

EFFECTS 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.

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. Two districts 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 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, fertilization, 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 ($P \leq 0.05$) 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 ($P \leq 0.05$) in the four districts for percentage mouldy beans, slaty, pH, fat content, mould count and faecal coliform. Moreover, recommended farmer practices had 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.

Keywords: deciduous forest, forest transition zone, mould, faecal coliforms, escherichia coli

1.0 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 (Wood and Lass, 1985).

Wood and Lass (1985) 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.

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 (Wood and Lass, 2001). 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 (Olivia and James, 2003).

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.

Comment [F1]: What were the names of the districts? State their GPRS locations too.

Comment [F2]: Were the results analysed? If so, then how? State the statistical tool did you employ?

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47 (Wood and Lass, 2001; Hui and Yui, 2006). During harvesting, care must be taken to avoid
48 damage to the junction of the stem as this is where future flowers and pods will emerge
49 (Wood and Lass, 2001; Hui and Yui, 2006). A total of 650 pods can be harvested per day per
50 person (Olivier and James, 2003; Gockowski and Oduwale, 2003).

51 Processing of cocoa beans through traditional method is desirable and responsible for the
52 much-loved taste and flavour of Ghanaian cocoa beans. As such the proportion of beans
53 processed locally has also soared from 20 to 35% with plans on-going to ensure that the
54 percentage reaches 50% target in the near future. It is also the target of the government that
55 alongside increased cocoa production, there is also an increase in the processing of cocoa into
56 desirable products for the local Ghanaian market and eventually into the international market
57 (Awuah, 2002).

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

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

70 The specific objectives of the research were to:

- 71 i. Identify through field survey, key agricultural practices of cocoa farmers that could
72 affect the quality of cocoa beans.
- 73 ii. Determine the effect of some agricultural practices on the physical bean quality
74 characteristics of cocoa beans through cut tests.
- 75 iii. Determine the effect of some agricultural practices on the chemical bean quality
76 characteristics of cocoa beans through laboratory test.
- 77 iv. Determine the effect of some agricultural practices on the microbial bean quality
78 characteristics of cocoa beans.

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82 **2.0 Materials and Methods**

83 **2.1 Survey**

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84 The cocoa districts were purposively selected due to their high production for accuracy.
85 The study was conducted at Goaso and Sankore cocoa districts in Deciduous Forest of Brong
86 Ahafo Region and Offinso and Tepa districts in Forest Transition Zone of the Ashanti Region
87 due to the quality of beans produced in those areas to ascertain impact of farmer practices in
88 those areas.

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90 2.2 Stakeholders (Population)

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91 Random sampling technique was used to select the respondents. The population consisted of
92 one hundred and twenty (120) respondents comprising one hundred (100) cocoa farmers and
93 twenty (20) cocoa purchasing clerks. They were then segregated into two farmer groups,
94 purchasing clerks based on interview, for those who follow recommended and non-
95 recommended practices and also physical observation on the field.

Comment [F9]: How did you determine sample size? There is a formular for calculating sample size? Which formular did you use?

96 2.3 Sampling techniques

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

104 2.4 Sample Collection Procedure

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

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

122 2.5 Research Design

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

126 2.6 Determination of Microbial Qualities of Cocoa Beans

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

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131
132 **2.6.1 Mould (fungi) count**
133 Mould were secluded and enumerated by pour plate method and grown on potato Dextrose
134 Agar (PDA). Serial dilutions of 10^{-1} to 10^{-4} were prepared by diluting 1g of the sample into
135 9ml of sterilized distilled water. One millilitre aliquots from each of the dilutions were
136 inoculated into the petri dishes with already prepared PDA. The plates were then incubated at
137 25°C for 24hrs. After incubation all white spot or multiply were counted and recorded as
138 mould using the colony counter.

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139
140 **2.6.2 Faecal coliforms**
141 The Most Probable Number (MPN) method was used to determine total and faecal coliforms
142 in the samples. Serial dilutions of 10^{-1} to 10^{-4} were prepared by picking 1g of the sample into
143 9ml sterilized distilled water. One millilitre aliquots from each of the dilutions were
144 inoculated into 5ml of macConkey broth with inverted Durham tubes and incubated at 35°C
145 for total coliforms and 44°C faecal Coliforms for 18-24 hours. Tubes showing colour change
146 from purple to yellow and gas collected in the Durham tubes after 24 hours were identified as
147 positive for both total and faecal coliforms. Counts per 100ml were calculated from Most
148 Probable Number (MPN) tables.

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149
150 **2.6.3 *Escherichia coli***
151 From each of the positive tubes identified a drop was transferred into a 5ml test tube of
152 tryptone water and incubated at 44°C for 24 hours. A drop of Kovacs' reagent was then added
153 to the tube of tryptone water. All tubes showing a red ring colour development after gentle
154 agitation denoted the presence of indole and recorded as presumptive for thermo-tolerant
155 coliforms (*E.coli*). Counts per 100ml were calculated from Most Probable Number (MPN)
156 tables.

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157
158 **2.7 Data Analysis**
159 The field survey result was analysed with SPSS version 21, whilst the cut test and laboratory
160 results were analysed with student statistic software version 9. Where significant differences
161 exist treatment means were separated with LSD at 1% probability level ($P \leq 0.01$).

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164 **3.0 Results and Discussion**

165 **3.1 Pre-harvest practices**

166 **3.1.1 Pruning Activity by Cocoa Farmers**

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167 **Table 1: Pruning activity by cocoa Farmers**

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Pruning	Deciduous Forest				Forest Transition Zone				Pooled	
	Goaso		Sankore		Tepa		Offinso			
	Freq.	%	Freq.	%	Freq.	%	Freq.	%	Freq.	%
Yes	23	92	21	84	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	10

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174 The table showed that majority of farmers practice pruning. In the case of respondent in
175 Goaso district, 92% practice pruning but 8% do not practice whilst for Sankore 84% practice
176 pruning but 16% do not undertake pruning. Furthermore, 92% of Tepa respondents practice
177 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 (Amo, 2012). 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 Fertilizer Application on Quality of Cocoa Beans

Table 2: Effect of fertilization on bean quality

186	Deciduous Forest					Forest Transition Zone						
187	Fertilization	Goaso		Sankore		Tepa		Offinso		Pooled		
188		Freq.	%	Freq.	%	Freq.	%	Freq.	%	Freq.	%	
189	Yes	17	68	16	64	24	96	20	80	77	77	
190	No	8	32	9	36	1	4	5	20	23	23	
191	Total	25	100	25	100	25	100	25	100	100	100	

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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 (Daviron,1999). Farmers who never applied fertilizer 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

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

Districts	Groups			Mean
	Recommended Farmer Group	Non- Recommended Farmer Group	Purchasing Clerks	
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				

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207 Table 4: Interaction effect of District and Groups on percentage Slaty Cocoa beans

Districts	Groups			Mean
	Recommended Farmer Group	Non-Recommended Farmer Group	Purchasing Clerks	
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				

208

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

Districts	Groups			Mean
	Recommended Farmer Group	Non-Recommended Farmer Group	Purchasing Clerks	
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				

210

211 From the results, Sankore district recorded the highest percentage mean mouldy beans
 212 (1.89%) while the lowest percentage mouldy beans were recorded at Offinso (1.09%). This
 213 could be due to inadequate drying of cocoa beans, storage of cocoa beans under highly humid
 214 or poorly ventilated conditions, wetness of cocoa beans in rain through transit, prolonged
 215 fermentation, stacking of cocoa on the bare floor and against the wall, harvesting of over-ripe
 216 pods and leaving them on the ground for several days. The reasons above were confirmed by
 217 Wood and Lass (1985) who submitted that, factors such as slow or inadequate drying of
 218 cocoa beans, long period of fermentation as well as storage of dried cocoa beans under
 219 extremely moist environment could result in mouldy cocoa beans. Damaged and germinated
 220 beans are also prone to becoming mouldy as added by the authors. When one consumes any
 221 cocoa product with mould particularly Ochratoxin 'A' which is a form of mycotoxin, it
 222 causes cancer. They also bring about high levels of free fatty acids which gives the cocoa
 223 bean an appalling flavour (Afoakwa *et al.*, 2010). Nevertheless, the percentage mouldy beans
 224 recorded in the four districts were within the acceptable level of not more than 4% to be well
 225 thought-out as good quality cocoa beans.

226 the cut test analysis which is a true reflection from the various districts under study.
 227 Furthermore, Mouldy beans emit off-flavours and impart a musty flavour to the chocolate,
 228

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229 certain mould species produce mycotoxins (a substance poisonous to both humans and
230 animals) (Danquah, 1991).

Comment [F64]: Too old citations. Review current literature. Review literature of latest 2015.

231 The cut test outcome indicated that Tapa district registered the highest (3.38%) mean slaty
232 beans whereas the lowest value was recorded at Offinso district (1.72%). Offinso recorded
233 the highest percentage of 84% from the survey of farmers who practiced turning. Yet, the
234 Tapa value was within the permissible level of not more than 8% to be of good quality cocoa
235 beans. Dand (1999) reported that slaty cocoa beans provide chocolate a bitter taste and also
236 decrease the market price of cocoa.

237 Daviron (1995) highlighted that factors that contribute to slaty cocoa beans included;
238 inadequate fermentation heap mass and also when the temperature outside the fermentation
239 heap is too low particularly during dry season's period. These were clearly shown in the
240 percentages by respondents in the survey at the various districts. Effect of slaty beans
241 includes; Destroying the flavour of manufactured chocolate, slaty beans are bitter and
242 astringent therefore it is not economical to the manufacturer as it takes more sugar for the
243 preparation of chocolate and slaty beans are cheesy and stick to the machine during the
244 process of grinding or milling (Fowler, 1995).

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

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

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

259
260 From the survey recommended farmer group practiced fertilisation very well, pruning,
261 disease and pest control, engaged timely and good harvesting, good fermentation, proper
262 drying and excellent storage by purchasing clerks compared to non-recommended farmer
263 group who undertook only bad pruning, bad fertilization, proper disease and pest control,
264 good harvesting, failure or inadequate fermentation days, good drying and inappropriate
265 storage. Recommended farmer group may be regarded as good practice farmers because their
266 respective values met the accepted levels of defects for cocoa to be regarded as grade one
267 while non-recommended farmer group may be regarded as bad practice farmers since they
268 fall within the levels to be regarded as grade two which does not meet the ultimate criteria
269 internationally. However, the result from recommended farmer group was the best and was
270 similar to results from purchasing clerks.
271

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

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

Districts	Groups		Purchasing Clerks	Mean
	Recommended Farmer Group	Non-Recommended Farmer Group		
Goaso	112.33cde	115.33bede	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				

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The effects of districts and groups on bean count of cocoa beans are presented in the above table . From the results, significant differences ($p \leq 0.05$) were observed among the groups. Beans from non-recommended farmer group (116.17) had significantly the highest bean count while beans 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 ($p \leq 0.05$). 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 ($p \leq 0.05$) 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

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

Comment [F76]: Format as shown above.

Districts	Groups		Purchasing Clerks	Mean
	Recommended Farmer Group	Non-Recommended Farmer Group		
Goaso	9.03c	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				

290

291 The effects of districts and groups on uniformity of cocoa beans are presented in the above
 292 Table. From the results, significant differences ($p \leq 0.05$) were observed among the groups.
 293 Beans from non-recommended farmer group (10.08%) had significantly the highest
 294 percentage of Uniformity Index while beans from recommended farmer group had the least
 295 (8.77%) but was not similar to beans from purchasing clerks (9.92%).
 296 For the districts, there were significant differences ($p \leq 0.05$). The highest uniformity index
 297 (10.17%) was recorded at Sankore while the lowest uniformity index (8.89%) was recorded
 298 at Offinso but was not similar to beans from Tapa.

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

303

304 3.3 Chemical bean quality characteristics

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

Comment [F77]: bold

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
Tapa	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 Groups * Districts = 2.90				

306

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

Comment [F78]: bold

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
Tapa	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				

308

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

Comment [F79]: Format as above.

Districts	Groups			Mean
	Recommended Farmer Group	Non-Recommended Farmer Group	Purchasing Clerks	
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				

310

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

Comment [F80]: Format as above

Districts	Groups			Mean
	Recommended Farmer Group	Non-Recommended Farmer Group	Purchasing Clerks	
Goaso	6.33d	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				

312

Wood and Lass (1985) 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 fertilization, bad fermentation, harvesting immature and unripe pods, decayed and black beans, the use of mouldy beans, germinated beans from over-ripened pods (Amanor, 2005).

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

331 recorded for Offinso was within the European union requirement of (1.75%) to be of good
332 quality cocoa beans (Fowler, 2009) while the results from Sankore was above the accepted
333 level of good quality cocoa.

334 For pH, Offinso district recorded the highest mean value (6.77) whilst Tepa district recorded
335 the least (4.76). The highest value recorded by Offinso district could be due to the fact that
336 majority of respondents undertook turning during fermentation as realized in the survey
337 compared to their counterparts from the other three districts, which was a little below Offinso
338 district. A good cocoa bean should have pH between 5.5 and 8.5 according to Thery, 1995.

339 Daviron (1995) also reported that lack of fermentation, inadequate fermentation days and
340 lack of turning during fermentation all lead to decreased level of pH, which would eventually
341 give the product a bitter taste.

342 According to quality control company quality measure, any parcel of cocoa with moisture
343 content above 7.5% is not up to standard. During successive storage and transport, moisture
344 contents beyond 8% could lead to mould growth inside the beans (Zijderveld, 1994).
345 Additionally, cocoa beans with high moisture content could cause beans to germinate under
346 favourable conditions; cause beans to rot and also could result to insect invasion. Fowler
347 (2009) submitted that these factors lead to high level of free fatty acid, which would
348 consistently affect the quality of cocoa beans. From the results, Sankore district recorded the
349 highest (7.37%) moisture content whilst Offinso district registered the least (6.52%). Hence
350 forth, the figures recorded were within the worldwide standard of 8% to be of good quality
351 (Folayan, 1993).

352 For the groups, non-recommended farmer group recorded the highest moisture percentage of
353 8.09%, Free fatty acids of 1.89%, pH of 4.23 and fat content of 34.90. These group may be
354 regarded as bad practice farmers because the values recorded does not meet the
355 recommended standards.

356 Recommended farmer group recorded moisture content of 6.60%, free fatty acids of 1.24 and
357 fat content of 36.45. Recommended farmer group may be regarded as good practice farmers
358 because the values fall within the accepted standard for good quality cocoa. From the
359 questionnaire recommended farmer group practiced fertilisation very well, pruning,
360 controlled disease and pest, engaged timely and good harvesting, good fermentation, proper
361 drying and excellent storage by purchasing clerks compared to non-recommended farmer
362 group who undertook only bad pruning, bad fertilization, proper disease and pest control,
363 harvesting, failure or inadequate fermentation days, good drying and inappropriate storage.
364

365 3.3 Microbial bean quality characteristics

366 3.3.1 Effect of districts and groups on mould count of cocoa beans

367 The effects of districts and groups on mould count of cocoa beans are presented in Table
368 below. From the results, significant differences ($p \leq 0.01$) were observed among the groups.
369 Beans from non-recommended farmer group (4.54×10^4) had significantly the highest
370 percentage mould count while beans from recommended farmer group had the least
371 (1.43×10^4) but was similar to beans from purchasing clerks (1.43×10^4).

For the districts, there were significant differences ($p \leq 0.01$). 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 ($p \leq 0.01$) 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.

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

Comment [F81]: Format as above

Districts	Groups			Mean
	Recommended Farmer Group (10^4)	Non-Recommended Farmer Group (10^4)	Purchasing Clerks (10^4)	
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	
C.V(%) 22.66				
L.S.D (1%) Groups = 6.3×10^4 L.S.D (1%) Districts = 7.4×10^4 L.S.D (1%) Groups* Districts = 1.2×10^4				

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

Comment [F82]: Format as above

Districts	Groups			Mean (10^5)
	Recommended Farmer Group	Non-Recommended Farmer Group (10^5)	Purchasing Clerks (10^5)	
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	0.00 b	0.00b	0.00b
Mean	0.00b	5.65a	0.57b	
C.V(%) 50.52				
L.S.D (1%) Groups = 3.92×10^5 L.S.D (1%) Districts = 4.61×10^5 L.S.D (1%) Groups* Districts = 7.93×10^5				

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 (Amoa- Awua *et al.*, 2007; Takrama, 2007).

395 Faecal coliforms are group of the total coliform that are regarded to be present especially in
396 the gut (lower intestine) and faeces of warm blooded animals. It can also be caused by dirty
397 water used in liquid fertilisation and spraying. Faeces from hand after toilet (during drying)
398 as well as animal's droppings and faeces from kids (Doyle and Ericksen, 2006).

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

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

407 For the farmer groups and purchasing clerks. Non-recommended farmer group recorded the
408 highest values in terms of faecal coliform and mould count as compared to recommended
409 farmer group which recorded the lowest results and similar to the purchasing clerks. This is in
410 line with the survey because the recommended farmer groups followed good practices
411 compared to non-recommended farmer group who ignored some of the good practices.
412

413 6.0 Conclusion and Recommendations

414

415 6.1 Conclusion

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

419 Practices such as pod breaking, fermentation as well as drying had an effect on the physical
420 beans quality such as mouldy and slaty cocoa beans. For percentage mouldy cocoa beans,
421 Sankore district recorded the highest mean value of 2.10 % whilst Offinso district registered
422 the least (1.30%) which falls within the standards for grade one cocoa, of less than or equal to
423 3%. Tepa district recorded the greatest percentage of slaty cocoa beans (3.31%) with Offinso
424 district registering the least (1.52%) to be also be considered as grade one cocoa bean.

425 Microbial quality was also affected by mould count and faecal coliform. However the highest
426 mould count and faecal coliform was recorded at Offinso district while the least was recorded
427 at sankore hence influencing the grading percentage of cocoa beans.

428 It is therefore concluded that the combined effect of two districts in Forest Savannah zone of
429 Ashanti Region performed better in terms of quality than the other two districts in Deciduous
430 Forest of Brong Ahafo Region. Beans from Offinso cocoa district was of the best in terms of
431 physical, chemical and microbial quality attributes as well as beans from recommended
432 farmer group.

433

434 6.2 Recommendations

435 The following recommendations have been made for further studies:

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

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

441

REFERENCES

- Afoakwa, E.O., Paterson, A. (2010). *Cocoa Fermentation: Chocolate Flavour Quality. Encyclopedia Of Biotechnology In Agriculture And Food*. Taylor And Francis Publishing Inc., Oxford, U.K, Pp 457–46
- Amo, A.I. (2012). *Multiple Comparison and Random Effect Model on Cocoa Production in Ghana (From 1969/70 To 2010/11 Production Years)*. Pp 34-45
- Amoah-Awuah, W.M., Madsen, J.F., Takrama, A., Olaiya, L., Ban-Koffi, F. and Jakobsen, M., (2007). *Quality Manual For Production and Processing Cocoa*. Department Of Food Science. University Of Copenhagen. Pp10-17
- Amanor, K. (2005). "Agricultural Markets in West Africa: Frontiers, Agribusiness and Social Differentiation." *IDS Bulletin. Journal of Agric and Technology*. 36 (2).35-38
- Awuah, P.K. (2002). *The Success Story Of Cocoa Processing And Chocolate Manufacturing In Ghana. The Success Story That Demolished A Myth*. 1-4, 33-50.
- Dand, R. (1999). *The International Cocoa Trade* (2ed.). Wood Head Publishing. ISBN 1-85573-434-6. p15
- Danquah, F. K. (1991). *The Capsid, Black Pod And Swollen Shoot Cacao Diseases In Ghana , 1910-1966*. Pp 56-75
- Daviron, B. (1995). *Economic Aspects Of Quality, Cocoa Meetings: The Various Aspect Of Quality, Seminar Proceedings, Montpellier*, Pp.125-13
- Doyle, M. P. and Erickson M. C. (2006). "Closing the door on the faecal coliform assay." *Microbe* 1:162-163. ISSN 1558-7460
- Folayan, J.A. (1993). *Effect Of Quality On Marketing And Acceptability Of Cocoa On International Market Paper Presented At The Nigerian Institute Of Food And Technology, Ondo State Polytechnic, Owo, Ondo State, Nigeria*. Pp13-20
- Fowler, M.S. (2009). *Cocoa Beans From Tree To Factory*. In: Beckett ST (Ed) *Industrial Chocolate Manufacture And Use*, 4th Edn. Wiley- Blackwell Science, Oxford, UK. Pp 137–152
- Gockowski, J. and Oduwale, S. (2003). *Labour practices in the cocoa sector of southwest Nigeria with a focus on the role of children*. *International Institute of Tropical Agriculture*. Pp. 11–15. ISBN 978-131-215-7
- Hui, Yiu .H. (2006). *Handbook of food science, technology, and engineering*. 4. CRC Press. ISBN 0-8493-9849-5
- Olivia. A. and James .G. (2003). *Labour practices in the cocoa sector of Ghana with a special focus on the role of children*. *International Institute of Tropical Agriculture (IITA)*. p14

- 477 Thery, V. (1995). *Quality for Cocoa Powder Producers, Cocoa Meetings: The various Aspect*
478 *Of Quality. Seminar Proceedings, Montpellier.* Pp155-157.
- 479 Wood, G. A. R.; Lass, R. A. (2001). *Cocoa Tropical Agriculture Series (4 Ed.). John Wiley*
480 *And Sons.* ISBN 0-632-06398-X.
- 481 Wood, G.A.R. and Lass, R.A. (1985). *Cocoa 4th Edition. Tropical Agricultural Series,*
482 *Longman Group, London.*p35
- 483 Zijderveld, J.A. (1994). *Raw cocoa: quality characteristics, Second International Congress*
484 *on Cocoa and Chocolate,* p9.