated that fertilisation had effect on quality while 80% of farmers from Offinso also submitted that fertilisation affected quality. Fertilisation results in big and quality cocoa beans, improves flavour of manufactured chocolate [11]. Farmers who never applied fertiliser gave reasons that animal droppings are better, it also had no effect on cocoa beans when used because it increases only yield but not quality.

3.2 Physical Bean Quality Characteristics

From the results, Sankore district recorded the highest percentage mean mouldy beans (2.10%) while the lowest percentage mouldy beans were recorded at Offinso (1.52%). This could be due to inadequate drying of cocoa beans, storage of cocoa beans under highly humid or poorly ventilated conditions, wetness of cocoa beans in rain through transit, prolonged fermentation, stacking of cocoa on the bare floor and against the wall, harvesting of over-ripe pods and leaving them on the ground for several days. The reasons above were confirmed by Wood and Lass [1] who submitted that, factors such as slow or inadequate drying of cocoa beans, long period of fermentation as well as storage of dried cocoa beans under extremely moist environment could result in mouldy cocoa beans. Damaged and

germinated beans are also prone to becoming mouldy as added by the authors. When one consumes any cocoa product with mould particularly Ochratoxin 'A' which is a form of mycotoxin, it causes cancer. They also bring about high levels of free fatty acids which gives the cocoa bean an appalling flavour [12]. Nevertheless, the percentage mouldy beans recorded in the four districts were within the acceptable level of not more than 4% to be well thought-out as good quality cocoa beans.

Furthermore, Mouldy beans emit off-flavours and impart a musty flavour to the chocolate, certain mould species produce mycotoxins (a substance poisonous to both humans and animals) [13].

Table 1. Pruning activity by cocoa farmers

Pruning	Semi-deciduous forest zone				Forest savannah transition				Pooled	
	Goaso		Sankore		Tepa		Offinso			
	Freq.	%	Freq.	%	Freq.	%	Freq.	%	Freq.	%
Yes	23	92	21	81	22	88	24	96	90	90
No	2	8	4	16	3	12	1	4	10	10
Total	25	100	25	100	25	100	25	100	100	100

Table 2. Perception of farmers concerning fertilisation application on quality of cocoa beans

Pruning	Semi-deciduous forest zone				Forest savannah transition				Pooled	
	Goaso		Sankore		Tepa		Offinso			
	Freq.	%	Freq.	%	Freq.	%	Freq.	%	Freq.	%
Yes	17	68	16	64	24	96	20	80	77	77
No	8	32	9	36	1	4	5	20	23	23
Total	25	100	25	100	25	100	25	100	100	100

Table 3. Interaction effect of district and groups on percentage mouldy cocoa beans

Districts	Groups			
	Recommended farmer group	Non-recommended farmer group	Purchasing clerks	Mean
Goaso	0.80d	2.67ab	1.00d	1.49ab
Sankore	1.10cd	3.87a	1.33cd	2.10a
Tepa	0.89d	2.63b	1.20cd	1.57ab
Offinso	0.77d	2.33bc	0.80d	1.30b
Mean	**0.89b**	**2.88a**	**1.08b**	

CV(%) 10.51

LSD (5%) Groups=0.61   LSD (5%) Districts=0.71

LSD (5%) Groups*Districts= 1.23

Note: Means with the same letters are not significantly different from each other and vice versa. eg.a,ab,abc. LSD = Least Significant Difference

Table 4. Interaction effect of district and groups on percentage Slaty cocoa beans

Districts	Groups			
	Recommended farmer group	Non-recommended farmer group	Purchasing clerks	Mean
Goaso	1.10d	3.33bc	1.20d	1.88b
Sankore	1.40cd	3.90b	1.38cd	2.23ab
Tepa	1.57cd	6.77a	1.60cd	3.31a
Offinso	0.90d	2.70bcd	0.97d	1.52b
Mean	**1.24b**	**4.18a**	**1.29b**	

CV(%) 8.56

LSD (5%) Groups=1.06   LSD(5%) Districts=1.22

LSD(5%) Groups*Districts= 2.12

Table 5. Interaction effect of district and groups on percentage purity of cocoa beans

Districts	Groups			
	Recommended farmer group	Non-recommended farmer group	Purchasing clerks	Mean
Goaso	96.57a	93.13bc	95.53ab	95.08a
Sankore	95.33ab	87.50d	93.67ab	92.16b
Tepa	94.47ab	90.20cd	94.46ab	93.04b
Offinso	96.90a	93.67ab	96.00ab	95.52a
Mean	**95.82a**	**91.13b**	**94.94a**	

CV(%) 1.55
LSD (5%) Groups=1.67   LSD (5%) Districts=1.93
LSD (5%) Groups*Districts=3.35

The cut test outcome indicated that Tepa district registered the highest (3.31%) mean slaty beans whereas the lowest value was recorded at Offinso district (1.52%). Offinso recorded the highest percentage of 84% from the survey of farmers who practised turning. Yet, the Tepa value was within the permissible level of not more than 8% to be of good quality cocoa beans. Dand [14] reported that slaty cocoa beans provide chocolate a bitter taste and also decrease the market price of cocoa.

Daviron [11] highlighted that factors that contribute to slaty cocoa beans included; inadequate fermentation heap mass and also when the temperature outside the fermentation heap is too low particularly during dry season's period. These were clearly shown in the percentages by respondents in the survey at the various districts. Effect of slaty beans includes; Destroying the flavour of manufactured chocolate, slaty beans are bitter and astringent therefore it is not economical to the manufacturer as it takes more sugar for the preparation of chocolate and slaty beans are cheesy and stick to the machine during the process of grinding or milling [15].

The results for purity showed that Offinso district recorded the highest (95.52%) mean brown (purity) beans value whilst Sankore district recorded the least (92.16%) purity beans.

Percentage purity beans occurs when all the percentage defects from the cocoa beans are added and subtracted from hundred percent. They are noted for their characteristic good flavour and taste, which is often chosen by manufacturers and for that matter buyer. From the survey, Sankore district recorded poorly in terms of pre-harvest, harvest and post-harvest practices whereas Offinso recorded better in terms of practices. These eventually affected the physical characteristics of cocoa beans as shown from the results.

Bean count usually determines category of cocoa beans which in tend ascertain the fat composition of cocoa beans, since it is usually measured per hundred grams. Bigger beans require less number to make hundred grams of cocoa during bean count which is a necessity of the buyers, whereas smaller beans is vice versa. Tepa district recorded the highest mean bean count of (118.11%) while the lowest bean count (97.78%) was recorded at Offinso, meaning the district recorded bigger beans hence regarded as main crop category.

From the survey recommended farmer group practiced fertilisation very well, pruning, disease and pest control, engaged timely and good harvesting, good fermentation, proper drying and excellent storage by purchasing clerks compared to non-recommended farmer group who undertook only bad pruning, bad fertilisation, proper disease and pest control, good harvesting, failure or inadequate fermentation days, good drying and inappropriate storage. Recommended farmer group may be regarded as good practice farmers because their respective values met the accepted levels of defects for cocoa to be regarded as grade one while non-recommended farmer group may be regarded as bad practice farmers since they fall within the levels to be regarded as grade two which does not meet the ultimate criteria internationally. However, the result from recommended farmer group was the best and was similar to results from purchasing clerks.

3.2.1 Effect of districts and groups on bean count of cocoa beans

The effects of districts and groups on bean count of cocoa beans are presented in the above table.

From the results, significant differences (p≤ 0.05) were observed among the groups. Beans from non-recommended farmer group (116.17) had significantly the highest bean count while beans

Table 6. Interaction effect of district and groups on bean count of cocoa beans

Districts	Groups			Mean
	Recommended farmer group	Non-recommended farmer group	Purchasing clerks	
Goaso	112.33cde	115.33bcde	111.67de	113.11b
Sankore	111.33e	128.00a	111.44e	116.92a
Tepa	118.00bc	119.00b	117.33bcd	118.11a
Offinso	92.00g	103.33f	98.00fg	97.78c
Mean	**108.42b**	**116.17a**	**109.61b**	

CV(%) 26.52
LSD (5%) Groups=2.90   LSD (5%) Districts=3.35
LSD (5%) Groups*Districts=5.80

Table 7. Interaction effect of district and groups on percentage Uniformity Index of cocoa beans

Districts	Groups			Mean
	Recommended farmer group	Non-recommended farmer group	Purchasing clerks	
Goaso	9.03	10.13abc	9.37abc	9.51ab
Sankore	9.80abc	10.00abc	10.73a	10.17a
Tepa	9.10bc	10.53ab	9.70abc	9.78a
Offinso	7.13d	9.67abc	9.88abc	8.89b
Mean	**8.77b**	**10.08a**	**9.92a**	

CV(%) 6.79
LSD (5%) Groups=0.72   LSD (5%) Districts=0.83
LSD (5%) Groups*Districts=1.44

Table 8. Interaction effect of district and groups on percentage fat content of cocoa beans

Districts	Groups			Mean
	Recommended farmer group	Non-recommended farmer group	Purchasing clerks	
Goaso	36.33abc	35.07abc	37.03ab	36.14ab
Sankore	35.63abc	34.00c	34.50bc	34.71b
Tepa	36.07abc	35.27abc	36.70abc	36.01ab
Offinso	37.77a	35.29abc	37.20ab	36.75a
Mean	**36.45a**	**34.90b**	**36.35ab**	

CV(%) 3.60
LSD (1%) Groups=1.45   LSD (1%) Districts=1.67
LSD (1%) Groups*Districts=2.90

Table 9. Interaction effect of districts and groups on free fatty acids of cocoa beans

Districts	Groups			Mean
	Recommended farmer group	Non-recommended farmer group	Purchasing clerks	
Goaso	1.21ef	1.82ab	1.28de	1.44c
Sankore	1.55bcd	1.95a	1.68abc	1.77a
Tepa	1.30de	1.83ab	1.40bcd	1.51bc
Offinso	0.90g	1.70ab	0.95fg	1.18b
Mean	**1.24b**	**1.87a**	**1.33b**	

CV(%) 16.52
LSD (1%) Groups=0.14   LSD (1%) Districts=0.16
LSD (1%) Groups*Districts=0.28

Note: Means with the same letters are not significantly different from each other and vice versa. eg.ef,fg,de LSD = Least Significant Difference

from recommended farmer group had the least (108.42) but was similar to beans from purchasing clerks (109.61).

For the districts, there were significant differences (p≤ 0.05). The highest bean count (118.11) was recorded at Tepa while the lowest (97.78) was recorded at Offinso but was significantly different from beans from Tepa and Goaso.

With regards to interaction between the groups and districts, significant differences (p≤ 0.05) were observed. The highest bean count was observed in beans from non-recommended farmer group at Sankore (128.00) while the least was recorded in cocoa beans from recommended farmer group one (92.00) at Offinso.

3.2.2 Effects of districts and groups on uniformity index of cocoa beans

The effects of districts and groups on uniformity of cocoa beans are presented in the above Table. From the results, significant differences (p≤0.05) were observed among the groups. Beans from non-recommended farmer group (10.08%) had significantly the highest percentage of Uniformity Index while beans from recommended farmer group had the least (8.77%) but was not similar to beans from purchasing clerks (9.92%).

For the districts, there were significant differences (p≤0.05).The highest uniformity index (10.17%) was recorded at Sankore while the lowest uniformity index (8.89%) was recorded at Offinso but was not similar to beans from Tepa.

With regards to interaction between the groups and districts, significant differences (p≤ 0.05) were observed. The highest uniformity index was observed in beans from farmer group two at Tepa (10.53%) while the least uniformity was recorded in cocoa beans from farmer group one (7.13%) at Offinso.

3.3 Chemical Bean Quality Characteristics

Wood and Lass [1] reported that fat content of cocoa is affected by variety, bean size, and quantity of rainfall during pod maturation, season harvesting, as well as soundness of beans. From the results, Offinso district recorded the highest mean percentage (36.75%) fat content with the least recorded by Sankore district (34.71%). Mouldy beans as well as disease and pest result in decrease levels of fat content. From the survey, higher percentage of respondents from Offinso controlled diseases and pest at the recommended number of times as compared to lower percentage in sankore.

For storage, fertilisation, fermentation, drying and harvesting, Offinso recorded the highest percentages in terms of recommended practices while Sankore recorded the lowest percentage from the survey. Hence all these had effect on the fat content as shown from the values indicated.

Free fatty acid happens as a consequence of bad pre and postharvest activities such diseases and pest infestation, poor fertilisation, bad fermentation, harvesting immature and unripe pods, decayed and black beans, the use of mouldy beans, germinated beans from over-ripened pods [16].

Table 10. Effect of district and groups on pH of cocoa beans

Districts	Groups			
	Recommended farmer group	Non-recommended farmer group	Purchasing clerks	Mean
Goaso	5.93b	4.67e	5.90b	5.50b
Sankore	5.60c	4.00f	5.20d	4.93c
Tepa	5.55c	3.13g	5.60c	4.76d
Offinso	6.80a	5.12d	6.77a	6.77a
Mean	**5.97a**	**4.23c**	**5.87b**	

CV(%) 0.76
LSD (1%) Groups=0.05   LSD (1%) Districts=0.06
LSD (1%) Groups*Districts=0.10

Note: Means with the same letters are not significantly different from each other and vice versa. eg.ef,fg,de LSD = Least Significant Difference

Table 11. Effect of districts and groups on percentage moisture content of cocoa beans

Districts	Groups			Mean
	Recommended farmer group	Non-recommended farmer group	Purchasing clerks	
Goaso	6.33b	8.00bc	6.21d	6.84bc
Sankore	7.00d	8.27b	6.83cd	7.37a
Tepa	6.80cd	0.87ab	6.50cd	7.15ab
Offinso	6.27d	7.90bc	6.10d	6.76c
Mean	**6.60b**	**8.09a**	**6.41b**	

CV(%) 5.79
LSD (1%) Groups=0.40   LSD (1%) Districts=0.46
LSD (1%) Groups*Districts=0.80

Long term storage of cocoa beans could also result to an increase in the free fatty acid level of dried cocoa beans. The results showed that Sankore district registered the highest mean (1.77%) value of FFA with Offinso district recording the least (1.18%). However, the value recorded for Offinso was within the European union requirement of (1.75%) to be of good quality cocoa beans [7] while the results from Sankore was above the accepted level of good quality cocoa.

For pH, Offinso district recorded the highest mean value (6.77) whilst Tepa district recorded the least (4.76).The highest value recorded by Offinso district could be due to the fact that majority of respondents undertook turning during fermentation as realised in the survey compared to their counterparts from the other three districts, which was a little below Offinso district. A good cocoa bean should have pH between 5.5 and 8.5 according to Thery [17].

Daviron [11] also reported that lack of fermentation, inadequate fermentation days and lack of turning during fermentation all lead to decreased level of pH, which would eventually give the product a bitter taste.

According to quality control company quality measure, any parcel of cocoa with moisture content above 7.5% is not up to standard. During successive storage and transport, moisture contents beyond 8% could lead to mould growth inside the beans [18]. Additionally, cocoa beans with high moisture content could cause beans to germinate under favourable conditions; cause beans to rot and also could result to insect invasion. Fowler [7] submitted that these factors lead to high level of free fatty acid, which would consistently affect the quality of cocoa beans. From the results, Sankore district recorded the highest (7.37%) moisture content whilst Offinso district registered the least (6.52%). Hence forth,

the figures recorded were within the worldwide standard of 8% to be of good quality [19].

For the groups, non-recommended farmer group recorded the highest moisture percentage of 8.09%, Free fatty acids of 1.89%, pH of 4.23 and fat content of 34.90.These group may be regarded as bad practice farmers because the values recorded does not meet the recommended standards.

Recommended farmer group recorded moisture content of 6.60%, free fatty acids of 1.24 and fat content of 36.45. Recommended farmer group may be regarded as good practice farmers because the values fall within the accepted standard for good quality cocoa. From the questionnaire recommended farmer group practiced fertilisation very well, pruning, controlled disease and pest, engaged timely and good harvesting, good fermentation, proper drying and excellent storage by purchasing clerks compared to non-recommended farmer group who undertook only bad pruning, bad fertilisation, proper disease and pest control, harvesting, failure or inadequate fermentation days, good drying and inappropriate storage.

3.3 Microbial bean Quality Characteristics

3.3.1 Effect of districts and groups on mould count of cocoa beans

The effects of districts and groups on mould count of cocoa beans are presented in Table 4.31 below. From the results, significant differences (p≤0.01) were observed among the groups. Beans from non-recommended farmer group (4.54×10^4) had significantly the highest percentage mould count while beans from recommended farmer group had the least (1.43×10^4) but was similar to beans from purchasing clerks (1.43×10^4).

For the districts, there were significant differences (p≤ 0.01).The highest mould count (4.21×10^4) was recorded at Sankore while the lowest (0.87×10^4) mould count was recorded at Offinso.

With regards to interaction between the groups and districts, significant differences (p≤ 0.01) were observed. The highest mould count was observed in beans from non-recommended farmer group at Sankore (7.46×10^4) while the least was recorded in cocoa beans from recommended farmer group (0.28×10^4) at Offinso.

Concerning human wellbeing, the main safety risk related to the production of cocoa is a toxin named Ochratoxin 'A'. Ochratoxin 'A' is one of the toxins that are together called mycotoxins, all of which are harmful to human health and are produced by mould species.

Ochratoxin 'A' is colourless and stable during cooking and fermentation, that is the difficulty associated to it. It may even be present in foods where no evident mould growth is seen. There is a high risk of contaminating the cocoa beans as soon as the pod is broken since Organisms that are able to produce Ochratoxin 'A' are also present all over the farm environment. Ochratoxin 'A' might develop in contaminated cocoa beans while drying ([8,9].

Faecal coliforms are group of the total coliform that are regarded to be present especially in the gut (lower intestine) and faeces of warm blooded animals. It can also be caused by dirty water used in liquid fertilisation and spraying. Faeces from hand after toilet (during drying) as well as animal's droppings and faeces from kids [20].

Mould count has to do with mouldiness as a result of high moisture content of beans. Ecoli gives an sign of faecal pollution and likely presence of pathogens.

For the districts the highest faecal coliform and mould count was recorded at Sankore and the lowest faecal coliform and mould count was recorded at Offinso. This is in agreement with the responses indicated in the survey about personal hygiene of farmers at the various districts. Farmers from Offinso harvested, fermented and dried their cocoa beans in a very good environment compared to those in Sankore in unhygienic environment, which affected the microbial content of cocoa beans. For the farmer groups and purchasing clerks. Non-

Table 12. Effect of districts and groups on mould count of cocoa beans

Districts	Groups			
	Recommended farmer group(10^4)	Non-recommended farmer group(10^4)	Purchasing clerks(10^4)	Mean
Goaso	1.33bcd	2.44b	9.44cd	1.64a
Sankore	2.42b	7.53a	2.67b	4.21b
Tepa	1.61bc	6.57a	1.53bcd	3.25c
Offinso	2.82d	1.61bc	7.62cd	8.71a
Mean	**1.43b**	**4.54a**	**1.54b**	

CV(%) 22.66
LSD (1%) Groups= 6.3×10^4   LSD (1%) Districts=7.4×10^4
LSD (1%) Groups*Districts=1.2×10^4

Note: Means with the same letters are not significantly different from each other and vice versa. eg.ef,fg, de LSD = Least Significant Difference

Table 13. Effect of districts and groups on faecal coliform of cocoa beans

Districts	Groups			
	Recommended farmer group	Non-recommended farmer group(10^5)	Purchasing clerks(10^5)	Mean
Goaso	0.00b	2.31ab	2.31ab	1.52a
Sankore	0.00b	16.1a	0.00b	5.36a
Tepa	0.00b	4.2ab	0.00b	1.41ab
Offinso	0.00b	0.00b	0.00b	0.00b
Mean	**0.00b**	**5.65a**	**0.57b**	

CV(%) 50.52
LSD (1%) Groups=3.92×10^5   LSD (1%) Districts=4.61×10^5
LSD (1%) Groups*Districts=7.93×10^5

recommended farmer group recorded the highest values in terms of faecal coliform and mould count as compared to recommended farmer group which recorded the lowest results and similar to the purchasing clerks. This is in line with the survey because the recommended farmer groups followed good practices compared to non-recommended farmer group who ignored some of the good practices.

6. CONCLUSION AND RECOMMENDA-TIONS

6.1 Conclusion

Major findings of the research included good quality cocoa beans from the recommended practice farmers compared with low quality cocoa beans from non-recommended farmer practice. It is therefore concluded that the combined effect of two districts in Forest Savannah zone of Ashanti Region performed better in terms of quality than the other two districts in Semi - Deciduous Forest Zone of Brong Ahafo Region.

Cocoa farmers from the various districts showed difference in some agricultural practices in the areas of pre-harvesting, harvesting and postharvest operations. These practices had adverse effect on the cocoa beans quality as revealed by the field survey conducted.

6.2 Recommendations

The following recommendations have been made for further studies:

Studies should be carried out at other districts to know the relationship between pre-harvest and post-postharvest practices on physical, chemical and microbial quality parameters.

Further research should be carried out on assessment of farmers practices and identify the practice that stand out in terms of having major influence on the postharvest quality of cocoa beans.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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