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Does Fermentation of Cocoa Beans Increase Farmers' Income? A Case Study Using a Nationwide Survey in Indonesia

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Abstract

This study evaluates the impact of cocoa bean fermentation on costs and revenues among cocoa farmers using Propensity Score Matching (PSM). The study used nationally-representative data of Indonesian cocoa farmers from the Indonesian Plantation Farm Household Survey 2014 comprised 23,189 farmers. The result shows that non-fermented cocoa bean farmers achieve higher production (1.04 kg/year) compared to fermented bean farmers (0.83 kg/year), a 26.27% increase. They also have higher revenue, earning $100.67 per year versus $84.42 for fermented bean farmers, a 19.25% increase. Additionally, non-fermented farmers exhibit higher farm value per hectare ($1,772.50 compared to $1,350.00). However, non-fermented farmers incur higher costs: seed costs ($7.19 vs. $5.58), labor costs ($329.05 vs. $295.25), and fertilizer costs ($39.95 vs. $36.46). Conversely, they have lower pesticide costs ($21.95 vs. $26.12). The findings indicate that while non-fermented cocoa beans result in higher production and revenue, they also come with higher input costs. Fermented cocoa farmers benefit from lower costs but achieve lower production and revenue, highlighting the trade-offs between fermentation practices and economic outcomes.

Keywords

Cocoa bean fermentation, Propensity Score Matching (PSM), non-fermented cocoa, fermented cocoa, input costs, economic outcomes.

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Introduction

The International Cocoa Organization (ICCO) ranks Indonesia among the top 10 largest cocoa-producing countries globally (ICCO, 2023). According to the Indonesian Central Statistics Agency (BPS) (2023), Indonesia produced 650,612 tons of cocoa beans in 2022, with 56.68% of this production exported to various countries such as India, the United States, Malaysia, China, and Australia. However, despite its strategic position as a producer, Indonesia has yet to be included among the top 10 largest cocoa bean-exporting countries in the world (Global Value Chains). One of the reasons for this is the low quality of cocoa beans in Indonesia, attributed to inadequate post-harvest handling, particularly in the cocoa bean fermentation process (Wijayati and Haqqi, 2022).

Cocoa bean fermentation plays a crucial technical and economic role in determining the quality of beans and facilitating the cocoa export process. Quality standards for cocoa beans in Indonesia are governed by the National Certification Body (BSN) through the Indonesian National Standard for Cocoa Beans, designated as SNI 2323:2008/Amd1:2010. These standards cover quality compliance, classification, packaging methods, testing procedures, color, taste, and aroma of cocoa beans. Cocoa bean fermentation is an essential process to meet these standards (Malau, 2018). Fermentation enhances the quality of cocoa beans by bringing out distinctive chocolatey aroma and flavor characteristics while preventing seed germination (Figueroa-Hernández et al., 2019). The cocoa bean fermentation process involves various microorganisms such as yeast, lactic and acetic acid bacteria, aerobic spore-forming bacteria, and filamentous fungal species (Guzmán-Alvarez and Márquez-Ramos, 2021). This process typically spans 5 to 7 days and leads to the evolution of microorganisms and enzymes that serve as precursors to cocoa aroma (Julian, 2021). According to (Morales-Rodriguez et al, 2024), fermented cocoa beans exhibit superior quality with a darker color, stronger aroma, and drier beans. Economically, cocoa bean fermentation is carried out to meet quality requirements set by the ICCO and export destination countries (Santos, 2020).

Despite the pivotal role of fermentation in determining cocoa quality, most previous studies in Indonesia have primarily examined its effects on bean quality, production, and farmers' decision-making processes rather than directly analyzing its impact on farmers' income. Research has shown that fermentation enhances cocoa bean quality and market price, influenced by factors such as farmer education, training, and production volume (Ambarawati and Esterina, 2024). However, only a few studies have quantitatively compared the income of farmers who ferment their cocoa with those who do not, demonstrating that fermentation can significantly increase income and add value to cocoa products(Intarini et al., 2020). These dynamics are further shaped by differences in farmers' preferences, knowledge, and socio-economic conditions, as highlighted in previous research by Soemarno (2015), Ahmad (2021), Hariyati et al. (2023), and Putro et al. (2023). Building on these insights, the present study distinguishes itself by employing a more comprehensive framework, incorporating a broader range of variables, a larger sample size, and diverse research locations, thereby offering a novel contribution to the understanding of how cocoa fermentation directly influences farmers' income in Indonesia.

Thus, this study aims to factors influencing farmers fermenting cocoa beans and investigate whether fermenting cocoa beans enhances farmers' income. According to the ICCO (2020), only 10% of Indonesia's total cocoa bean exports meet quality standards for taste and bean suitability. The Food and Agriculture Organization (FAO) states that the majority of Indonesian cocoa farmers sell unfermented cocoa beans (FAO, 2024). For instance, Effendy et al. (2019) observes that over 50% of cocoa farmers in Central Sulawesi do not ferment cocoa beans, citing a perceived lack of significant price difference as a primary reason. On the other hand, 99.63% of cocoa plantations in Indonesia are smallholder farms, and the majority of smallholder farmers do not understand the fermentation process (Badan Pusat Statistik, 2023).

Understanding the relationship between cocoa bean fermentation and farmers' income is crucial for improving cocoa farming practices and enhancing the livelihoods of Indonesian farmers. This study utilizes nationally representative survey data of Indonesian cocoa farmers, making its findings highly relevant for the policymaking process. By addressing the gap in research and providing valuable insights, this study aims to inform policymakers and stakeholders in the cocoa industry. By identifying barriers to fermentation adoption and evaluating its impact on farmers' income, this research contributes to the development of targeted interventions to promote sustainable cocoa farming practices in Indonesia.

Materials and methods

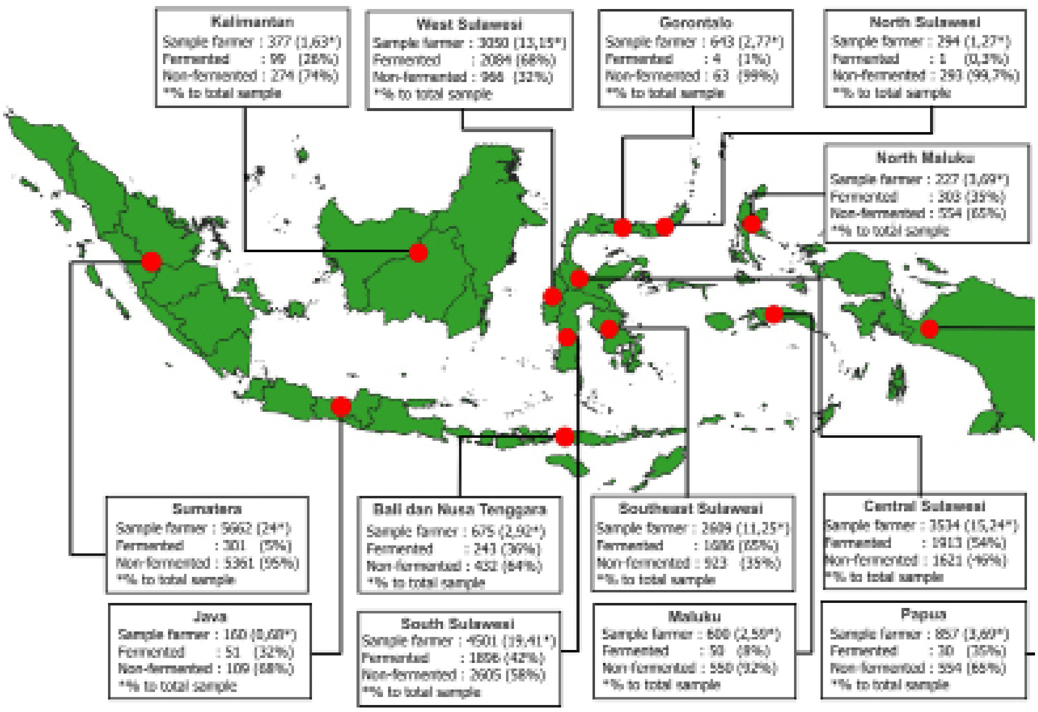
Research design

The background highlights that although cocoa bean fermentation is essential for improving quality, meeting international standards, and potentially increasing market value, most Indonesian cocoa farmers who dominate the national cocoa production still sell unfermented beans due to limited knowledge, socio-economic constraints, and perceptions of insignificant price differences. This condition has hindered Indonesia's competitiveness in the global cocoa market and contributed to low export performance. To address this gap, the present study employs a quantitative research design to systematically analyze the factors influencing farmers' decisions to ferment their cocoa and to measure the subsequent impact on income and expenses. By utilizing the nationally representative 2014 Indonesian Plantation Farm Household Survey (IPFHS), this research ensures robust and comprehensive data coverage across different regions. The quantitative approach allows comparison between farmers who ferment and those who do not, thereby directly aligning with the study's objective of assessing whether fermentation enhances farmers' income. This methodological choice not only responds to the limited prior research that directly connects fermentation with farmers' welfare but also generates evidence-based insights that can inform policymaking and targeted interventions to promote sustainable cocoa farming practices in Indonesia.

Data

This study utilizes data from the 2014 Indonesian Plantation Farm Household Survey (IPFHS), part of the Agricultural Census conducted every ten years by Indonesia's Central Statistics Agency (BPS). Although the dataset represents a cross-section from 2014, it remains the most comprehensive nationwide survey available to date. It offers a critical baseline for understanding structural issues in the Indonesian cocoa sector, specifically the low adoption of fermentation, which persist as relevant challenges in the current agricultural landscape. The dataset covers a range of plantation commodities, including coffee, cocoa, rubber, and palm oil (BPS, 2015). The rationale for using this data includes: (1) Rigorous Data Collection: The survey was conducted using stringent and standardized methods, ensuring high validity and reliability for up to ten years after publication. (2) Comprehensive Coverage: The dataset encompasses various aspects of farmers' socio-economic conditions, institutional factors, and support systems for cocoa farming in Indonesia. This breadth of information allows for a well-rounded and detailed analysis. (3) National and Regional Detail: The data provides national coverage with detailed insights into specific cocoa-producing regions in Indonesia. This extensive respondent base and geographic scope offer a comprehensive understanding of the research topic. These factors collectively ensure that the study's findings are robust and highly relevant for policy-making processes.

The research spans all cocoa-producing regions in Indonesia. Figure 1 shows the detailed distribution of these regions, starting with Sumatra Island, which includes the provinces of Aceh, North Sumatra, West Sumatra, Riau, Jambi, South Sumatra, Bengkulu, Lampung, and the Bangka Belitung Islands. Java Island comprises the provinces of West Java, Central Java, East Java, and Banten. The Bali and Nusa Tenggara regions encompass Bali, West Nusa Tenggara, and East Nusa Tenggara provinces. Kalimantan Island includes the provinces of West Kalimantan, Central Kalimantan, and East Kalimantan. Sulawesi Island covers the provinces of North Sulawesi, Central Sulawesi, South Sulawesi, Southeast Sulawesi, Gorontalo, and West Sulawesi. The Maluku Islands consist of Maluku and North Maluku provinces. Papua Island includes the provinces of West Papua and Papua. In total, the research covers 7 island groups and 29 provinces across Indonesia, representing all cocoa farmers in the country.



Source: Indonesia's Central Statistics Agency (BPS), 2014

Figure 1: Distribution of sample cocoa farmers in the study.

Analytical framework

The research employs a quantitative methodology aimed at identifying patterns and measuring specific variables through statistical and mathematical tests. The collected data are selected and classified into dependent and independent variables. The data analysis consists of Binary Logistic Regression and Propensity Score Matching. Binary Logistic Regression is used to analyze the factors influencing farmers' decisions to ferment cocoa beans. Subsequently, Propensity Score Matching will be applied to determine the differences in impact between farmers who ferment cocoa and those who do not, focusing on cost and revenue aspects. These analyses are conducted with the goal of uncovering patterns and providing a more detailed explanation of the cocoa bean fermentation issues in Indonesia.

Binary logistic regression

Logistic regression is a statistical tool used to determine whether there is a relationship between independent and dependent variables (Salam et al., 2024). The dependent variable is typically binary or qualitative dichotomous data with only two possible values, often represented as 0 and 1. In this study, the binary variable is defined as 0 for farmers who do not ferment cocoa beans and 1 for farmers who do ferment cocoa beans. The formula for binary logistic regression with two categories is as follows:

$$f(y_i) = \pi_i^{y_i}(1 - \pi_i)^{1-y_i} \tag{1}$$

where: π_i = probability of the i-th event, y_i = i-th random variable, which takes the value of 0 or 1.

The logistic regression equation with a single predictor variable is presented as follows:

$$\pi(x) = \frac{\exp(\beta_0 + \beta_1 x)}{1+\exp(\beta_0 + \beta_1 x)} \tag{2}$$

To facilitate the estimation of regression parameters, $\pi(x)$ in the previous equation is transformed to yield the logit form of logistic regression as follows:

$$g(x) = \ln\left[\frac{\pi(x)}{1-\pi(x)}\right] = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \ldots + \beta_n X_n \tag{3}$$

Estimating the impact of cocoa bean fermentation on smallholder cocoa farmers' performance

The differences in impact between farmers who ferment cocoa beans and those who do not are analyzed using Propensity Score Matching (PSM). The impact on farmers is examined in terms of costs incurred and revenues received. These aspects of costs and revenues are further detailed into indicator variables as shown in the following Table 1.

Table 1 displays the indicator variables used to assess the impact experienced by farmers who do and do not ferment cocoa beans. The treatment variable used in the Propensity Score Matching (PSM) analysis is represented by 0 and 1, where 0 denotes farmers who do not ferment cocoa beans, and 1 represents those who do. Predictor variables, which are also used in the logistic regression analysis, include those variables analyzed to determine their effect on cocoa bean fermentation. The use of the same predictor variables in both logistic regression and PSM aims to provide a more accurate estimation of treatment effects and to minimize the potential for treatment effects being influenced by selection bias (Guo et al., 2020). Additionally, employing consistent variables ensures a detailed and structured depiction of the research topic being addressed (Powell et al., 2020).

The Propensity Score Matching (PSM) analysis process consists of several stages before obtaining the final values, one of which is the Match Balance

Variable	Unit	Description
Production	kg/year	Total cocoa bean production over one year
Revenue	USD/year	Total revenue from the sale of cocoa beans over one year, excluding derivatives
Farm value per land area	USD/ha	Revenue per unit area of land used
Value per kg of production	USD/kg	Revenue per kg of cocoa bean production
Seed costs	USD/year	Costs incurred for purchasing cocoa seeds
Labor costs	USD/AWU	Costs for paying labor per Agricultural Work Unit (AWU)
Fertilizer costs	USD/year	Costs for purchasing fertilizer (solid/liquid) over one year
Pesticide costs	USD/year	Costs for purchasing pesticides (solid/liquid) over one year

Source: Authors identification, 2025

Table 1: The farm performance indicators.

stage. Match Balance is a phase where the control and treatment groups are adjusted to ensure that they have similar distributions of characteristics, making the comparison between the two groups more valid. The purpose of balancing data during the PSM analysis is to align covariate variables between the two groups, reduce selection bias and confounding, and enhance the causal validity of the research findings. In this stage, data that is evenly distributed between the two groups will be used, while data that does not meet this criterion will be excluded from the matching function. According to (Kane et al., 2020), there are three methods for achieving match balance: nearest neighbor matching, caliper matching, and kernel matching. The method employed in this study is nearest neighbor matching combined with a caliper of 0.3. This method was chosen because it is easier to implement and provides more accurate data balance with the appropriate caliper setting. Additionally, this method is more sensitive to outliers, allowing researchers to achieve balance by adjusting the caliper.

The final results of Propensity Score Matching (PSM) can be observed from the Average Treatment Effect on the Treated (ATT) values. ATT measures the effectiveness of the treatment applied to the treatment group compared to the control group. In this study, the ATT value is used to assess the effectiveness of cocoa bean fermentation among the treated group, where 0 represents farmers who did not ferment their cocoa beans, and 1 represents farmers who did. The formula for calculating ATT is given as follows:

$$ATT = E\left(Y_{1j} \middle| D_j = 1, P(X_{1j})\right) - E\left(Y_{0j} \middle| D_j = 0, P(X_{0j})\right) \quad (4)$$

Where E denotes the expected value of the outcome variable for farmers who engage in fermentation (Y_{1j}) and those who do not engage in fermentation (Y_{0j}).

Propensity Score Matching (PSM) utilizes probability values derived from propensity scores, which are obtained using either logistic regression or probit models. According to (Kane et al., 2020), these two methods are quite similar, but their use depends on the assumptions and the fit of the model to the data. This study employs a logistic regression model, where the interpretation of the regression coefficients in logistic regression refers to changes in the log-odds ratio for each one-unit change in the independent variable. The dependent variable in the model is whether farmers engage in cocoa bean fermentation, while the dependent variable consists of 10 variables used in the first research question. The formula for calculating propensity scores using the logistic regression model is as follows:

$$Y_i = \ln\left(\frac{P_i}{1 - P_i}\right) = \frac{e^{\beta_0 + \beta_1 X_{1i} + \cdots + \beta_k X_{ki}}}{1 + e^{\beta_0 + \beta_1 X_{1i} + \cdots + \beta_k X_{ki}}} \quad (5)$$

Y_i represents the decision of farmers to ferment cocoa beans or not (1 = fermentation, 0 = no fermentation), β_0 is the regression constant, β_1 are the parameters to be estimated, and X_1 are the independent variables.

Results and discussion

Socio-economic characteristics of Indonesian smallholder cocoa farmers

The socio-economic characteristics provide an overview of the conditions of cocoa farmers across Indonesia's 7 islands and 29 provinces. This overview includes various aspects such as social conditions examined through age, education level, and gender; economic aspects—assessed by land ownership and capital; and institutional aspects evaluated by farmers' participation in partnerships. Additionally, there are supplementary aspects such as the number of workers (both family and non-family), the condition of cocoa plants (productive or non-productive), and the status of seeds used (certified or uncertified). The detailed socio-economic characteristics of Indonesian cocoa farmers are summarized in the following Table 2.

Table 2 presents the details of the socio-economic characteristics of cocoa farmers, distinguishing between those who ferment their cocoa beans and those who do not. The analysis of age shows that the average age of cocoa farmers is similar between those who ferment (46 years) and those who do not (47 years). In terms of education, there is a notable difference between the two groups. Both groups have a similar percentage of farmers with no formal education (28%). However, there is a significant difference in the levels of secondary and higher education. Among farmers who practice fermentation, 32.4% have secondary or higher education, compared to 37.2% among those who do not practice fermentation. Gender distribution shows no significant difference between the two groups, with a majority of cocoa farmers in Indonesia being male (91%), and females accounting for 9%. This distribution is partly because cocoa farming is generally considered more suitable for men (Rahmaniah et al., 2022).

No	Variable	Fermented			Non-fermented		
		Mean	SD.	Freq1	Mean	SD.	Freq1
1	Age (year)	46.64	12.14		47.65	12.27	
2	Education						
	No			2,442 (28.1)			4,054 (28)
	Elementary			3,439 (39.5)			5,313 (36.7)
	Middle			1,362 (15.7)			2,408 (16.6)
	High			1,453 (16.7)			2,718 (20)
3	Gender						
	Male			7,905 (91)			13,183 (91)
	Female			791 (9)			1,310 (9)
4	UAA (m2)	495.55	622.05		641.51	1,393.38	
5	Trees						
	Yielding plants	768.80	770.72		641.81	993.97	
	Non-yielding plants	87.16	300.51		60.99	188.61	
6	Capital (IDR)	63.36	103.14		288.99	429.78	
7	Contract farming						
	Participate			2,110 (24.3)			106 (0.7)
	Non participate			6,586 (75.7)			14,387 (99.3)
8	Hired labour	0.30	1.30		0.83	1.65	
9	Family labour	2.47	2.96		2.26	0.95	
10	Seed plant						
	Certified			836 (9.6)			1,710 (11.8)
	Non-certified			7,860 (90.4)			12,783 (88.2)
	Sample size (n)			8,696			14,493

Note: The value represents the number of the farmer for each category in each group for the categorical variable
Source: Authors identification, 2025

Table 2: Socio-economic characteristics of Indonesian smallholder cacao farmer.

Farmers who do not ferment their cocoa beans have an average land size of 641.51 m², while those who practice fermentation have an average land size of 495.55 m². This indicates that non-fermenting farmers generally have 146 m² more land than fermenting farmers. Despite this, fermenting farmers tend to have a higher average number of cocoa trees compared to non-fermenting farmers. On average, fermenting farmers have 768 productive and 87 non-productive cocoa trees, while non-fermenting farmers have 641 productive and 61 non-productive trees. This is contrasted by the average capital expenditure. Non-fermenting farmers spend an average of $289, whereas fermenting farmers spend only $63.33 per observation cycle (one year). This discrepancy in capital expenditure reflects various factors, including the larger land area of non-fermenting farmers, leading to higher expenses for fertilizers, pesticides, labor costs, and other inputs.

Partnership networks are one of the ways farmers seek additional support for their agricultural activities. In terms of partnership networks, data shows that farmers who engage in cocoa bean fermentation are significantly more involved in such partnerships, with 24.3% of these farmers participating, compared to only 0.7% among those who do not practice fermentation. Farmers involved in partnerships typically receive training related to cocoa farming, especially on fermentation techniques. Additionally, most partnership agreements require farmers to sell their cocoa in fermented form. Consequently, a substantial proportion of farmers practicing fermentation are associated with these partnership networks.

The labor used in cocoa farming is divided into two categories: family labor and non-family labor. Family labor consists of relatives who often work voluntarily without payment, although they may work on a rotational basis. Non-family labor refers to workers who are not related to the farmer and are paid according to an agreed-upon rate between the two parties. Farmers who practice fermentation tend to employ less non-family labor, with an average of 0.30 workers, compared to 0.83 for non-fermenting farmers. On the other hand, the number of family laborers employed by fermenting farmers is higher, averaging 2.47, compared to 2.27 for non-fermenting farmers. Overall, this indicates that fermenting farmers use more family labor compared to non-family labor, partly to reduce costs or capital expenditures.

The characteristics of cocoa farmers vary between those who practice fermentation and those who do not, including aspects such as the use of cocoa seedlings. Cocoa seedlings used by farmers fall into two categories: certified and non-certified. Farmers who do not engage in fermentation tend to use certified seedlings more frequently (11.8%) compared to those who practice fermentation (9.6%). These socio-economic differences influence farmers' decisions to either practice or forgo fermentation. To statistically substantiate this, the study will examine the factors influencing farmers' decisions to engage in fermentation, which will be discussed in the following sections.

Factors influencing farmers fermenting cocoa beans

The factors influencing farmers to ferment cocoa beans are detailed in Table 3. The variables age and education show significant results with *β* values of 0.007 and 0.56, respectively. These values indicate that each one-unit increase in age and education will increase the likelihood of farmers fermenting cocoa beans by 0.7% and 5.6%, respectively. Research conducted by (Effendy et al., 2019) and (Rifin, 2020) suggests that older farmers tend to have more complex experiences in farming, harvesting, post-harvest processing, and sales. Additionally, they have higher levels of wisdom in accepting and applying acquired technological innovations. This finding aligns with research by (Daudu et al., 2021) on the education variable. The study indicates that the higher the education level attained by farmers, the better their ability to access information, understand and apply technology, manage economic incentives, and comprehend quality standards. Collectively, these abilities encourage farmers to adopt and apply innovations in agriculture.

Variable	β	S.E.	Sig
Age	0.007	0.001	0.000
Education	0.056	0.013	0.000
Gender	-0.003	0.047	0.941
UAA	0.000	0.000	0.019
Yielding plants	0.000	0.000	0.000
Non-yielding plants	0.001	0.000	0.000
Capital	0.000	0.000	0.000
Contract farming	3.154	0.125	0.000
Hired labor	-0.011	0.012	0.373
Family labor	0.035	0.007	0.000
Seed plants	-0.229	0.045	0.000
Constant	-0.663	0.311	0.033
Number of obs	23.189		
LR chi^2	345.69		
Prob > chi^2	0.000		
Pseudo R^2	0.120		

Source: Authors computation, 2025

Table 3: Estimated factors influencing farmers fermenting cocoa beans.

Before interpreting the individual parameters, it is crucial to evaluate the overall performance of the binary logistic regression model. The likelihood ratio test yields a Chi-square value (LR chi^2) of 345.69. The magnitude of this value indicates that the estimated model is highly suitable for predicting the factors influencing cocoa fermentation adoption. With a p-value (Prob > chi^2) of 0.000, the result is statistically significant at the 1% level ($p<0.01$), confirming that the logistic regression model is valid and feasible for use. This signifies that the set of predictor variables (age, education, UAA, yielding and non-yielding plants, capital, family labor, and seed plants) significantly improves the model's fit compared to the null model (intercept only). Furthermore, the Pseudo R-squared value of 0.120 suggests that the model explains approximately 12% of the variability in the farmers' decision to ferment cocoa beans, while the remaining 88% of the variation is influenced by unobserved variables outside the model. Although this R-squared value is typical for cross-sectional studies in social sciences, the highly significant Chi-square statistic confirms that the explanatory variables collectively play a substantial role in determining fermentation adoption.

The gender variable shows insignificant results in influencing farmers to ferment cocoa beans, meaning there is no significant difference between male and female farmers in making decisions or applying fermentation to cocoa beans. This condition arises because both male and female farmers manage cocoa beans with equal experience in farming, capital, and market access. Moreover, decisions are made collectively or based on the consensus of a group or community. Therefore, there is no tendency for one party to have more access or capability in determining various aspects, particularly in fermenting cocoa beans. This finding is consistent with the research by (Maduka et al., 2023), which states that both male and female farmers have equal access to resources, information, and training in agriculture and are equally involved in decision-making processes. According to (Bulkis et al., 2020), male and female farmers have their respective roles in cocoa farming, but harvesting, post-harvest activities, and marketing decisions are made together in a balanced manner.

Utilized Agricultural Area (UAA) and Yielding Plants both show significant results in influencing farmers to ferment cocoa beans. In general, these two variables are related in supporting farmers to ferment. The β values obtained are both 0.000, indicating that any increase in UAA and yielding plants has a negligible impact on the decision to ferment cocoa beans. This means that although significant, there is no practical impact on the farmers' decision to ferment cocoa beans. This is due to various reasons, including the possibility that fermentation activities are more influenced by other factors that play a more critical role once a certain production threshold is reached, such as age, education, capital, contract farming, family labor, and seed plants. However, despite this, research conducted by (Feyisa, 2020) and (Abebe and Bekele, 2015) shows that UAA has a significant positive value in applying the given innovations. This is because the larger the agricultural area, the more likely farmers are to utilize the entire area by planting all parts of the land with crops to increase income. Additionally, farmers with larger land areas have better capital management, so they tend to be more willing to accept and apply the given innovations to maximize income.

Non-yielding plants are cocoa trees that no longer bear fruit or have passed their productive age. These plants are usually not immediately replaced or cut down because farmers use them as temporary shade trees or for other ecological benefits without directly contributing to cocoa bean production. Therefore, they do not significantly influence farmers' decisions to ferment cocoa beans. In contrast, the variable Capital has a significant impact on the decision to ferment. A positive β value indicates that an increase in capital and contract farming by one unit increases the likelihood of farmers fermenting by 10%. Capital is a crucial aspect of sustaining cocoa farming operations. According to (Bukuru and Tabitha, 2021), capital influences farmers' responses to changes in farming conditions. Farmers with higher capital are more adaptable in accepting agricultural innovations. Additionally, (Attipoe et al., 2021) states that farmers with greater capital availability are more likely to adopt better technology and innovations because they have the necessary resources for operations and support infrastructure.

Farmers involved in contract farming are more likely to ferment their cocoa beans compared to those not involved. The analysis in this study shows a significant positive influence of contract farming on farmers' decisions to ferment. This occurs because farmers in contract farming often receive training and information dissemination, which encourages them to apply various innovative technologies, including cocoa bean fermentation (Callahan, 2019 and Kalimang`asi, N et al., 2014). Some contract farming arrangements even require their partners (farmers) to sell fermented cocoa beans, which directly encourages farmers to ferment before selling (Ngoong, J and Forgha, N, 2013). Furthermore, (Daudu et al., 2021) indicates that farmers involved in contract farming tend to ferment their beans due to price transparency between non-fermented and fermented cocoa, as well as technical support such as technical assistance and training.

The variables Hired labor and Family labor have different impacts on farmers' decisions to ferment cocoa beans. Hired labor has an insignificant effect, with a negative β value. This means that as the amount of hired labor increases, the likelihood of farmers deciding to ferment decreases. In contrast, Family labor has a positive and significant effect, with a β value of 3.5%. This indicates that family labor significantly influences the decision to ferment cocoa beans. Each unit increase in family labor results in a 3.5% increase in the likelihood of farmers deciding to ferment their cocoa beans. According to (Solarte-Guerrero et al., 2023) and (Kalimang`asi, N et al., 2014), this is due to cost considerations; as the number of family laborers increases, farmers can reallocate funds from hired labor costs to enhance production and quality by adopting innovations such as cocoa bean fermentation.

Seed plant is a nominal data variable where 0 = uncertified seeds and 1 = certified seeds.

The analysis in Table 3 shows that seed plant significantly influences farmers' decisions to ferment. However, the β value is -0.229, meaning that the decision to use certified seeds decreases the likelihood of fermentation. Conversely, farmers using uncertified seeds often have lower-quality cocoa yields compared to those using certified seeds. Therefore, farmers might ferment their cocoa beans to enhance quality and add value, as the cocoa beans from uncertified seeds tend to be of lower grade. Farmers who use certified seeds generally achieve better harvests, reducing the need for fermentation since their cocoa beans are already of high quality. Additionally, farmers using uncertified seeds may ferment their beans to improve quality and value (Gitaningtyas, 2022; and Effendy and Antara, 2015). Juanda et al. (2023) notes that farmers ferment cocoa beans to increase their value and quality, aiming to boost income.

Impact of cocoa bean fermentation on costs and revenues

The estimation of the impact differences between cocoa farmers who ferment their beans and those who do not is assessed in terms of revenue and costs using Propensity Score Matching (PSM). The analysis results are detailed in Table 4, where revenue aspects are measured using variables such as production per unit area, revenue, farm value per unit area, and production value per unit of production. Cost aspects are measured using variables such as seed costs, labor costs, fertilizer costs, and pesticide costs. The production per unit area variable represents the output obtained by farmers per unit of land area. This variable shows that the average production for non-fermented bean farmers is 1.04 kg/year, compared to 0.83 kg/year for fermented bean farmers. This indicates that non-fermented bean production per unit area is 26.27% or 0.21 kg/year higher than that of fermented bean farmers.

This trend is also observed in the variables of revenue, farm value per unit area, and production value per unit, where non-fermented bean farmers have higher values compared to fermented bean farmers. The average revenue for fermented bean farmers is only $84.42 per year, which is lower compared to $100.67 per year for non-fermented bean farmers. In terms of revenue, non-fermented bean farmers earn 19.25% more than their fermented counterparts. Research by (Sudibyo, 2017; and Awaliyah et al., 2023) indicates that farmers who do not ferment their beans have higher incomes because they can sell a greater quantity of cocoa beans compared to those who ferment their beans, due to damage during the fermentation process. In some cases, there is higher demand or better prices for non-fermented cocoa beans of certain quality. This condition drives higher income for non-fermented cocoa beans compared to fermented beans (Muñoz et al., 2020).

The agricultural value per hectare for non-fermented cocoa farmers is higher compared to fermented cocoa farmers. This value represents the income that farmers obtain per unit area of land. Non-fermented cocoa farmers have an average income of $1,772.50 per hectare per year, while fermented cocoa farmers have an average of $1,350.00 per hectare per year. The Average Treatment Effect (ATT) of 422.50 indicates that non-fermented cocoa farmers have a higher agricultural value per hectare by $422.50 per hectare per year compared to fermented farmers. A similar trend is observed in the value of production per unit, where non-fermented farmers have a higher value by 1.61% with an ATT of 0.03 compared to fermented farmers. Although this difference is

Variable	Fermented	Non-fermented	ATT	S.E.	t-stat
Production (kg/year)	0.83	1.05	0.22	1.07	20.40
Revenue (USD/year)	84.42	100.67	16.17	0.19	8.30
Farm value per land area (USD/ha)	1,350.00	1,772.50	422.50	40.00	10.37
Value per kg of production (USD/kg)	1.74	1.77	0.03	0.01	2.74
Seed costs (USD/year)	5.58	7.19	1.62	0.67	2.39
Labor costs (USD/AWU)	295.25	329.05	33.81	7.07	4.78
Fertilizer costs (USD/year)	36.46	39.95	3.48	1.40	2.48
Pesticide costs (USD/year)	26.12	21.95	-4.17	1.12	-3.74

Note: Currency conversion is based on the 2014 average exchange rate of approximately 1 USD = 12,000 IDR. Production is measured in kg/year and is not converted to currency.

Source: Authors computation, 2025

Table 4: Estimation results of propensity score matching.

not statistically significant, it suggests that each kilogram of cocoa beans sold by non-fermented farmers generates higher revenue compared to fermented farmers. This disparity is attributed to a decrease in quality due to failures or inefficiencies in the fermentation process. Consequently, the grading of cocoa beans affects pricing, where beans in certain grades can fetch higher prices even without fermentation (Forte et al., 2023). Moreover, price differences are influenced not only by quality but also by market factors, such as contextual variables that determine price management mechanisms within market dynamics and supply chains, institutional environmental strengths, production and product characteristics, and the presence of service sectors (Dixon et al., 2024).

Regarding costs, non-fermented farmers also incur higher expenses compared to fermented farmers. However, from a different perspective, Table 4 shows that fermented farmers have lower agricultural costs compared to non-fermented farmers. Fermented farmers spend an average of $5.58 per year on seeds, whereas non-fermented farmers spend $7.19 per year. Fermented farmers are often part of agricultural organizations or partnerships. In addition to receiving price stability, farmers in partnerships benefit from various aids, including seed provision. This assistance helps fermented farmers minimize their seed procurement costs (Daudu et al., 2021; Attipoe et al., 2021; and Ngoong and Forgha, 2013). The labor costs incurred by fermented cocoa farmers are 10% lower, or $33.81 less, compared to those of non-fermented cocoa farmers. Analysis from Table 3 indicates that fermented farmers rely more on family labor, leveraging a communal system that helps reduce labor costs (Oluyole et al., 2013). However, research suggests that family labor can be less effective in various tasks, leading cocoa farmers to potentially spend more on hired labor (Kissi and Herzig, 2024).

The cost of fertilizers for fermented cocoa farmers is 8.7% lower than for non-fermented farmers. The Average Treatment Effect (ATT) of 3.48 indicates that fermented farmers spend $3.48 less on fertilizers compared to non-fermented farmers. According to (Amerino et al., 2024., Owusu et al., 2022 and Anang, B, 2016), farmers who engage in fermentation have access to technology and information from various sources, enabling them to reduce fertilizer costs through methods such as using cover crops to improve soil nutrient content and moisture, maintain ecosystems, and extend the lifespan of cocoa trees. Additionally, Massresha et al. (2021), Feyisa (2020) and Djauhari et al. (2013) suggest that farmers who adopt innovations tend to have better access to information and training, allowing them to manage their farming practices more efficiently and reduce expenses. In contrast, non-fermented cocoa farmers incur lower pesticide costs compared to their fermented counterparts. Non-fermented farmers spend $21.95 per year on pesticides, while fermented farmers spend $26.12 per year. Fermented farmers thus incur 19.02% higher pesticide costs, which is attributed to the need to control pest and disease outbreaks that can damage the quality of cocoa beans.

Overall, the differences between fermented and non-fermented cocoa farmers in terms of revenue and costs indicate that non-fermented farmers have higher values for each indicator variable. According to (Ahmad et al., 2022., Purwaningsih et al., 2019 and Soemarno et al., 2015), fermented cocoa yields an added value ranging from $0.08 to $0.21 per kilogram, with a fermentation period of 6-8 days. In this study, the price per kilogram for non-fermented cocoa is $0.03 or 1.16% higher compared to fermented cocoa. Thus, the average price of non-fermented cocoa in the local market ranges from $0.08 to $0.22 per kilogram. This suggests that the local market price of cocoa does not differ significantly based on fermentation alone and is influenced by other factors such as grading, the type of cocoa cultivated, and the quality of the fermented cocoa beans. It is important to emphasize that this finding represents the national average spread across 7 islands and 29 provinces. This small price disparity might conceal significant differences at specific regional or community levels that possess shorter supply chains or specialized pricing schemes, which are not captured by the national average analysis. Meanwhile, the costs incurred by fermented farmers are generally lower for variables such as seed costs, labor costs, and fertilizer costs. In contrast, non-fermented farmers spend more to maintain the quality of their cocoa beans. This approach ensures that even though the cocoa is not fermented, its price remains comparable to that of fermented cocoa beans.

Conclusion

This study highlights the diverse socio-economic characteristics of Indonesian smallholder cocoa farmers and identifies key factors influencing their decision to ferment cocoa beans. Fermenting farmers tend to be younger, more educated, and more involved in partnerships, utilizing more family labor and incurring lower costs in seed procurement, labor, and fertilizers. However, non-fermenting farmers typically have larger land sizes, higher capital expenditure, and greater production per unit area, leading to higher overall revenue. The findings suggest that while fermentation can improve cocoa quality and value, it may not always translate to higher revenue due to increased costs and potential quality control issues during the fermentation process. Although national average data suggest that non-fermentation leads to higher revenues, the conclusion regarding the potential unprofitability of fermentation must be qualified as it is based on average values. In specific communities, or with appropriate policy interventions—especially considering that farmers in contract farming are more likely to ferment—profitability results could substantially differ. Policymakers and agricultural extension services should consider these dynamics when promoting fermentation practices, ensuring that farmers receive adequate support and training to maximize the benefits of cocoa bean fermentation.

However, this study has several limitations. First, the analysis utilized national survey data from 2014; while this serves as a robust nationwide baseline, it may not fully reflect long-term developments or recent changes in price policies, export conditions, and support systems. Second, the reliance on BPS survey data constrained the detailed analysis of key variables, such as individual farmer experience, the quality of local infrastructure, and the specific depth of technical support, thereby limiting insights into practical barriers. Finally, it is important to note that this study specifically focuses on the market environment, social structure, and policy support systems within Indonesia. Therefore, these results may not be directly transferable to other cocoa-producing countries with different institutional contexts, and the observed unprofitability of fermentation based on national averages might differ in specific communities with premium market access. Future research is therefore advised to collect in-depth primary data to investigate these specific factors and explore the long-term economic impacts of fermentation decisions.

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