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EVALUATION OF QUALITY ATTRIBUTES OF COCOA (*THEOBROMA CACAO* L.) INTERCROPPED IN COCONUT IN EAST GODAVARI DISTRICT OF ANDHRA PRADESH INDIA

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ABSTRACT

Cocoa (*Theobroma cacao* L.) is an important plantation crop valued for its beans, which are the basis for chocolate and confectionery industries. Bean quality is determined by both physical and biochemical attributes that influence processing and end-product acceptability. The present study was conducted in 10 cocoa-growing plantations which are intercropped in coconut and Forastero type in East Godavari district of Andhra Pradesh, to evaluate quality parameters including shelling percentage, nib recovery, phenolic content, protein content, carbohydrate content, fat percentage and total soluble solids (TSS). Significant variation was observed among locations, reflecting the influence of soil and environmental conditions. Shelling percentage ranged between 12.12 % and 22.27 %, with corresponding nib recovery of 77.37 to 88.17 %. Fat content, a key determinant of industrial value, varied from 44.22 to 58.62 %. Carbohydrate content ranged from 23.62 to 32.85 (g/100gm). Phenolic content and TSS showed marked differences, suggesting variable flavour potential. Phenols ranged from 22.57 to 59.33 (mg/g) and TSS varied from 15.39 to 20.81(^{0} Brix). The study highlights location-specific variation in cocoa quality and provides useful information for selection of superior sites and planting materials suited for high-quality cocoa production in East Godavari.

***Key words*:** Cocoa, Quality attributes, Nib recovery, Fat content, Carbohydrates, Phenolics, East Godavari, Andhra Pradesh.

Introduction

Cocoa (*Theobroma cacao* L.), belonging to the family Malvaceae, is a commercially significant crop cultivated primarily for its beans, which serve as the raw material for chocolate, confectionery, and cosmetic industries. Bean quality is a crucial factor influencing market price and consumer preference. Key quality traits include physical parameters such as shelling percentage and nib recovery, and biochemical constituents such as phenolics, proteins, carbohydrates, fat, and total soluble solids (TSS).

India's cocoa cultivation is concentrated in Andhra Pradesh, Kerala, Karnataka, and Tamil Nadu, with East Godavari district of Andhra Pradesh emerging as a major cocoa belt due to favourable climate and intercropping systems with coconut and oil palm. Despite expansion, limited systematic evaluation has been done on the quality attributes of cocoa beans across diverse locations in East

Godavari. Understanding this variation is important for identifying superior producing areas and improving cocoa value chains. Therefore, the present investigation was undertaken with the objective of assessing cocoa quality parameters across 10 locations of East Godavari district.

Materials and Methods

Study Area

The study was carried out during 2024-2025 in cocoa intercropped in coconut in 10 locations of East Godavari district, Andhra Pradesh. The district is characterized by tropical humid climate, annual rainfall of 475.6 mm, and mean temperatures ranging from 29 to 34°C. Cocoa plantations sampled were predominantly intercropped under coconut. 15 years aged plantations were selected for this study. The details of the geographical locations were presented in Table 1.

Sample Collection

From each location, fully matured healthy pods were harvested at random from multiple trees in 4 replications. Pods were broken, beans extracted, fermented under local practices, and dried to standard moisture content (7%). Processed beans were subjected to quality analysis.

Parameters Studied

Physical attributes

Shelling percentage (%): Shell percentage of the bean was calculated by using the formula,

$$\text{Shelling Percentage (\%)} = \frac{\text{Shell weight of bean}}{\text{Dry weight of bean}} \times 100$$

Nib recovery (%): Nib recovery percentage of the bean was calculated by using the following formula,

$$\text{Nib recovery Percentage (\%)} = \frac{\text{Nib weight of bean}}{\text{Dry weight of bean}} \times 100$$

Biochemical attributes

Phenolic content (mg GAE/g)

Total phenol content in cocoa beans was estimated using Folin Cio-calteau reagent (Sadasivam and Manickam, 2005). About 0.5 g of dried bean sample was weighed, grounded with pestle and mortar with 10 times volume of 80 % ethanol. The extract was centrifuged at 10,000 rpm for twenty minutes and supernatant was collected. The residues were reextracted in the centrifuge by adding 80 % ethanol for five times, supernatants were pooled and allowed to evaporate for drying. The residue was dissolved in 5 ml of distilled water and different aliquots of 0.2 to 2 ml were pipetted out into test tubes. Each tube was made up to 3 ml with water and 0.5 ml of Folin Cio-calteau reagent was added. After three minutes,

Table 1: Geographical location details of cocoa plantations intercropped in coconut, selected in East Godavari District of Andhra Pradesh.

Plantation No.	Latitude	Longitude
1	N 16 ^{0} 66’7971"	E 82^{0}02’6796"
2	N 16^0.67’2536"	E 81^{0}91’6586"
3	N 16^0 59’9058"	E 81^{0}92’1465"
4	N 16^0 69’3257"	E 81^{0}98’1008"
5	N 16^0 65’9576"	E 81^{0}86’2560"
6	N 17^{0}32’9482"	E 82^{0}43’7867"
7	N 17^{0}36’1522"	E 82^{0}40’3639"
8	N 16^{0}97’2983"	E 81^{0}82’5233"
9	N 16^0 79’0002"	E 81^{0}77’6139"
10	N 16^0 84’6436"	E 81^{0}28’2681"

2 ml of 20 % sodium carbonate was added to each test tube and mixed thoroughly. The tubes were kept in boiling water for one minute exactly and were allowed to cool. After cooling, the absorbance was measured at 650 nm against blank. A standard curve was prepared by different concentrations of gallic acid to find out the concentration of phenols in cocoa sample and expressed as mg phenolic content per one gram material.

Protein (g/100 gm)

About 0.5 g of dried cocoa bean sample was weighed and powdered with the help of pestle and mortar by adding 10 ml phosphate buffer having pH of 7.6. The supernatant was collected by centrifuging the extract at 10,000 rpm for 10 minutes which will be used for protein estimation. An aliquot of 0.5 ml was taken from supernatant and made up to one millilitre by adding distilled water. A tube with one millilitre of distilled water served as the blank. Alkaline copper solution (Reagent C) of about 5 ml was prepared by adding 50 ml of 2% sodium carbonate in 0.1 N sodium hydroxide (Reagent A) and 1 ml of 0.5 % copper sulphate in 1 % potassium sodium tartarate (Reagent B). The copper solution was added to each tube including blank prior to use only, mixed well and allowed to stand for 10 minutes to which 0.5 ml of FC reagent (Folin Ciocalteau) was added. The tubes were incubated in dark at room temperature for about 30 minutes. Later on, blue colour developed which was read at 660 nm and amount of protein in the bean sample was quantified using a standard curve prepared with known concentrations of bovine serum albumin (BSA), as determined by Lowry *et al*., (1951).

Carbohydrates (g/100 gm)

100 mg of the sample was weighed and transferred into a test tube. The contents were hydrolysed by keeping the test tube in a boiling water bath for three hours with 5 ml of 2.5 N HCL and cooled to room temperature.

Then it was neutralised with solid sodium carbonate until the effervescence ceases. The volume was made to 100 ml and centrifuged. The supernatant was collected and taken 0.5 and 1ml aliquot for analysis. Standards were prepared by taking 0, 0.2, 0.4, 0.6, 0.8 and 1ml of the working standard and 0 served as blank. The volume was made to 1ml in all the tubes including the sample tubes by adding distilled water. Then 4 ml of anthrone reagent was added and kept in boiling water bath for eight minutes. Cooled rapidly and reading of green to dark green colour was recorded at 630 nm. Standard graph was drawn by plotting concentration of the standard on the X-axis versus absorbance on the Y-axis. From the graph, the amount of carbohydrate present in the sample test tube was calculated. (Hedge & Hofreiter, 1962)

Fat (%)

Fat percentage in dried cocoa beans was estimated by using petroleum ether extraction method through Soxhlet apparatus (AOAC, 2000) and expressed in percentage. About 10 grams of powdered cocoa bean sample was weighed and packed in a Whatman no-42 filter paper. The extraction chamber of the apparatus was filled with packed samples and attached to round bottom flask holding petroleum ether of 300 ml. The condenser was placed over the extraction chamber provided with running water tubes and entire unit was kept over a heating unit maintained at a temperature of 40 to 60^{0}C. Due to heating, the petroleum ether gets evaporated and reaches the condenser, where it cools and reaches the extraction chamber to solubilize the fat content in the beans. Petroleum ether in the extraction chamber gets siphoned and reaches to the bottom flask through side tubes. About 6-8 such siphoning was required for complete extraction of fat from sample and the petroleum ether was evaporated. The apparatus was cooled with the help of desiccator; the sample packets were taken out and weighed. The fat content in the beans was calculated by using following formula

$$\text{Percentage of fat content} = \frac{\text{W2 - W1}}{\text{Weight of the sample (100-M)}} \times 100$$

Where,

W1- weight of the round bottom flask

W2- Weight of the flask filled with petroleum ether

M-Moisture content of the sample

Total soluble solids (TSS, °Brix)

Total soluble solids (TSS) content was determined by using Pocket Refractometer (0-85 ºBrix). The refractometer was calibrated with distilled water before use and then a few drops of pulp juice was placed on the prism and the readings were recorded. The results were expressed in ºBrix.

Statistical Analysis

Data collected from 10 locations were subjected to analysis of variance (ANOVA), Randomized Block Design using [SPSS]. Mean separation was done using least significant difference (LSD) at 5% probability level. (Panse and Shukatme,1985)

Results and Discussion

The performance of cocoa quality traits varied significantly among the 10 plantations studied (Table 2) and Fig. 1 & Fig. 2. The overall mean values across plantations were 15.69% for shelling percentage, 84.30% for nib recovery, 26.11 g/100g for carbohydrates, 34.41 mg/g for phenols, 12.31 g/100g for proteins, 52.14 % for fat, and 18.20 °Brix for total soluble solids (TSS).

Physical Parameters

Shelling percentage (%)

Shelling percentage ranged from 12.12% (Plantation 1) to 22.27% (Plantation 4), with a grand mean of 15.69%. The differences among plantations were significant (CD = 0.47 at 5%). Plantations 4 and 5 exhibited the highest

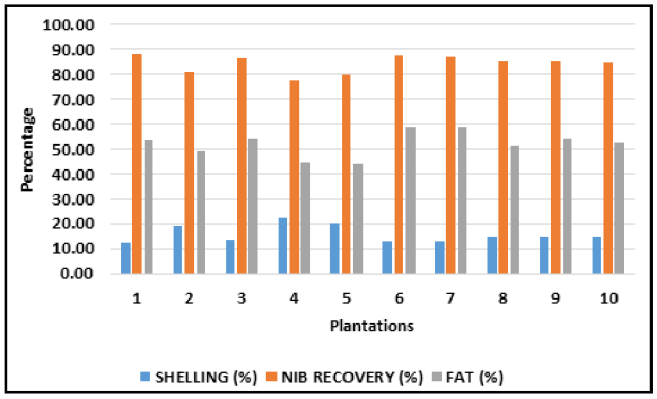

Fig. 1: Comparative mean performance of quality attributes (Shelling (%), Nib Recovery (%) and Fat (%) of cocoa beans.

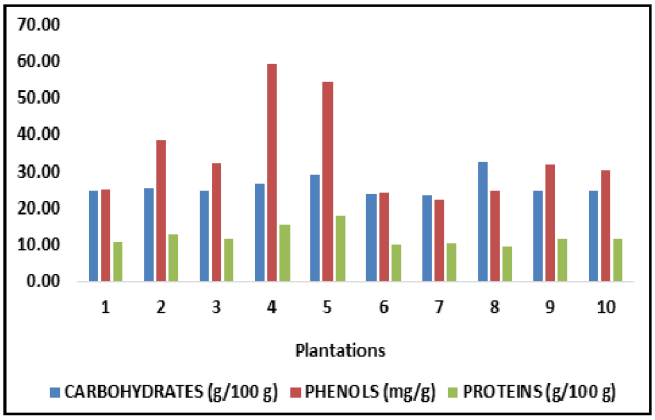

Fig. 2: Comparative mean performance of Carbohydrates, Phenols and Protein content of Cocoa beans.

Table 2: Mean Performance of Quality Characters of Cocoa intercropped in Coconut in East Godavari District of Andhra Pradesh.

Plantation No.	Shelling (%)	Nib recovery (%)	Carbohydrates (g/100 g)	Phenols (mg/g)	Proteins (g/100 gm)	Fat (%)	TSS (^{0} Brix)
1	12.12	88.17	24.58	24.99	10.78	53.85	15.39
2	18.99	80.75	25.56	38.69	13.00	49.16	15.57
3	13.69	86.55	24.93	32.39	11.79	54.09	18.42
4	22.27	77.37	26.73	59.33	15.81	44.75	19.56
5	20.00	79.84	28.99	54.48	17.95	44.22	19.29
6	12.71	87.61	24.05	24.45	10.25	58.62	17.93
7	13.00	86.99	23.62	22.57	10.38	58.56	19.00
8	14.73	85.60	32.85	24.92	9.76	51.26	18.74
9	14.54	85.22	24.80	31.80	11.58	54.26	17.30
10	14.85	84.92	24.93	30.44	11.79	52.58	20.81
GRAND MEAN	15.69	84.30	26.11	34.41	12.31	52.14	18.20
S.E.m (±)	0.23	0.30	0.28	0.59	0.15	0.53	0.28
CV (%)	2.05	0.51	1.50	2.43	1.67	1.44	2.21
CD (0.05)	0.47	0.62	0.57	1.21	0.30	1.09	0.58

shelling percentages, while plantations 1, 6 and 7 recorded the lowest values. These results indicate genetic as well as environmental influences on shell weight relative to nib yield. These variations reaffirm the influence of bean size, shell thickness, and genotype on shelling performance. (Afoakwa *et al*., 2013).

Nib recovery (%)

Nib recovery, a critical determinant of bean quality, ranged from 77.37% (Plantation 4) to 88.17% (Plantation 1). The overall mean was 84.30%. Plantations 1, 6 and 7 recorded significantly higher nib recovery than others (CD = 0.62). These results confirm that higher nib recovery is associated with lighter shells and more efficient processing, consistent with earlier findings that optimal nib recovery should exceed 80%. Similar ranges have been documented in fermented and unfermented cocoa beans, where nib proportions ranged from 74.1% to 83.5%. (Afoakwa *et al*., 2013). Shell thickness, bean size and maturity strongly influence these parameters, directly impacting processing efficiency and chocolate yield. (Michelle End & Robin Dand, 2016).

Biochemical Parameters

Fat (%)

Cocoa butter is the most economically important component, generally ranging between 46-57% of nib dry matter (Lannes *et al*., 2013). Fat content, an important determinant of cocoa butter yield, varied from 44.22% (Plantation 5) to 58.62% (Plantation 6), with a mean of 52.14%. Plantations 6 and 7 recorded significantly higher fat percentages. This variation has direct industrial relevance since fat content influences cocoa butter recovery in chocolate manufacturing. The findings are relevant with findings of Apshara, 2016.

Phenols (mg/g)

Phenol content showed wide variability, ranging from 22.57 mg/100g (Plantation 7) to 59.33 mg/100g (Plantation 4), with a mean of 34.41 mg/100g. Differences were highly significant (CD = 1.21). Plantations 4 and 5 recorded markedly higher phenol concentrations, which are desirable for antioxidant properties and also contribute to bitterness. Such variations are commonly attributed to both genotype and soil–climate interactions. (Mazor Jolic *et al*., 2011). Fermentation and drying typically reduce polyphenol levels due to oxidation and enzymatic degradation, explaining variability among plantations. (Kyi *et al*., 2005).

Proteins (g/100 g)

Protein content ranged from 9.76 g/100g (Plantation 8) to 17.95 g/100g (Plantation 5), with a mean of 12.31 g/100g. Plantations 4 and 5 exhibited significantly higher protein contents compared to others, suggesting superior nutritional quality. Proteins play a role in flavour precursor formation (peptides and amino acids) during roasting, which contributes to the characteristic cocoa aroma. (Afoakwa *et al.,* 2013).

Carbohydrates (g/100 g)

Carbohydrate content varied between 23.62 g/100g (Plantation 7) and 32.85 g/100g (Plantation 8). The plantation mean was 26.11 g/100g, with significant differences across locations (CD = 0.57). Plantation 8 stood out with the highest carbohydrate content, whereas plantation 7 had the lowest. The variation reflects both genetic potential and agro-climatic influences on carbohydrate partitioning in beans. Sugars, serve as key

precursors for Maillard reactions during roasting, thereby influencing flavour development (Afoakwa *et al.*, 2013).

Total Soluble Solids (TSS)

TSS ranged from 15.39 to 20.81 °Brix, with an average of 18.20 °Brix, reflecting differences in sugar content and fermentation efficiency. The variation was significant (CD = 0.58). Plantations 9 and 10 recorded the highest TSS values, indicating superior sweetness and flavour precursors. Although direct comparisons are scarce, sugars (mainly sucrose, glucose, and fructose) have been linked to sweetness and flavour precursor development in cocoa (Afoakwa *et al*., 2013).

Conclusion

The study revealed significant variation in cocoa quality traits across 10 locations in East Godavari. Nib recovery and fat content were highest in plantation 1 and 6 respectively, while phenols, carbohydrates, TSS and protein levels showed marked differences. The observed variation indicates that cocoa quality in East Godavari district is strongly influenced by location-specific factors such as soil type, microclimate, and management along with the genotype and environmental influence. Identifying superior and quality hotspots with high nib recovery and fat content can guide farmers and industries to source high-quality raw material. Further, biochemical data provide a baseline for breeding and selection of superior clones suited to the region.

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