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# **Physical Quality Responses of Cocoa Beans to Inclusion and Exclusion of Placenta and Varied Fermentation Periods**

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## **ABSTRACT**

Ghana's premium quality cocoa could be sustained by purging off foreign matter introduced somewhat by placenta mixed with extracted cocoa beans. This study thus examined the effect of placenta and varied fermentation periods on physical quality characteristics of cocoa beans. A field and laboratory studies were done at the Department of Horticulture and Pharmacy, KNUST Kumasi. Experimental design for laboratory work was 2×5 factorial of placenta inclusion or exclusion and varied fermentation days in CRD and replicated three times. Cut test revealed that cocoa beans without placenta were totally clean. Also, the longer the fermentation days with placenta the more chaff content. Longer drying time resulted in the formation of more purple beans while those beans fermented for over six days produced the highest germinated beans. It was concluded that for premium quality cocoa beans, fermentation should be done for, at least, six days without placenta since that improved the physical attributes of the cocoa beans.

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*Keywords:* slaty, purple, anthocyanin, defects, flavouring and tannins

## **1. INTRODUCTION**

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As the world's second largest producer and major contributor to the growth of the country, cocoa is highly valued by Ghana. Currently, Ghana exports about 80% of its raw cocoa beans [1]. According to the Global Trade Atlas, as of March 2009, the Netherlands imported cocoa beans to the tune of USD 352,505,018. The United States imported USD 40,785,667, worth of cocoa powder and France imported USD 288,328,480 worth of retail chocolate. These three countries are the highest Importers in the respective categories of cocoa product [2]. Cocoa pulp is reported to be rich in fermentable sugars, such as glucose, fructose and sucrose, and has a low pH of 3.0–3.5, mainly because of the presence of citric acid [3] making it a rich medium for microbial growth<sup>4</sup>. Proteins, free amino acids, vitamins, and minerals are also present in the pulp. Work done by [4] showed that the ratio of sucrose, glucose, and fructose present in the pulp varies with the age of the pod. The pulp is also reported to contain high amount of pectin and other polysaccharides which make the pulp viscous, limiting diffusion of air through the beans during fermentation [5]. Cocoa beans are mostly processed into chocolate and cocoa products using a wide range of intermediate products such as cocoa liquor, cocoa butter, cocoa cake and raw cocoa powder. Cocoa powder is essentially used in flavouring biscuits, ice cream and other dairy products, drinks and cakes and in the manufacture of coatings for confections and frozen desserts [6-8]. Currently, the pod husks and shells are used for the preparation of animal feed and fertilizer in Ghana [9].

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Ghana's premium cocoa is facing a quality decline due to issues like suspected adulteration, mouldy beans, and presence of inert matter which may possibly be due to presence of placenta mixed with extracted cocoa beans during the process of fermentation and drying). Folayan [10] explained that, the root cause of quality anomalies in cocoa could be traced to poor postharvest handling techniques which included addition of placenta during the bean extraction from the pod stage, bad fermentation including overly fermenting the beans coupled with inadequate drying. Many research works have mentioned the benefits of certain postharvest activities on the quality of cocoa beans. For instance, [11] indicated that the

35 fermentation process breaks down the mucilaginous pulp surrounding the beans and causes cotyledon death leading  
36 quality beans. [12] also opined that fermentation triggers biochemical transformation inside the beans, leading to reduction  
37 in bitterness and astringency, development of flavour precursors such as, free amino acids, peptides and sugars.  
38 Furthermore, [13] reported that pod storage and fermentation influenced to varied levels the chemical composition and  
39 physical characteristics of Ghanaian cocoa beans. However, little is known about the effect of placenta inclusion or  
40 exclusion on the physical characteristics of cocoa beans. The objective of this study was to determine the effect of  
41 placenta (with or without) and fermentation duration on physical quality of dried cocoa beans.

## 42 43 **2. MATERIAL AND METHODS** 44

### 45 **EXPERIMENTAL SITE**

46 The study was conducted in the Bekwai Municipality of Ashanti Region. Bekwai municipal is one of the 30 administrative  
47 districts in the Ashanti Region. The municipal shares boundaries with Amansie West District to the west, Bosomtwe  
48 District to the north, Adansi south and North Districts to the south and the Asante Akim south District to the east. With a  
49 population of 208,987, and an intercensal growth rate of 3.2 percent males in the municipal constitute 52 % while females  
50 constituting 48%. The rural population of the municipal is 8.4% while the urban population is 11.6%. Farming is the  
51 dominant occupation of the people in the municipal with cocoa farming being the main crop produced.

### 52 **EXPERIMENTAL DESIGN**

53 A 2X5 factorial Completely Randomized Design with two experimental factors (Extracted cocoa beans with and without  
54 placenta) and five different fermentations periods (4 days, 5 days, 6 days, 7 days and 8 days) which were replicated three  
55 times was used for the field experiment.

### 56 57 **SAMPLE COLLECTION PROCEDURE**

#### 58 **Harvesting, Sorting and Pod Storage**

59 Six hundred (600) cocoa pods of mixed hybrid variety which is translated to be equivalent to one bag of cocoa beans (62.5  
60 kg) were harvested from a selected cocoa farm over a period of five days with 120 pods per day for the experiment at  
61 Ashanti Bekwai. The riped pods on the cocoa tree stem were harvested using a well sharpened machete while fruits high  
62 up the tree were harvested using pruning hook or go to hell [14]. Debris, diseased infested and blemished pods were  
63 sorted out from the harvested stock in order to prevent them from being added to the experimental samples. Each daily  
64 harvested batch of pods (120 pods) were stored or rested for three days period as recommended by [14] before pod  
65 breaking process commenced.

#### 66 **Pod Breaking and Bean Extraction**

67 The one hundred and twenty harvested cocoa pods for the first batch treatment were divided into two equal groups, sixty  
68 (60) pods each and were opened for the beans to be extracted. Breaking of the pods were done using a blunt cutlass to  
69 expose the beans. This facilitated ease of bean-scooping from the pods. The mucilaginous beans from first 60 pods were  
70 extracted with placenta and replicated into three groups and the other remaining 60 pods were extracted without placenta  
71 and also replicated into three and were put on a plantain leaves for the fermentation process. This procedure was  
72 repeated for the subsequent harvested batches.

#### 73 **Fermentation Method and Procedure**

74 The traditional heap fermentation method was used with varied fermentation periods (4 days, 5 days, 6 days, 7 days and  
75 8 days). In this method, cocoa beans were heaped on a bed of banana leaves with or without placenta. This was  
76 replicated into three groups and located at three different locations in the cocoa farm for the fermentation process. The  
77 heap fermentation method was used because it is cheap, produces well fermented cocoa beans and is good for small  
78 production volumes. This was followed up by the turning of the cocoa beans every two days to ensure even fermentation  
79 within every two days [14], until the end of the four to eight days.

## 81 **Drying of Fermented Beans**

82 Drying was done on a raffia mat at a cocoa depot in Bekwai. The drying raffia mat was raised one meter above ground  
83 and supported below with sawn bamboo sticks which facilitated movement of air around the platforms. Drying started from  
84 8:00am to 5:00 pm each day. Beans were periodically stirred every three hours to ensure uniform drying. Drying  
85 continued until 7.5 to 6% moisture content was achieved. Polyethylene sheet was used to cover the beans on occasion of  
86 raining and sunset.

## 87 **PHYSICAL PARAMETERS MEASURED**

### 88 **Bean Count of the Dried Cocoa Samples**

89 The bean count per 100g [16] was taken in triplicate and measured on an electronic scale. The amount attained after the  
90 count aided to determine the category of the beans being counted.

### 91 **Chaff (%) in the Dried Cocoa Bean Sample**

92 The chaff content (bean equivalent i.e. 1g chaff  $\equiv$  1 whole bean) among the treated samples were picked and expressed  
93 as percentage to the total bean count and its equivalent whole bean was determined using 1g whole bean equivalent.

94  $\% \text{ Chaff content in beans (C)} = (\text{Total chaff by weight}) / (100\text{g of beans weighed}) \times 100$

### 95 **Average Slaty Beans (%) of the Dried Cocoa Samples**

96 Slaty bean, as a defect, were observed from 100 beans cut for each treatment and expressed as a percentage using the  
97 formula below [17].

98  $\% \text{ Slaty beans (S)} = (\text{Number of slaty beans}) / (\text{Total number of beans cut}) \times 100$

### 99 **Purple Beans Count (%) of the Dried Cocoa Bean Samples**

100 Purple as a defect, was determined from 100 beans cut from each tray and the number of beans found to exhibit the  
101 features of purpleness counted. This was expressed as a percentage using the formula below [16]

102  $\% \text{ Purple beans (P)} = (\text{Number of purple beans}) / (\text{Total number of beans cut}) \times 100$

### 103 **Average Germinated Beans (%) of the Dried Cocoa Samples**

104 Germinated beans as a defect were observed from 100 beans cut from each treatment and the number of beans found to  
105 exhibit the features of germination were counted. This was expressed as a percentage for each treatment by the formula  
106 below [16]:

107  $\% \text{ Germinated beans (G)} = (\text{Number of Germinated beans}) / (\text{Total number of beans cut}) \times 100$

### 108 **Other Defects (%) of the Dried Cocoa Samples**

109 Other defective beans such as weevily, flat, foreign matter among others were observed from 100 beans cut from each  
110 treatment and the number of beans found to exhibit the features of other defects were counted. This were expressed as a  
111 percentage for each treatment by the formula below [18]:

112  $\% \text{ Other defective beans (OD)} = (\text{Number of defective beans}) / (\text{Total number of beans cut}) \times 100$

### 113 **All Other Defects (%) of the Dried Cocoa Samples**

114 All other defects were observed from 100 beans cut from each treatment and the number of beans found to exhibit the  
115 features of all other defects were counted. This were expressed as a percentage for each treatment by the formula below  
116 [18]:

117  $\% \text{ All other Defects (AOD)} = (\text{Number of All other defects}) / (\text{Total number of bean cut}) \times 100$

118 Purity (%) of the Dried Cocoa Samples

119 Purity as a measure of the overall effect of the observed defects on the quality of cocoa, was expressed as a percentage  
120 by the formula [18].

121 % Purity= 100 – [M + S + AOD+PP]

122 Where M = mouldy beans, S=slaty beans, AOD = all other defects and

123 PP = purple beans

## 124 RESULTS

125 Total bean count of dried cocoa beans were significantly ( $p \leq 0.05$ ) affected by fermentation days and placenta interaction  
126 (Table 1). Highest Total bean count (254.00 beans) was produced by cocoa beans with placenta fermented for eight days.  
127 The least (225.00 beans) Total bean count was recorded by beans without placenta fermented for eight which was similar  
128 to those fermented for four days without placenta (216.67 beans). Across the fermentation days, there were no significant  
129 differences ( $p \leq 0.05$ ) in the Total bean count. Across the Placenta, there were no significant differences ( $p \leq 0.05$ ) in the  
130 Total bean count.

131 Table 1: Total bean count of cocoa fermented for various days with or without placenta.

| Fermentation Days                                                                    | Placenta             |                      | Means <sup>132</sup> |
|--------------------------------------------------------------------------------------|----------------------|----------------------|----------------------|
|                                                                                      | With Placenta        | Without Placenta     |                      |
| 4                                                                                    | 231.67 <sup>ab</sup> | 216.67 <sup>b</sup>  | 224.17 <sup>a</sup>  |
| 5                                                                                    | 228.00 <sup>ab</sup> | 236.00 <sup>ab</sup> | 232.00 <sup>a</sup>  |
| 6                                                                                    | 229.67 <sup>ab</sup> | 240.33 <sup>ab</sup> | 235.00 <sup>a</sup>  |
| 7                                                                                    | 227.00 <sup>ab</sup> | 235.33 <sup>ab</sup> | 231.17 <sup>a</sup>  |
| 8                                                                                    | 254.00 <sup>a</sup>  | 225.00 <sup>b</sup>  | 239.50 <sup>a</sup>  |
| <b>Means</b>                                                                         | 234.07 <sup>a</sup>  | 230.67 <sup>a</sup>  |                      |
| CV=4.08                                                                              |                      |                      |                      |
| HSD (0.01) Fermentation days=16.55, Placenta=7.23 Fermentation days X placenta=27.74 |                      |                      |                      |

143 \*Means followed by the same alphabets are not significantly different ( $p \leq 0.05$ ) from each other.

## 144 Average Bean Count on Cocoa Beans Fermented for Various Days With or Without Placenta.

145 Average bean count of dried cocoa beans were significantly ( $p \leq 0.05$ ) affected by fermentation days and placenta  
146 interaction (Table 2). Highest average bean count (84.67 beans) was produced by cocoa beans with placenta fermented  
147 for eight days and the least (72.33 beans) average bean count was recorded by beans without placenta and fermented for  
148 four which was similar to those without placenta fermented for eight days (75.00 beans). Across the fermentation days,  
149 there were no significant differences for average bean count. Across the Placenta, there were no significant differences  
150 for average bean count.

151 Table 2. Average bean count (%) of cocoa fermented for various days with or without placenta.

| Fermentation Days | Placenta             |                     | Means              |
|-------------------|----------------------|---------------------|--------------------|
|                   | With Placenta        | Without Placenta    |                    |
| 4                 | 77.33 <sup>ab*</sup> | 72.33 <sup>b</sup>  | 74.83 <sup>a</sup> |
| 5                 | 76.00 <sup>ab</sup>  | 79.00 <sup>ab</sup> | 77.50 <sup>a</sup> |
| 6                 | 76.33 <sup>ab</sup>  | 80.33 <sup>ab</sup> | 78.33 <sup>a</sup> |
| 7                 | 75.67 <sup>ab</sup>  | 78.33 <sup>ab</sup> | 77.00 <sup>a</sup> |
| 8                 | 84.67 <sup>a</sup>   | 75.00 <sup>b</sup>  | 79.83 <sup>a</sup> |
| <b>Means</b>      | 78.00 <sup>a</sup>   | 77.00 <sup>a</sup>  |                    |

CV= 4.14

HSD (0.01) Fermentation days=5.60, Placenta=2.46 Fermentation days X placenta=9.39

\* Means followed by the same alphabets are not significantly different ( $p \leq 0.05$ ) from each other.

### Percentage Chaff of Cocoa Beans Fermented on Various Days With or Without Placenta.

Percentage chaff content in the dried cocoa beans was significantly ( $p \leq 0.05$ ) affected by fermentation days and placenta interaction (Table 3). Highest percentage chaff (18.50%) was produced by cocoa beans with placenta fermented for eight days. The least (0.00) percentage chaff was recorded by beans without placenta fermented for four, five, six, seven and eight days. Across the fermentation days, highest percentage chaff (9.25%) was recorded by beans fermented for eight days and the least (3.82%) was those fermented for four days. Across the Placenta, highest percentage chaff was recorded by beans with placenta (13.69%) and the least (0.00%) was those without placenta.

Table 3: Percentage chaff of cocoa beans fermented on various days with or without placenta.

| Fermentation Days | Placenta            |                     | Mean               |
|-------------------|---------------------|---------------------|--------------------|
|                   | With                | Without             |                    |
| 4                 | 7.63 <sup>d*</sup>  | 0.00 <sup>e</sup>   | 3.82 <sup>d</sup>  |
| 5                 | 11.53 <sup>c</sup>  | 0.00 <sup>e</sup>   | 5.77 <sup>c</sup>  |
| 6                 | 14.63 <sup>b</sup>  | 0.00 <sup>e</sup>   | 7.32 <sup>c</sup>  |
| 7                 | 16.17 <sup>ab</sup> | 0.00 <sup>e</sup>   | 8.08 <sup>ab</sup> |
| 8                 | 18.50 <sup>a</sup>  | 0.00 <sup>e</sup>   | 9.25 <sup>a</sup>  |
| <b>Means</b>      | 13.69 <sup>a</sup>  | 0.0000 <sup>b</sup> |                    |

CV (%) = 14.43

HSD (0.05) Fermentation days=1.70, Placenta=0.75, Fermentation days X placenta=2.85

\* Means followed by the same alphabets are not significantly different ( $p \leq 0.05$ ) from each other.

### Percentage Bean Equivalent of the Chaff of the Cocoa Fermented on Various Days With or Without Placenta.

163 Equivalent cocoa beans were significantly ( $p \leq 0.05$ ) affected by fermentation days and placenta interaction (Table 4).  
 164 Highest bean equivalent (15.33) was produced by cocoa beans with placenta fermented for eight days. The least (0.00)  
 165 bean equivalent was recorded by beans without placenta fermented for four, five, six, seven and eight days. Across the  
 166 fermentation days, highest bean equivalent was recorded by beans fermented for eight days and the least was those  
 167 fermented for four and five days. Across the Placenta, highest bean equivalent was recorded by beans with placenta and  
 168 the least was those without placenta.

169 Table 4: Percentage bean equivalent of the chaff of the cocoa fermented on various days with or without placenta.

| Fermentation Days | Placenta            |                   | Mean               |
|-------------------|---------------------|-------------------|--------------------|
|                   | With                | Without           |                    |
| 4                 | 7.00 <sup>c</sup>   | 0.00 <sup>d</sup> | 3.50 <sup>c</sup>  |
| 5                 | 11.00 <sup>b</sup>  | 0.00 <sup>d</sup> | 5.50 <sup>b</sup>  |
| 6                 | 11.67 <sup>b</sup>  | 0.00 <sup>d</sup> | 5.83 <sup>b</sup>  |
| 7                 | 13.00 <sup>ab</sup> | 0.00 <sup>d</sup> | 6.50 <sup>ab</sup> |
| 8                 | 15.33 <sup>a</sup>  | 0.00 <sup>d</sup> | 7.67 <sup>a</sup>  |
| <b>Means</b>      | 11.60 <sup>a</sup>  | 0.00 <sup>b</sup> |                    |

CV (%) = 16.05

HSD (0.05) Fermentation days=1.61, Placenta=0.71, Fermentation days X placenta=2.69

170 \* Means followed by the same alphabets are not significantly different ( $p \leq 0.05$ ) from each other.

171 **Slaty Beans (%) of Cocoa Fermented for Various Days With or Without Placenta.**

172 Slatiness of dried cocoa beans was significantly ( $p \leq 0.05$ ) affected by fermentation days and placenta interaction (Table 5).  
 173 The highest slatiness (2.53%) was produced by cocoa beans with placenta fermented for five days which was similar to  
 174 beans fermented for five days without placenta (2.47%). The least slatiness (0.10%) was recorded by beans without  
 175 placenta and fermented for eight days. Across the fermentation days, highest slatiness (2.50%) was produced by cocoa  
 176 beans fermented for five days and the least (0.77%) was recorded by beans fermented for eight days which was similar to  
 177 that of six days (1.10%). Across the Placenta, there were no significant differences ( $p \leq 0.05$ ) in the slatiness of the beans.

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183 Table 5: Slatiness (%) of cocoa beans fermented on various days with or without placenta.

| Fermentation Days | Placenta           |                    | Means              |
|-------------------|--------------------|--------------------|--------------------|
|                   | With Placenta      | Without Placenta   |                    |
| 4                 | 1.47 <sup>ab</sup> | 1.10 <sup>ab</sup> | 1.28 <sup>ab</sup> |

|              |                    |                    |                    |
|--------------|--------------------|--------------------|--------------------|
| 5            | 2.53 <sup>a</sup>  | 2.47 <sup>a</sup>  | 2.50 <sup>a</sup>  |
| 6            | 1.10 <sup>ab</sup> | 1.10 <sup>ab</sup> | 1.10 <sup>b</sup>  |
| 7            | 1.23 <sup>ab</sup> | 1.00 <sup>ab</sup> | 1.12 <sup>ab</sup> |
| 8            | 1.43 <sup>ab</sup> | 0.10 <sup>b</sup>  | 0.77 <sup>b</sup>  |
| <b>Means</b> | 1.55 <sup>a</sup>  | 1.15 <sup>a</sup>  |                    |

CV=58.62

HSD (0.01) Fermentation days=1.39, Placenta=0.61 Fermentation days X placenta=2.32

\* Means followed by the same alphabets are not significantly different ( $p \leq 0.05$ ) from each other

### Purple Beans (%) on Cocoa Fermented for Various Days With or Without Placenta.

Purple bean count (%) was affected significantly ( $p \leq 0.05$ ) by fermentation days (Figure 1). The highest purpleness (23.12%) was recorded by beans fermented for four days and the least (7.63%) was recorded by those fermented for eight days which was similar to those fermented for six and seven days (10.17% and 9.78%).

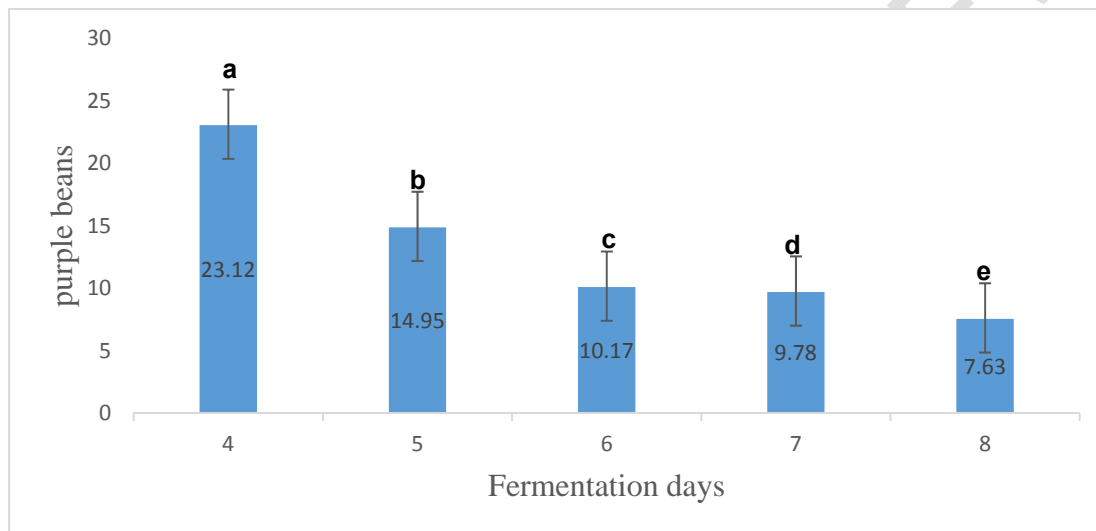


Figure 1: Purple beans (%) on cocoa fermented variedly with or without placenta

### Germinated beans (%) on cocoa fermented for various days

The average germinated beans was significantly ( $p \leq 0.05$ ) affected by fermentation days (Figure 2). Significantly ( $p \leq 0.05$ ) highest (1.33% and 1.05%) germinated beans were recorded by beans fermented for seven and eight days, while the least (0.43% and 0.38%) were recorded by beans fermented for four and five days.

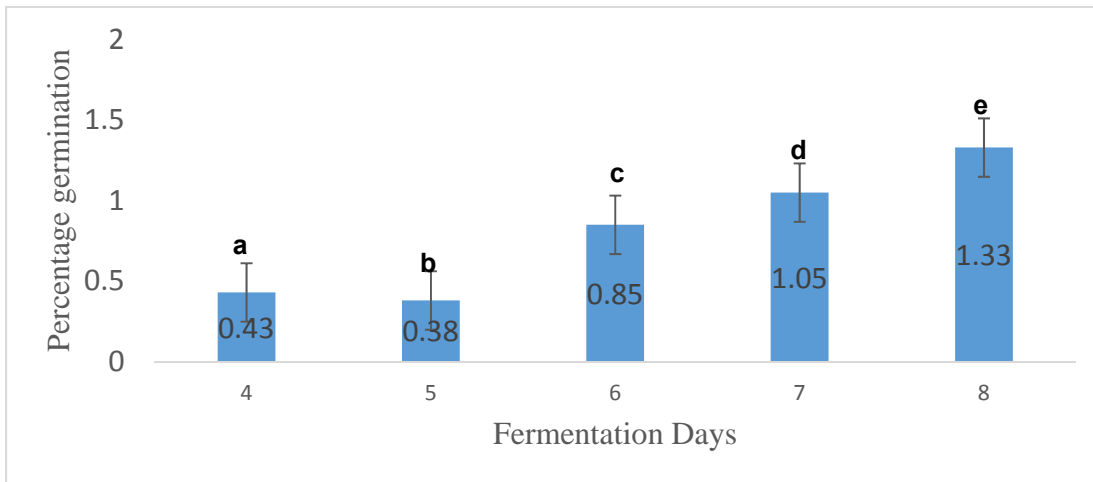


Figure 2: Germinated beans (%) on cocoa fermented for various days

### Germination of beans (%) of cocoa with or without placenta.

Average germinated beans was significantly ( $p \leq 0.05$ ) affected by placenta (Figure 3). Significantly ( $p \leq 0.05$ ) highest (1.05%) germinated beans were recorded by beans with placenta while the least (0.57%) was recorded by beans fermented without placenta.

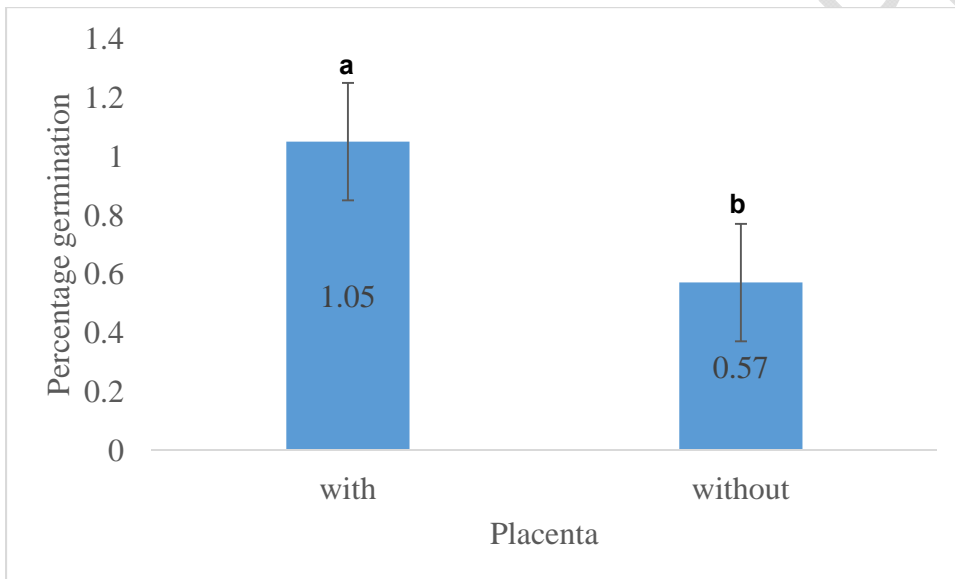


Figure 3: Germinated beans (%) cocoa with or without placenta.

### All Other Defects (%) of Cocoa Beans Fermented for Various Days With or Without Placenta.

All other defects of dried cocoa beans were significantly ( $p \leq 0.05$ ) affected by fermentation days and placenta interaction (Table 6). Significantly ( $p \leq 0.05$ ) highest all other defects (8.67%) were produced by cocoa beans with placenta fermented for eight days. The least (0.90%, 0.67%, 0.77%, 2.27% and 0.90%) all other defects were recorded by beans without placenta fermented for four, five, six, seven and eight days which were similar to beans with placenta but fermented for five and six days (2.20% and 2.47%). Across the fermentation days, significantly ( $p \leq 0.05$ ) highest all other defects were produced by cocoa beans fermented for eight days (4.78%) and the least was recorded by beans fermented for five days (1.43%). Across the Placenta, significantly ( $p \leq 0.05$ ) all other defects (4.31%) were produced by beans with placenta and the least (1.18%) was produced by those without placenta.



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214 Table 6: All other defects (%) on cocoa beans fermented for various days with or without placenta.

| Fermentation Days | Placenta           |                   | Means              |
|-------------------|--------------------|-------------------|--------------------|
|                   | With Placenta      | Without Placenta  |                    |
| 4                 | 4.10 <sup>ab</sup> | 0.90 <sup>b</sup> | 2.50 <sup>ab</sup> |
| 5                 | 2.20 <sup>b</sup>  | 0.67 <sup>b</sup> | 1.43 <sup>b</sup>  |
| 6                 | 2.47 <sup>b</sup>  | 0.77 <sup>b</sup> | 1.62 <sup>ab</sup> |
| 7                 | 4.10 <sup>ab</sup> | 2.67 <sup>b</sup> | 3.38 <sup>ab</sup> |
| 8                 | 8.67 <sup>a</sup>  | 0.90 <sup>b</sup> | 4.78 <sup>a</sup>  |
| <b>Means</b>      | 4.31 <sup>a</sup>  | 1.18 <sup>b</sup> |                    |

CV (%) = 69.57

HSD (0.01) Fermentation days=3.33, Placenta=1.46 Fermentation days X placenta=5.59

215 \* Means followed by the same alphabets are not significantly different ( $p \leq 0.05$ ) from each other.216 **Percentage Purity (%) of Cocoa Beans Fermented on Various Days With or Without Placenta.**

217 Percentage purity of dried cocoa beans was significantly ( $p \leq 0.05$ ) affected by fermentation days and placenta interaction  
 218 (Table 7). Maximum (98.53%) percentage purity was produced by cocoa beans without placenta fermented for eight days  
 219 which was similar to beans without placenta fermented four and six days (97.77% and 98.37%) respectively while the  
 220 minimum (89.90%) purity was recorded by beans with placenta fermented for eight days. Across the fermentation days,  
 221 there were no significant differences ( $p \leq 0.05$ ) in the percentage purity. Across the Placenta, the highest purity (98.21%)  
 222 was recorded by beans without placenta and the least (94.11%) was recorded by beans with placenta

223 Table 7: Percentage purity (%) of cocoa beans fermented for various days with or without placenta.

| Fermentation Days | Placenta            |                     | Means              |
|-------------------|---------------------|---------------------|--------------------|
|                   | With Placenta       | Without Placenta    |                    |
| 4                 | 94.77 <sup>ab</sup> | 97.77 <sup>a</sup>  | 96.27 <sup>a</sup> |
| 5                 | 95.47 <sup>ab</sup> | 95.23 <sup>ab</sup> | 95.35 <sup>a</sup> |
| 6                 | 96.43 <sup>ab</sup> | 98.37 <sup>a</sup>  | 97.40 <sup>a</sup> |
| 7                 | 94.00 <sup>ab</sup> | 96.13 <sup>ab</sup> | 95.07 <sup>a</sup> |
| 8                 | 89.90 <sup>b</sup>  | 98.53 <sup>a</sup>  | 94.22 <sup>a</sup> |
| <b>Means</b>      | 94.11 <sup>b</sup>  | 97.21 <sup>a</sup>  |                    |

CV=2.54

HSD (0.01) Fermentation days=4.24, Placenta=1.87 Fermentation days X placenta=7.11

224 \* Means followed by the same alphabets are not significantly different ( $p \leq 0.05$ ) from each other.

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## 226 DISCUSSION

227 Total and Average Bean Count of Dried Cocoa Beans Fermented on Varied Periods with or Without Placenta.

228 The total bean count for all the cocoa samples ranged from 224 beans to 240 beans with their corresponding average  
229 beans ranging between 75 beans and 80 beans, (Table 2) According to QCC [16] all the cocoa treated samples fall within  
230 category 'S' indicating super main crop beans. A Bean Count test tells the size of beans. There are seven categories of  
231 bean size: Super main crop, Main crop, Super light, Light crop, Small beans and remnant category. It is a part of the  
232 chocolate manufacturing requirements that cocoa beans are of reasonable same size. This will ensure even roasting of all  
233 beans and prevent small beans in being charred.

234 Chaff Content (%) And Bean Equivalent in the Dried Cocoa Samples.

235 The most useful and valuable part of the cocoa crop is the bean. Meaning that any substance other than cocoa beans for  
236 instance; cocoa related matter, flat beans, sievings, husk as well as traces of placenta are considered as foreign matter  
237 [19]. The result of the current study reveals cocoa sample fermented for eight days with placenta as having the highest  
238 percentage (18.5%) of chaff content representing 15.33 bean equivalent. This means that, the longer the fermentation  
239 days and the quicker the drying time for those cocoa bean samples with placenta the more the chaff production. This may  
240 be due to cells of placenta not degraded or high production of placenta debris or the rapid release of placenta attached to  
241 the cocoa beans during the drying process. This indicates higher levels of cocoa bean adulteration and foreign matter  
242 existence in the cocoa sample with placenta. Consequently this high foreign matter content levels may affect the premium  
243 quality of the cocoa beans leading to it being graded as a sub-standard [16]. Conferring to [20] such high levels of chaff  
244 content in a sampled cocoa sample triggers rejection and subsequent confiscation. This has been affirmed by [21] who  
245 asserted that such too high levels of foreign matters are not allowed or permitted by the international buyers. According  
246 to International Cocoa Standards requirements, cocoa of tradable quality should be well fermented, thoroughly dried, free  
247 from smoky beans, abnormal or foreign odor, foreign matter and free from any evidence of adulteration [22]. [10]  
248 explained that the root cause of quality anomalies in cocoa could be traced to poor postharvest handling techniques which  
249 included addition of placenta during the bean extraction from the pod stage, bad fermentation including overly fermenting  
250 the beans coupled with inadequate drying makes the produce vulnerable to mould and bacterial growth. Foreign matter  
251 not only affects the wholesomeness of the product but may also affect the flavour, cause damage to plant and machinery  
252 and reduce the yield of edible material [19]. The presence of foreign matter will also affect the yield of edible material and  
253 hence reduce the value of the cocoa to the chocolate manufacturer, and may also affect the flavour and be a source of  
254 contamination to the product. It also portrays a false weight to both producers and buyers.

255 Slaty Bean Content (%) of Cocoa Beans Fermented on Various Days With or Without Placenta.

256 From the current study, placenta presence or absence was not a contribution factor for slatiness but rather fermentation  
257 duration. Lower fermentation days (5 days) resulted in highest slaty bean count (2.53%), while those cocoa beans  
258 samples which were fermented for eight days had the least slaty beans count (0.10%). The presence of grey or slaty  
259 beans is an indication of poor fermentation. This result from the current study has confirmed that of [23], who stated that  
260 improper fermentation of less than six days' result in formation of slaty beans. Though slatiness in cocoa has also been  
261 found to be contributed by fermenting inadequate ripened beans from immature pods which does not allow the beans to  
262 undergo effective fermentation, [3] and [19]. [24] enumerated factors that contribute to slatiness of cocoa beans to  
263 include; inadequate fermentation, large heap mass of beans per unit area and also when the temperature outside the  
264 fermentation heap is too low particularly during dry seasons. He also included harvesting of immature cocoa pods coupled  
265 with inadequate turning of cocoa beans during fermentation as well as diseased pods as contributing factors to slatiness  
266 of fermented cocoa beans. Chocolate made from slaty beans is dark grey, extremely bitter, astringent and lacks the  
267 typical chocolate flavor [19]. To avoid slatiness, proper fermentation with adequate turning coupled with harvesting of fully  
268 ripped pods should be adhered to.

269 Purple Bean Content (%) of Dried Cocoa Beans Variedly Fermented With or Without Placenta.

270 From the current study, placenta is not a contribution factor to purpleness but rather fermentation days. The highest  
271 purple bean count was recorded by beans fermented for four days (23.12%) while the least (7.63%) was recorded by  
272 those beans fermented for eight days. From the results obtained, purple colouration decreased drastically with increasing  
273 duration of fermentation. That is, less fermentation days' result in increased anthocyanins in beans due to the fact that  
274 Glycosides in the beans have not hitherto broken down [26], though according to [27], fermentation of cocoa beans for six

275 or seven days did not guarantee the complete removal of anthocyanins and purpleness from the cocoa beans. [28]  
276 reported that, the brown pigments might also be produced from complexation of condensed tannin, a high molecular  
277 weight product of flavonoid polymerization, with protein, through hydrogen bonding.

278 The results of the current study validates the findings of [29] who indicated that, high percentage of purple beans in cocoa  
279 might be due to the short length of fermentation, while increased browning and the reduction of purple coloration in the  
280 dried beans indicate increased degree of fermentation. [29], explained that indicators of well-fermented and dried quality  
281 cocoa beans are a good brown colour, low astringency and bitterness, and an absence of off-flavours such as smoky  
282 beans and excessive acidity. [29], explained that the observance of the traditional fermentation period of at least six days  
283 ensured much decrease of the anthocyanins or polyphenols (purple) compound content in the cocoa beans to as low as  
284 between nine to fifteen per cent but the three to four-day fermentation could keep the compound to as high as between  
285 forty to eighty percent in the bean. This was later on confirmed by [30].

286 According to [31], oxidation of polyphenol during the aerobic phase of cocoa fermentation is largely responsible for the  
287 characteristic brown colour of fermented cocoa beans. [32] asserted that, the percentage purple beans decrease with  
288 aeration. This is so because purple colouration and loss of the characteristic chocolate brown colour is a function of  
289 fermentation. Purple bean occurrence has been of a major worry to the Ghana COCOBOD over the past few years as it  
290 poses a great threat to the nations well known premium cocoa beans at the international level [30].

291 Percentage Germination Content (%) of Cocoa Beans Fermented on Various Days With or Without Placenta.

292 Cocoa beans are known to be recalcitrant inherently [33]. This suggests that cocoa beans are short-lived, unable to  
293 survive desiccation when extracted from the pods, germinate in a few days after harvesting and cannot withstand drying  
294 [3]. Germination of beans normally occurs before or during fermentation when optimum conditions are created [35]. From  
295 figure 2, result shows higher germinated percentage for 8 days fermentation. Again beans extracted with placenta had  
296 highest germination (Figure 3). These results from the current study reveal that fermenting cocoa beans for more than  
297 seven days with placenta enhances germination probably due to the presence of placenta serving as a conducive medium  
298 for the bean to germinate. This is because, [36], suggested that seed germination is induced by both the environmental  
299 and inherent seed behaviors. He added that when over riped pods are harvested, the beans may have already  
300 germinated or do so during the beginning of fermentation thereby reducing the weight as well as the commercial value of  
301 the beans. [37] also reported that the lack of generation of enough acids to kill cotyledon results in germination of cocoa  
302 beans. According to [32] germinated beans assist the entrance of mould through the ripped hull of the beans. Since longer  
303 fermentation days (8 days) with placenta favoured the emergence of higher percentage of germination, well riped cocoa  
304 beans could be fermented for at most seven days without placenta to reduced germination incidence in postharvest  
305 processing of cocoa.

306 Other Defects and All Other Defects of Cocoa Beans Fermented on Various Days With or Without Placenta.

307 Cocoa beans which were fermented for longer days with placenta gave highest percentage of all other defects. This is  
308 perhaps due to the fact that, the beans over fermented with high moisture content from the placenta leading to the  
309 deterioration and defective beans. All other defects entail Germinated beans, weevils and other defects like placental  
310 masses, chaff, debris or anything other than cocoa beans in a given cocoa sample to be graded [22].

311 When cocoa over ferments, it leads to increased inherent microbial deterioration processes as asserted by [17]. According  
312 to [38], in cocoa bean fermentation, sugars in the mucilage are converted into alcohol by yeast which proliferate after the  
313 sterile mass from the pod is exposed to the surrounding air. The result of the current study collaborates with the above  
314 findings. Beans fermented with placenta for eight days having the highest all other defects could be as a result of the  
315 presence of high germinated beans, other defects like traces of placental mass, chaff and other materials other than  
316 cocoa beans.

317 Purity Content (%) of Cocoa Beans Fermented on Various Days With or Without Placenta.

318 Percentage purity which is the overall assessment of the impact of all the defects on the quality of the cocoa under  
319 consideration indicated an overall good performance for those cocoa beans fermented for six days without placenta. The  
320 results of the current study shows that beans fermented with placenta reduced percentage purity (94.11%) considerably,  
321 while those fermented without placenta gave the highest purity (97.21%) undoubtedly due to presence of high counts of  
322 placental masses, chaff, flat beans, germinated beans and other defects (Foreign matter) which are mostly associated  
323 with presence of placenta inclusion during postharvest handling of cocoa beans. According to [39], cocoa mucilage  
324 together with its placenta consists of about 87% water, 15% sugar, 3% pentosans, 3% citric acid, and 1.5% pectin.

325 Proteins, amino acids, vitamins (mainly vitamin C), and minerals. These composition makes placental mucilage a rich  
326 medium for microbial growth and thereby leading to defective and mouldy beans which are the highest source of impure  
327 cocoa beans [22].

## 330 CONCLUSION

331 For the cut test, study revealed a significant placenta and fermentation days' interaction. Significantly ( $p \leq 0.05$ ), highest all  
332 other defects, other defects, unusual bean count and average bean count were produced by cocoa beans with placenta  
333 fermented for eight days. Cocoa beans fermented for eight days without placenta had the highest total bean count and  
334 percentage purity. Beans without placenta gave clean beans. But for those with placenta the longer the fermentation days  
335 the more the chaff content produced. Cocoa beans fermented for less than six days with placenta had the highest  
336 slatiness whiles beans fermented for less than six days had the highest purple beans and the longer it took the samples to  
337 dry the more purple formation. Also those beans fermented for more than seven days had the highest germinated beans.

## 339 COMPETING INTERESTS

340  
341 "Authors have declared that no competing interests exist."  
342

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