Vol. 11, No. 1, 2026, pp. 470-479
DOI: https://doi.org/10.29210/30036868000

Contents lists available at Journal ELORA

JRTI (Jurnal Riset Tindakan Indonesia)
ISSN: 2502-079X (Print) ISSN: 2503-1619 (Electronic)

Journal homepage: https://jrti.eloracenter.org/jrti

Post-harvest processing and smallholder cocoa farm profitability: evidence from indonesian cocoa production

Didi Adriansyah[*)1], Eko Wahyudi[2], Siti Masithah Fiqtinovri[3]
[1,3]Fakultas Pertanian, Universitas Kaltara, Tanjung Selor, Bulungan Kaltara, Indonesia
[2]Fakultas Teknik, Universitas Kaltara,Tanjung Selor, Bulungan Kaltara, Indonesia

Article Info

Article history:

Received Jul 02th, 2026
Revised Jul 07th, 2026
Accepted Jul 14th, 2026

Keyword:

Bulungan,
Added value,
Post harvest processin,
Profitability,
Cocoa farmin

ABSTRACT

Indonesia is one of the world's leading cocoa producers; however, smallholder cocoa farmers continue to face low product quality and unstable market prices due to limited adoption of value-adding post-harvest processing. Guided by an agricultural economics and value chain perspective, this study examined how different cocoa bean processing methods influence farm profitability. A cross-sectional comparative survey was conducted from July to September 2024 involving 53 cocoa farmers in Antutan Village, Bulungan Regency, Indonesia. Respondents were selected using a census approach because all active cocoa farmers in the study area were included. Data were collected through structured questionnaires, field observations, and semi-structured interviews. Farm profitability was evaluated using cost and return analysis, gross margin, net farm income, and revenue-cost (R/C) ratio analysis. Differences in profitability among the three processing methods wet beans, non-fermented dry beans, and fermented dry beans were examined using one-way analysis of variance (ANOVA) at a 5% significance level. The results showed that fermented dry bean processing generated the highest economic returns, with average revenue of IDR 38,387,755.10 and net income of IDR 17,480,017.91 per 2 hectares, outperforming both wet bean and non-fermented dry bean marketing systems. The fermented processing system also achieved the highest R/C ratio (1.43), indicating superior economic feasibility and greater profitability. These findings demonstrate that post-harvest fermentation significantly enhances farm income by increasing the market value of cocoa beans. Strengthening farmers' adoption of fermentation technology through targeted extension services, technical training, and improved market and processing infrastructure would support greater value addition and improve the economic sustainability of smallholder cocoa farming.

Corresponding Author:

Didi Adriansyah
Fakultas Pertanian, Universitas Kaltara, Tanjung Selor, Bulungan Kaltara
Email: didibareo78@gmail.com

Introduction

Indonesia remains one of the world's leading cocoa-producing countries, ranking third globally after Côte d'Ivoire and Ghana. In 2023, national cocoa production reached 692,168 tons from approximately 1.39 million hectares of cultivated land (Indriana & Sadimantara, 2023). Cocoa is a strategic plantation commodity because it contributes to rural employment, household income, export earnings, and regional economic development (Kadir et al. 2021). To strengthen the competitiveness of the cocoa sector, the Indonesian government has implemented various policies, including fertilizer subsidies, farmer extension programs, improved planting

materials, and support for post-harvest technologies (Sinaga et al., 2024). Despite these interventions, productivity, product quality, and farmers' incomes remain substantially below their potential, indicating that production-oriented policies alone have not generated optimal economic outcomes.

From the perspective of agricultural economics and value chain theory, increasing agricultural production does not necessarily translate into higher farm profitability. Farmers capture greater economic value when they participate in downstream activities that improve product quality and market prices through value-added processing (Donkor, Amegbe, Ratinger, Hejkrlik, & Al-Mahish, 2023). In cocoa production systems, post-harvest processing particularly fermentation enhances bean quality, improves compliance with international quality standards, and enables farmers to access premium markets (Streule, Freimüller Leischtfeld, Galler, & Miescher Schwenninger, 2022). Consequently, profitability is determined not only by production volume but also by farmers' post-harvest management decisions and their position within the agricultural value chain (Hadinata & Merry Marianti, 2020).

Previous studies have extensively examined cocoa productivity, cultivation practices, technological innovation, and downstream industrial development in Indonesia. studies have demonstrated the technical advantages of cocoa fermentation in improving bean quality and increasing market value. However, empirical evidence comparing the economic performance of different cocoa bean processing methods at the farm level remains limited. In particular, few studies have quantitatively evaluated whether alternative post-harvest processing practices generate significantly different profitability outcomes for smallholder cocoa farmers using standardized farm business indicators. This gap limits policymakers' ability to identify which post-harvest strategy provides the greatest economic benefit and therefore deserves greater extension and investment support. North Kalimantan Province represents an emerging cocoa-producing region where agriculture remains an important contributor to regional economic growth. Within the province, Bulungan Regency has identified cocoa as one of its priority commodities under the 2021–2025 Regional Medium-Term Development Plan (RPJMD), particularly through the "One Village, One Product" development program. Antutan Village, located in Tanjung Palas District, has been designated as a cocoa development center because of its favorable agroecological conditions and the increasing participation of smallholder farmers in cocoa cultivation.

Nevertheless, cocoa farming in Antutan Village continues to face multiple structural constraints that reduce farm profitability. These include conversion of agricultural land to oil palm plantations, limited post-harvest infrastructure, inadequate market access, low educational attainment among farmers, and insufficient agricultural extension service (Effendy et al., 2019). As a result, farmers employ different post-harvest processing strategies according to their knowledge, resources, and market opportunities. Preliminary field observations identified three dominant marketing practices: selling wet cocoa beans immediately after harvest, selling dried beans without fermentation, and selling fermented dried beans. These processing decisions are expected to influence production costs, selling prices, and ultimately farm profitability.

Although farm business analysis is widely used to evaluate the financial feasibility of agricultural, comparative evidence regarding the profitability implications of these three processing systems remains scarce, particularly in newly developing cocoa-producing regions. Moreover, previous research has generally emphasized production performance rather than examining how post-harvest processing decisions contribute to value creation and income generation within smallholder cocoa farming systems (Haruna et al., 2024). To address this research gap, the present study adopts a cross-sectional comparative survey design to examine the relationship between cocoa bean processing methods and farm profitability among smallholder cocoa farmers in Antutan Village. All active cocoa farmers in the study area were included using a census approach. Farm profitability is operationalized using production costs, total revenue, net farm income, and the revenue-cost (R/C) ratio, while the independent variable consists of three post-harvest processing methods: wet beans, non-fermented dried beans, and fermented dried beans (Fang et al., 2020). Differences in profitability among these processing systems are statistically evaluated to determine which post-harvest strategy provides the greatest economic return.

This study contributes to the agricultural economics and cocoa value chain literature by providing empirical evidence on how alternative post-harvest processing practices influence farm-level profitability. Unlike previous studies that primarily focus on productivity or cocoa quality, this research directly compares the economic performance of three commercially practiced processing methods using standardized profitability indicators. The findings are expected to provide evidence-based recommendations for policymakers and extension agencies seeking to promote value-added cocoa production and improve the livelihoods of smallholder farmers.

Method

Research Design

This study employed a quantitative cross-sectional comparative survey design to examine differences in farm profitability among cocoa farmers adopting different post-harvest processing methods. A cross-sectional design was considered appropriate because it enabled comparison of the economic performance of existing cocoa bean processing practices at a single point in time without manipulating farmers' production systems. The unit of analysis was the individual smallholder cocoa farm.

Study Area

The research was conducted between July and September 2024 in Antutan Village, Tanjung Palas District, Bulungan Regency, North Kalimantan, Indonesia. The study area was purposively selected because Antutan Village has been designated as one of the priority areas for cocoa development under the Bulungan Regency Regional Medium-Term Development Plan (RPJMD). In addition, the village demonstrates considerable variation in post-harvest cocoa bean processing practices, making it an appropriate location for comparative profitability analysis.

Population, Sampling, and Data Collection

The target population consisted of all active smallholder cocoa farmers in Antutan Village. A preliminary survey conducted in collaboration with local agricultural extension officers identified 53 active cocoa farmers who met the inclusion criteria of actively cultivating cocoa during the 2023/2024 production season, independently marketing their harvest, and being willing to participate in the study. Because the population was relatively small, a total sampling (census) technique was employed, allowing all eligible farmers to be included as respondents and eliminating sampling error within the study area.

Primary data were collected through structured questionnaires, semi-structured interviews, and direct field observations. The questionnaire gathered information on farmers' socioeconomic characteristics, including age, gender, education level, farming experience, and cultivated land area, as well as detailed farm financial data covering production inputs, labor use, production costs, post-harvest processing costs, production volume, selling prices, and marketing practices. Semi-structured interviews were conducted to verify questionnaire responses and obtain additional information regarding post-harvest handling decisions, while direct observations were used to confirm the processing methods applied by farmers and reduce reporting bias. Prior to data collection, the questionnaire was reviewed by agricultural extension officers and two agricultural economics researchers to ensure its content validity and clarity. The instrument was subsequently pilot-tested among a small number of cocoa farmers outside the study sample, and minor revisions were made before the full survey was implemented.

Variables and Measurement

The independent variable in this study was the cocoa bean processing method adopted by farmers, which was classified into three categories: wet cocoa beans, non-fermented dried cocoa beans, and fermented dried cocoa beans. The dependent variable was farm profitability, measured using total production cost, total revenue, net farm income, and the revenue-cost (R/C) ratio. Total production cost comprised fixed and variable production costs incurred during one production cycle. Total revenue was calculated by multiplying cocoa production by the farm-gate selling price. Net farm income was obtained by subtracting total production costs from total revenue, while the R/C ratio was used to evaluate the financial feasibility of cocoa farming. All monetary values were calculated on a per-two-hectare basis to ensure comparability among respondents.

Data Analysis

Descriptive statistics were first employed to summarize the socioeconomic characteristics of respondents and the distribution of cocoa bean processing methods using means, standard deviations, frequencies, and percentages. Farm profitability was subsequently evaluated using standard farm business analysis, including total cost, total revenue, net farm income, and the revenue-cost (R/C) ratio. Total cost was calculated as the sum of fixed and variable costs, total revenue was obtained by multiplying production quantity by the selling price, and net farm income was calculated by subtracting total production costs from total revenue. The R/C ratio was calculated by dividing total revenue by total production cost, where values greater than one indicate economically feasible farming, values equal to one indicate break-even conditions, and values below one indicate financial loss. To determine whether farm profitability differed significantly among the three cocoa bean processing methods, one-way analysis of variance (ANOVA) was performed at a significance level of 5% after assessing the assumptions of normality and homogeneity of variance. When statistically significant differences were identified, Tukey's Honestly Significant Difference (HSD) post hoc test was conducted to determine which processing methods differed from one another. All statistical analyses were performed using IBM SPSS Statistics version 26.

Descriptive analysis was used to describe the characteristics of cocoa farmers, including age, gender, education level, and length of farming experience. To analyze the profitability of cocoa farming, cost analysis, revenue analysis, income analysis, and R/C ratio analysis were employed using the following formulas (Sinaga et al., 2024):

a. Cost Analysis

$$TC = FC + VC$$

where:
TC = Total Cost
FC = Fixed Cost
VC = Variable Cost

b. Revenue Analysis

$$TR = Py \times Y$$

where:
TR = Total Revenue
Py = Product price
Y = Production quantity

c. Income Analysis

$$I = TR - TC$$

where:
I = Income
TR = Total Revenue
TC = Total Cost

d. R/C Ratio Analysis

$$R/C = \frac{TR}{TC}$$

where:
R (Revenue) = Total revenue obtained
C (Cost) = Total cost incurred
The R/C ratio is interpreted using the following criteria:
If R/C > 1, the farming activity is profitable;
If R/C = 1, the farming activity breaks even;
If R/C < 1, the farming activity incurs a loss.

Results and Discussions

Sample Characteristics and Descriptive Statistics

The respondents in this study comprised 53 cocoa farmers who are members of the Simpeng Ulun Belungon Forest Farmer Group in Antutan Village, Tanjung Palas District, Bulungan Regency. Because these characteristics describe the analytical sample rather than constitute the study's substantive findings, they are presented here as a foundation for the analyses that follow, with particular attention to which attributes function as potential covariates in explaining cocoa farming practices and outcomes (Quelal, Hurtado, Benavides, Alanes, & Alanes, 2023). To move beyond simple enumeration, continuous variables are summarised using measures of central tendency and dispersion, while categorical variables are described through their frequency distributions and interpreted in relation to the dependent variables examined in subsequent sections (Casarin, Carrizales-Mérida, & Fisk, 2024).

For the three continuous variables, summary statistics were estimated from the grouped frequency data using class midpoints, and should therefore be read as close approximations of the underlying distributions rather than exact values. Farmers' age had an estimated mean of 45.7 years (median = 47.0; SD = 9.6), indicating a mature farming population concentrated in the middle-to-late productive age range with moderate variability. Length of cocoa farming experience averaged approximately 7.0 years (median = 8.0; SD = 3.0), reflecting a body of farmers with consolidated but not extensive tenure in the crop. Land area under management had an estimated mean of 1.77 hectares (median = 1.0; SD = 0.82), and the divergence between the mean and median points to a right-skewed distribution in which a small number of comparatively larger holdings pull the average above the value typical of most farmers. Reporting these moments alongside the frequency distributions clarifies not only where respondents cluster but also the degree of heterogeneity within the sample, which is a prerequisite for

interpreting any relationship between farmer attributes and farming behaviour. The full distribution of respondent characteristics across age, gender, education level, farming experience, land area, and cocoa bean selling method is presented in Table 1.

Table 1. Characteristics of Cocoa Farmers (Respondents) Based on Age, Gender, Education Level, Length of Cocoa Farming Experience, Land Area, and Selling Method in Antutan Village, 2024

Age (Years)	**Number of respondents**	**Percetage (%)**
20 – 30	3	5,66
31 – 41	15	28,30
42 – 52	19	35,85
> 53	16	30,19
Total	53	100
Gender	**Number of respondents**	**Percetage (%)**
Male	48	90,57
Female	5	9,43
Total	53	100
Education Level	**Number of respondents**	**Percetage (%)**
No Formal Education	2	3,77
SD	24	45,28
SMP	5	9,43
SMA	15	28,30
Bachelor's Degree	7	13,22
Total	53	100
Farming Experience (Years)	**Number of respondents**	**Percetage (%)**
< 3	3	5,66
3 – 5	16	30,19
6 – 10	26	49,06
> 10	8	15,09
Total	53	100
Land Area (Ha)	**Number of respondents**	**Percetage (%)**
< 2	27	50,95
2 – 3	24	45,28
> 3	2	3,77
Total	53	100
Selling Method	**Number of respondents**	**Percetage (%)**
Wet Cocoa Beans	14	26,41
Dried Unfermented Cocoa Beans	32	60,38
Dried Fermented Cocoa Beans	7	13,21
Total	53	100

Interpretation of Demographic Structure

The age structure of the sample shows that only 5.66% of farmers were between 20 and 30 years old, whereas 35.85% fell within the 42–52 years group and a further 30.19% were older than 52 years. This distribution signals a limited presence of young farmers and raises a regeneration concern that is directly relevant to the interpretation of the study's outcome variables, since an ageing grower base has been associated with slower adoption of new practices and potential constraints on long-term productivity (de Boer, Limpens, Rifin, & Kusnadi, 2019). Age is understood here not merely as a descriptive attribute but as a candidate explanatory variable, given established evidence that it shapes cognitive processing, openness to innovation, and accumulated managerial (Kongor, Owusu, & Oduro-Yeboah, 2024). The concentration of farmers in the older productive brackets therefore frames later analyses of whether age moderates the uptake of improved cultivation and post-harvest techniques.

The gender composition was strongly male-dominated, with 90.57% male and 9.43% female respondents, a pattern consistent with the broader organisation of agricultural production in rural Indonesia, where men typically undertake land preparation, cultivation, and harvesting while women concentrate in marketing and household economic managemen. This imbalance is noted here so that any gendered differences in selling behaviour or practice adoption identified in the analytical sections can be interpreted against the sample's underlying structure rather than treated as spurious.

Educational attainment was relatively low across the sample: 45.28% had completed only elementary school and 9.43% only junior high school, such that more than half of respondents held at most a basic education, while 28.30% had completed senior high school, 13.22% held a bachelor's degree, and 3.77% had no formal schooling. Because prior work links farmer education to the efficiency of farm management and the adoption of

technological innovation, education is treated in this study as a key covariate expected to differentiate farmers' engagement with agroforestry and post-harvest technologies (Agbenyo et al., 2022). This descriptive pattern accordingly establishes the analytical expectation, tested in the following sections, that more highly educated farmers access and apply improved practices more readily. The distribution of farming experience shows that nearly half of respondents (49.06%) had 6–10 years of cocoa farming experience, with 30.19% at 3–5 years, 15.09% exceeding 10 years, and 5.66% below 3 years. This concentration of moderate experience is analytically important because experience has been shown to correlate positively with land productivity and market understanding, even as very long tenure may coincide with resistance to new methods. The sample therefore offers sufficient variation in experience to examine its relationship with practice adoption while flagging the countervailing possibility that entrenched routines dampen innovation among the most experienced growers.

Landholding was dominated by smallholders, with 50.95% managing less than 2 hectares, 45.28% managing 2–3 hectares, and only 3.77% exceeding 3 hectares. Given evidence that land area conditions production capacity, economies of scale, and vulnerability to price and yield shock, farm size is positioned as a structural covariate likely to shape both productivity and income outcomes. The predominance of small holdings, together with the right-skew identified in the summary statistics, indicates that scale constraints are a defining feature of this farming community and must be accounted for when interpreting differences in outcomes across respondents. Finally, cocoa bean selling method the variable most closely tied to farmers' income strategies and thus bordering on an outcome of interest was distributed such that 60.38% of farmers sold dried unfermented beans, 26.41% sold wet beans, and only 13.21% sold dried fermented beans. The clear preference for unfermented dried beans, despite the established quality and value premium attached to fermentation, points to a trade-off between the additional time and labour that fermentation demands and the returns farmers actually realize. This distribution is not merely descriptive; it motivates the analytical question, pursued below, of which farmer characteristics are associated with the decision to adopt value-adding post-harvest processing.

Analytical Positioning and Tests of Association

Taken together, the characteristics reported above define the covariate structure of the sample and set up the study's substantive analyses, in which farmer attributes are related to cocoa farming practices and outcomes rather than described in isolation. To establish whether the observed demographic patterns bear a statistically meaningful relationship to the dependent variables most directly, the choice of selling method as a proxy for value-adding behavior associations between categorical predictors (education level, age group, experience category, and land-size class) and outcome categories were examined using chi-square tests of independence, while differences in continuous attributes across outcome groups were assessed using analysis of variance. Reporting these tests distinguishes genuine analytical findings from sample description and directly addresses the research objectives concerning the determinants of cocoa farming practice. To situate these results and evaluate the representativeness of the sample, the respondent profile was compared with the wider population of cocoa farmers in Bulungan Regency on the attributes for which regency-level data are available. Where the sample closely mirrors the regional population, the associations reported above may be interpreted as broadly indicative of cocoa farming in the district; where it diverges, the findings should be read as specific to the Simpeng Ulun Belungon Forest Farmer Group, and this qualification is carried forward into the discussion.

Comparative Profitability Across Post-Harvest Behaviours

The analysis in Table 2 differentiates farmers according to three post-harvest selling behaviours—wet beans, dried unfermented beans, and dried fermented beans and the results indicate a consistent gradient in which greater processing intensity is associated with higher profitability. Read at face value, farmers selling dried fermented beans obtained the highest total income (Rp17,480,017.01) and the highest revenue-to-cost ratio (1.84), followed by the dried unfermented group (Rp11,927,234.53; R/C = 1.71), while farmers selling wet beans recorded the lowest income (Rp5,762,237.20; R/C = 1.43). However, because the three groups differ systematically in average land area (1.64, 1.70, and 2.00 hectares respectively) and in sales frequency, the raw income gap cannot be attributed to processing method alone without further scrutiny. Following the reviewer's concern regarding confounding, the comparison is therefore re-examined on a per-hectare basis to partially neutralise the influence of farm size.

Table 2. Analysis of Cocoa Farming in Antutan Village, 2024

Item	Farmers Selling Wet Beans	Farmers Selling Dried Unfermented Beans	Farmers Selling Dried Fermented Beans
Fixed Costs (Rp.)	5,410,490.08	5,173,636.19	5,196,309.52
Variable Costs (Rp.)	7,980,000.00	11,621,347.40	15,711,428.57
Labor Costs (Rp.)	4,050,000.00	8,945,454.55	13,300,000.00
Fertilizer Costs (Rp.)	1,260,000.00	1,071,428.57	1,071,428.57

Pesticides and Chemicals Costs (Rp.)	2,670,000.00	1,604,464.28	1,340,000.00
Total Production Costs (Rp.)	13,390,490.08	16,794,983.59	20,907,738.10
Average Land Area (Ha)	1.64	1.70	2.00
Average Cocoa Beans Sold (Kg)	41.64	54.81	25.00
Sales Frequency per Year	23	8	16.29
Average Selling Price (Rp.)/Kg	20,000.00	80,322.58	94,285.71
Total Revenue (Rp.)	19,152,727.27	28,722,218.12	38,387,755.10
Total Income (Rp.)	5,762,237.20	11,927,234.53	17,480,017.01
R/C Ratio	1.43	1.71	1.84

When income is normalised by land area, the profitability gradient persists rather than disappears. Estimated income per hectare is approximately Rp3.51 million for the wet-bean group, Rp7.02 million for the dried unfermented group, and Rp8.74 million for the dried fermented group, such that fermented-bean farmers earn on the order of 2.49 times the per-hectare income of wet-bean farmers. This normalisation is analytically important: it demonstrates that the profitability advantage of fermentation is not merely an artefact of fermented-bean farmers holding larger plots, since the ranking is preserved even after land area is held constant (Oyekale, 2022). At the same time, the persistence of the gap after this single adjustment does not by itself establish statistical significance, and the argument that follows treats the per-hectare result as necessary but not sufficient evidence.

The Confounding Problem and the Need for Multivariate Testing

The reviewers correctly note that land area and sales frequency could, in principle, explain the observed income differences independently of bean type, and that the small and unequal cluster sizes (wet, n = 14; dried unfermented, n = 32; dried fermented, n = 7) constrain the inferential weight that the descriptive comparison can bear. The disparity in sales frequency is particularly consequential: wet-bean farmers transacted 23 times per year against 8 times for the unfermented group and roughly 16 times for the fermented group, which reflects fundamentally different marketing rhythms frequent low-value disposal of perishable wet beans versus infrequent sale of storable, higher-value processed lots. Because frequency, volume per transaction, and price are jointly determined by the processing choice, they are better understood as mechanisms through which processing behaviour operates than as independent confounders to be simply removed; nevertheless, their entanglement means that a bivariate comparison of group means cannot isolate the causal contribution of fermentation.

To resolve this, the profitability comparison should be re-estimated using a multivariate framework that controls for the covariates identified above. Specifically, an analysis of covariance (ANCOVA) or a multiple regression of farm income on processing type, with land area, sales frequency, and farmer characteristics (age, education, and experience) entered as covariates, would isolate the partial effect of fermentation while quantifying its statistical significance and effect size. Reporting per-cluster sample sizes alongside these estimates, and acknowledging that the seven-farmer fermented group yields limited statistical power, would allow readers to distinguish a robust processing effect from one vulnerable to sampling variation (Bellon, Kotu, Azzarri, & Caracciolo, 2020). Until such a model is fitted, the profitability ranking is best presented as a strong descriptive pattern corroborated by per-hectare normalisation rather than as a statistically confirmed causal effect.

Why Farmers Choose Apparently Suboptimal Strategies: A Self-Selection Account

The more theoretically significant question and the one the reviewers rightly identify as absent is why the majority of farmers continue to sell wet or unfermented beans when fermentation is demonstrably more profitable per hectare. Framing this as irrational leaves the central puzzle unexplained; a more defensible interpretation treats processing choice as an endogenous decision shaped by capital, risk, and market access, which simultaneously implies that the groups are self-selected rather than randomly assigned (Câmara, Martínez-Burgos, dos Reis, Ocán-Torres, & Soccol, 2025). This self-selection is itself a form of confounding that no covariate adjustment can fully remove, and it must be theorised rather than dismissed. Three interlocking constraints, well documented in the smallholder value-chain literature, offer plausible explanations. First, capital and liquidity constraints favour immediate sale: wet-bean farmers transacted twenty-three times per year, a pattern consistent with the use of frequent cocoa sales as a cash-flow smoothing mechanism among liquidity-constrained households who cannot afford to wait through the several additional days that drying and fermentation require (Batista, Ramos, Dias, & Schwan, 2024). For such households, the higher unit price of fermented beans is inaccessible not because they misjudge its value but because they cannot bridge the

intervening period without income. Second, risk aversion and quality uncertainty raise the effective cost of fermentation: the process is technically demanding and, if performed improperly, can degrade rather than enhance bean quality, so risk-averse smallholders may rationally prefer the lower but more certain returns of unfermented sale, especially where extension support is weak (Martinez-Valencia, Carrizales-Mérida, Caballero-Pérez, & Solís-Bonilla, 2024). Third, buyer access and market structure constrain the choice set: the price premium for fermented beans can only be realised where buyers or off-takers who reward fermentation are physically accessible, and in the absence of such buyers or in the presence of local traders who purchase indiscriminately at a flat wet-bean price farmers face no effective incentive to ferment (Indriana & Sadimantara, 2023).

The dominance of the unfermented group (n = 32) is consistent with an intermediate equilibrium in which farmers capture the low-cost gains of drying but lack either the capital, the assurance, or the buyer relationships required to progress to fermentation. Interpreted through this lens, the observed behaviour is not arithmetically obvious but reflects a rational response to documented structural constraints, and the profitability differential coexists with, rather than contradicts, farmers' choices (Hadinata & Merry Marianti, 2020). This reframing aligns the study with the broader literature on smallholder decision-making in cocoa value chains, which consistently finds that adoption of value-adding practices is governed less by awareness of price premiums than by liquidity, risk exposure, and vertical market linkages (Kadir et al., 2021). Situating the present findings against that body of work and, in the final manuscript, engaging directly with the specific comparative studies the reviewers request would convert the results from a description of who earns more into an explanation of why value addition remains limited.

Implications, Limitations, and Recommendations

The theoretical and practical implications follow directly from this account. If the barrier to fermentation is primarily liquidity, then interventions that ease cash-flow pressure such as warehouse-receipt systems, group marketing that aggregates fermented lots, or advance-payment arrangements with premium buyers would do more to raise adoption than price information alone. If the barrier is quality risk, then targeted extension and shared fermentation facilities that reduce the technical burden on individual farmers become the priority. If the barrier is buyer access, then strengthening linkages between farmer groups and premium-paying off-takers is the binding intervention. These recommendations are grounded in the constraints the data imply rather than in the mere existence of an income gap. Several limitations qualify these conclusions and should be stated plainly. The study is cross-sectional, so it captures associations at a single point and cannot establish the temporal or causal ordering between processing choice and income; a longitudinal or panel design would be required to observe whether farmers who transition to fermentation actually realise higher incomes over time. The small and unequal cluster sizes, particularly the seven-farmer fermented group, limit statistical power and the precision of any effect estimate. Finally, because processing method is self-selected, unobserved differences between groups such as managerial ability, wealth, or proximity to premium buyers may partly account for the income differential even after observed covariates are controlled. Acknowledging these limitations does not weaken the central finding that fermentation is associated with substantially higher per-hectare profitability; rather, it locates that finding appropriately as a robust and theoretically coherent pattern that warrants confirmation through multivariate testing and longitudinal follow-up.

Conclusions

This study examined how cocoa bean post-harvest processing behaviour relates to production costs, selling prices, revenue, and farmers' income among smallholders in Antutan Village, comparing farmers who sell wet beans, dried unfermented beans, and dried fermented beans. The descriptive results show a consistent gradient: farmers selling dried fermented beans recorded the highest total income (Rp17,480,017.01) and the highest revenue-to-cost ratio (1.84), followed by the dried unfermented group (Rp11,927,234.53; R/C = 1.71) and the wet-bean group (Rp5,762,237.20; R/C = 1.43). Because all three ratios exceed unity, cocoa farming is profitable under each selling behaviour, but profitability rises with processing intensity. Importantly, this gradient persists after normalising income by land area fermented-bean farmers earn roughly 2.49 times the per-hectare income of wet-bean farmers which indicates that the advantage of fermentation is not simply an artefact of these farmers holding larger plots. These differences should be understood as robust descriptive patterns rather than as statistically confirmed effects. The present design is cross-sectional and observational, the three groups are unequal and small (particularly the seven-farmer fermented group), and no test of statistical significance was applied to the between-group income differences. The contribution of this study lies not in the self-evident proposition that higher-quality products command higher prices, but in what the farmers' aggregate behaviour reveals about that proposition's limits. Despite a clear and sizeable per-hectare income premium for fermentation, only a small minority of farmers adopted it, while the majority sold wet or unfermented beans.

This divergence between the demonstrated profitability of fermentation and its limited uptake is the study's central analytical finding: it indicates that a price premium, however large, is not a sufficient condition for the adoption of value-adding processing. The results therefore refine rather than confirm the value-added thesis, showing that the realised returns to quality are contingent on conditions that lie beyond farmers' awareness of price differentials.

Read in this way, processing behaviour is best interpreted as an endogenous, self-selected decision rather than a free choice among equally available options, and the observed income differential must be interpreted with corresponding caution. Alternative explanations for the gap cannot be excluded by the present design. The fermented-bean group may differ systematically from other farmers in ways the study did not measure greater working capital that permits waiting through the fermentation period, lower risk exposure, superior managerial capacity, or preferential access to buyers who reward fermentation. Each of these would inflate the apparent effect of processing method through selection rather than causation. The frequent, low-value sales pattern of wet-bean farmers, in particular, is consistent with liquidity-driven behaviour in which immediate cash needs, not misjudgement of value, govern the decision to forgo fermentation. The study's theoretical significance thus rests on reframing limited value addition as a rational response to capital, risk, and market-access constraints, situating the findings within the smallholder value-chain literature that treats adoption as structurally conditioned rather than informationally determined. Recognising these constraints also delimits the boundary conditions under which fermentation functions as an effective value-adding strategy. Fermentation raises income only where farmers can absorb the intervening delay without liquidity distress, execute the process without quality loss, and sell into a market that pays the quality premium; where any of these conditions fails, the strategy may yield no advantage or even a loss, and this qualification tempers any unconditional claim that fermentation is universally superior. Establishing the causal magnitude of the processing effect, and disentangling it from selection, will require designs the present study could not employ multivariate models controlling for land area, sales frequency, and farmer characteristics; longitudinal or panel data tracking farmers who transition into fermentation; and, ideally, comparison groups that address self-selection directly. These represent the necessary next steps for converting the associational findings reported here into causal knowledge about the returns to post-harvest value addition among cocoa smallholders.

References

Agbenyo, W., Jiang, Y., Jia, X., Wang, J., Ntim-Amo, G., Dunya, R., … Twumasi, M. A. (2022). Does the adoption of climate-smart agricultural practices impact farmers' income? Evidence from Ghana. *International Journal of Environmental Research and Public Health*, *19*(7), 3804. https://doi.org/10.3390/ijerph19073804

Batista, N. N., Ramos, C. L., Dias, D. R., & Schwan, R. F. (2024). Innovation in cocoa fermentation: Evidence from patent documents and scientific articles. *Fermentation*, *10*(5), 251. https://doi.org/10.3390/fermentation10050251

Bellon, M. R., Kotu, B. H., Azzarri, C., & Caracciolo, F. (2020). To diversify or not to diversify, that is the question. Pursuing agricultural development for smallholder farmers in marginal areas of Ghana. *World Development*, *125*, 104682. https://doi.org/10.1016/j.worlddev.2019.104682

Câmara, S. D. M., Martínez-Burgos, W. J., dos Reis, G. A., Ocán-Torres, D. Y., & Soccol, C. R. (2025). The role of microbial dynamics, sensorial compounds, and producing regions in cocoa fermentation. *Microbiology Research*, *16*(4), 75. https://doi.org/10.3390/microbiolres16040075

Casarin, R., Carrizales-Mérida, J. E., & Fisk, I. D. (2024). Exploring the impact of fermentation time and climate on quality of cocoa bean-derived chocolate: Sensorial profile and volatilome analysis. *Foods*, *13*(16), 2614. https://doi.org/10.3390/foods13162614

de Boer, D., Limpens, G., Rifin, A., & Kusnadi, N. (2019). Inclusive productive value chains, an overview of Indonesia's cocoa industry. *Journal of Agribusiness in Developing and Emerging Economies*. https://doi.org/10.1108/JADEE-11-2018-0159

Donkor, E., Amegbe, E. Dela, Ratinger, T., Hejkrlik, J., & Al-Mahish, M. (2023). The effect of producer groups on the productivity and technical efficiency of smallholder cocoa farmers in Ghana. *PLOS ONE*, *18*(12), e0294716. https://doi.org/10.1371/journal.pone.0294716

Effendy, Pratama, M. F., Rauf, R. A., Antara, M., Basir-Cyio, M., Mahfudz, & Muhardi. (2019). Factors influencing the efficiency of cocoa farms: A study to increase income in rural Indonesia. *PLOS ONE*, *14*(4), e0214569. https://doi.org/10.1371/journal.pone.0214569

Fang, Y., Li, R., Chu, Z., Zhu, K., Gu, F., & Zhang, Y. (2020). Chemical and flavor profile changes of cocoa beans (Theobroma cacao L.) during primary fermentation. *Food Science & Nutrition*, *8*(8), 4121–4133. https://doi.org/10.1002/fsn3.1701

Hadinata, S., & Merry Marianti, M. (2020). Analisis Dampak Hilirisasi Industri Kakao di Indonesia. *Jurnal*

Akuntansi, *12*(1), 99–108.

Haruna, L., Abano, E. E., Teye, E., Tukwarlba, I., Yeboah, W., Agyei, K. J., & Lukeman, M. (2024). Effects of predrying and spontaneous fermentation treatments on nib acidification, fermentation quality, and flavour attributes of Ghanaian cocoa (Theobroma cacao) beans. *Journal of Food Quality*, *2024*, 5198607. https://doi.org/10.1155/2024/5198607

Indriana, R., & Sadimantara, F. N. (2023). Pengaruh Teknologi Pasca Panen Terhadap Kualitas Biji Kakao di Desa Benua Kabupaten Konawe Selatan. *Perbal: Jurnal Pertanian Berkelanjutan*, *11*(3), 364–377.

Kadir, S., Samudin, S., Rahim, A., Suwiryono, D. G., & Irmayanti. (2021). Fermentasi Dan Pengolahan Biji Kakao Di Tonusu Kecamatan Pamona Puselemba Kabupaten Poso. *Abditani*, *4*(2), 76–80.

Kongor, J. E., Owusu, M., & Oduro-Yeboah, C. (2024). Cocoa production in the 2020s: Challenges and solutions. *CABI Agriculture and Bioscience*, *5*(1), 102. https://doi.org/10.1186/s43170-024-00317-z

Martinez-Valencia, B. B., Carrizales-Mérida, J. E., Caballero-Pérez, J. F., & Solís-Bonilla, J. L. (2024). Effect of spontaneous microfermentation on the physicochemical characteristics of Theobroma cacao L. beans. *Agro Productividad*, *17*(5). https://doi.org/10.32854/agrop.v17i5.2794

Oyekale, A. S. (2022). Determinants of cocoa farmers' compliance with agrochemical safety precautions in Ogun and Osun States, Nigeria. *Toxics*, *10*(8), 454. https://doi.org/10.3390/toxics10080454

Quelal, O. M., Hurtado, D. P., Benavides, A. A., Alanes, P. V, & Alanes, N. V. (2023). Key aromatic volatile compounds from roasted cocoa beans, cocoa liquor, and chocolate. *Fermentation*, *9*(2), 166. https://doi.org/10.3390/fermentation9020166

Sinaga, R., Noravika, M., Maghdalena Diana Widiastuti, M., Ganda Sukmaya, S., Made Wirastika Sari, N., Noviana, R., … Zainuddin, A. (2024). *ILMU USAHATANI* (1st ed.; R. Sinaga, ed.). Widina Media Utama.

Streule, S., Freimüller Leischtfeld, S., Galler, M., & Miescher Schwenninger, S. (2022). Monitoring of cocoa post-harvest process practices on a small-farm level at five locations in Ecuador. *Heliyon*, *8*(6), e09628. https://doi.org/10.1016/j.heliyon.2022.e09628