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Business Finance and Value-Added Evaluation of Pagar Alam Robusta Coffee (Coffea Canephora) Functional Product with the Addition of Crude Catechin Extract from Gambir (Uncaria gambir (Hunter) Roxb)

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Abstract

This study evaluates the value added, operational cost dynamics, and ex-ante capital budgeting of full-wash Pagar Alam Robusta coffee enriched with a four percent crude catechin extract from gambier. Primary empirical processing parameters from field processing units were integrated into a enterprise simulation operating at 270 kilograms per cycle. Value-added transformation was determined using the Hayami method, while multi-year feasibility was evaluated over a five-year horizon discounted at four point seven five percent. Results show that the functional formulation yields a value-added margin of IDR 189,265 per kilogram, representing a value-added ratio of 52.57 percent. At full cycle capacity, the unit production cost of IDR 130,682 per kilogram and a cost-plus retail price of IDR 347,000 per kilogram generate an operational surplus of IDR 58,405,833 per batch. Discounted cash flow analyses indicate an ex-ante net present value of IDR 434,485,985.07, an internal rate of return of 51.80 percent, and a benefit-cost ratio of 1.031 against an initial outlay of IDR 250,650,000. Therefore, bio-fortifying Robusta coffee with natural catechins represents a financially feasible agro-industrial enterprise.

Keywords : *Crude Catechin Extract, Financial Feasibility, Full-Wash Processing, Robusta Coffee, Value Added.*

INTRODUCTION

The global functional beverage market has experienced an unprecedented paradigm shift driven by escalating consumer demand for natural health promoting foods and preventive healthcare dietary strategies. Within this evolving industrial landscape specialty coffee commodities are undergoing a transformative redefinition from simple stimulant beverages into sophisticated vehicles for bioactive compound delivery. Postharvest processing methods play a decisive role in shaping the chemical composition, volatile profiles, and organoleptic characteristics of coffee beans (Várady et al., 2022). Furthermore, controlled postharvest processing methodologies such as fully washed processing alter underlying biochemical dynamics, which directly dictates the retention of native antioxidants and sensory precursors (Wulandari et al., 2021). Parallel to developments in coffee science, botanical matrix fortificants derived from tropical flora have gained substantial momentum due to their dense concentration of secondary metabolites. In particular, Uncaria gambir represents an exceptional plant source abundant in bioactive polyphenols and crude catechin extracts that exhibit potent therapeutic properties (Wibowo et al., 2026). Consequently, integrating bioactive botanical extracts into premium processed coffee matrices creates an innovative frontier at the intersection of food engineering and agricultural economics.

Extensive scholarly research has evaluated the multi faceted chemical, pharmacological, and industrial applications of Uncaria gambir and postharvest coffee processing. Studies examining gambir extract applications demonstrate its remarkable functional versatility, ranging from natural antioxidant defense mechanisms against metabolic oxidative stress to therapeutic enhancement of endogenous antioxidant enzymes in physiological models (Utaminingsih et al., 2026). Beyond pharmaceutical and clinical contexts, crude gambir extract and its adhesive phenolic derivatives have been successfully utilized in industrial bio composites and novelty personal care formulations (Sucipto et al., 2020; Zaadah et al., 2020). Biological investigations further highlight that Uncaria gambir harbors diverse fungal endophytes with intrinsic bioactivity, reinforcing the profound biochemical complexity of this botanical resource (Waruwu et al., 2026). Concurrently, empirical assessments of specialty coffee processing reveal that wet processing methods consistently preserve desirable chemical profiles while minimizing off flavor fermentations, thereby establishing a standardized baseline bean matrix highly suitable for functional enrichment (Várady et al., 2022; Wulandari et al., 2021).

Despite these significant advances in food chemistry and botanical pharmacology, a critical conceptual and empirical gap persists in current literature regarding the economic translation of functional coffee innovation. Existing research remains predominantly constrained to laboratory scale chemical characterization, isolated extraction yields, or medical efficacy trials without evaluating the microeconomic realities of product commercialization. Scholars frequently investigate the bioactivity of crude catechin extracts or coffee processing methods in isolation, yet they overlook how functional fortificants alter processing cost structures, capital outlay, and revenue distribution. Furthermore, the integration of specialized extraction technologies such as rotary evaporation introduces substantial capital expenditure and variable input costs that traditional coffee value chain models fail to account for. Current economic literature lacks a comprehensive, integrated framework that simultaneously quantifies financial feasibility metrics alongside Hayami value added distribution for biofortified functional coffee products originating from regional production hubs.

This literature gap creates severe scientific and practical urgency, particularly for regional agricultural economies that remain vulnerable to commodity price volatility. Regional producers in major Robusta coffee belts, such as Pagar Alam in South Sumatra, predominantly export raw green beans or minimally processed commodities, thereby forfeiting the vast majority of economic surplus to downstream processing entities. While introducing 4% crude catechin extract from Uncaria gambir into full wash processed Robusta coffee offers a compelling value creation opportunity, the lack of rigorous ex ante financial analysis creates prohibitive uncertainty for local agro industrial entrepreneurs. Without precise quantification of net present value, internal rate of return, and factor share distribution between capital and labor, stakeholders cannot evaluate whether the substantial upfront investment in extraction technology can be financially sustained. Resolving this ambiguity is essential to establish evidence based decision making models that can successfully bridge laboratory level food innovation with viable regional industrialization.

To address this strategic knowledge void, this research establishes a novel academic bridge between postharvest food processing technology and microeconomic capital evaluation. Positioned squarely at the intersection of functional food engineering, industrial cost accounting, and agricultural value chain optimization, this study provides an integrated dual analytical framework. By combining the Hayami value added method with comprehensive ex ante financial capital evaluation, this investigation contextualizes a specific, standardized functional product formulation comprising Pagar Alam full wash Robusta coffee enriched with 4% crude catechin extract from Uncaria gambir. Unlike conventional studies that offer broad descriptive surveys of agricultural commodities, this research rigorously models real world production parameters, input output margins, factor compensations, and discounting cash flows under actual regional operating conditions (Wibowo et al., 2026; Wulandari et al., 2021).

The primary objective of this study is to evaluate the economic value added and ex ante financial feasibility of producing functional Pagar Alam Robusta coffee enriched with 4% crude catechin extract from Uncaria gambir. Methodologically, this paper advances agro industrial research by demonstrating an operational protocol for quantifying conversion factors, labor share, processing profit, and capital profitability metrics such as Net Present Value, Internal Rate of Return, and Benefit Cost Ratio under real world production constraints. Theoretical contributions include expanding agro industrial value chain theory through the explicit integration of botanical extraction investment dynamics into classical value added conversion frameworks. Ultimately, this research offers robust empirical guidance for regional coffee processors, policy makers, and agribusiness investors seeking to establish sustainable, high value functional coffee enterprises.

RESEARCH METHODS

This study is empirical in nature, utilizing a descriptive quantitative research design that combines postharvest agroindustrial processing with field based techno economic simulation for a single novel functional beverage product. The innovation development process encompasses the full wash processing of Pagar Alam Robusta coffee beans systematically enriched with a four percent weight by weight crude catechin extract derived from gambier leaves through solvent extraction, filtration, and rotary evaporation. Primary empirical data regarding physical mass balances, raw material expenditures, equipment capital outlay, utility consumption, and direct labor requirements fixed at two human work hours per kilogram were directly collected from field operations and processing units in Pagar Alam, South Sumatra. These empirical parameters were subsequently operationalized within a controlled enterprise simulation framework operating at a capacity of 270 kilograms per production cycle to establish a precise foundation for economic modeling.

Methodological robustness and analytical rigor are ensured through a dual framework evaluating value added transformation and ex ante financial viability over a five year operational horizon. Economic value creation is evaluated using the Hayami method on a standardized one kilogram finished product basis to determine conversion factors, processing margins, labor remuneration, and net processing profit generated by functional product differentiation. Enterprise feasibility is rigorously validated using Net Present Value, Internal Rate of Return, and Benefit Cost Ratio metrics discounted at a baseline rate of four point seven five percent, supplemented by cost plus pricing mechanisms utilizing a one hundred sixty five percent markup over unit production costs. By integrating empirical primary data with formal capital budgeting and discounted cash flow modeling, this methodology provides a unique, highly replicable analytical structure specifically tailored for evaluating functional agroindustrial ventures.

RESULTS AND DISCUSSION

Value-Added Evaluation and Transformation Dynamics of Functional Pagar Alam Robusta Coffee

The empirical evaluation of processing Pagar Alam Robusta coffee (Coffea canephora) through full-wash processing supplemented with crude catechin extract from gambir (Uncaria gambir (Hunter) Roxb) reveals a significant transformation in economic value. Land suitability and regional agronomic mapping in West Sumatra and South Sumatra highlight the strategic advantage of integrating gambir and coffee supply chains in local agroindustries (Aflizar et al., 2023). Postharvest wet processing systematically removes pulp and mucilage, stabilizing raw bean quality before the functional bio-enrichment phase (Pereira et al., 2020). The incorporation of active polyphenols alters the physical and chemical matrix of green coffee beans, creating a distinct value proposition (Bastian et al., 2021). Consequently, functional differentiation converts bulk coffee commodities into high-value health-oriented beverages with enhanced commercial appeal (Agustini et al., 2022).

The baseline physical conversion factor is established at 1.00 based on the standardized output-to-input ratio during the finished product formulation stage. Labor inputs are quantified at exactly 2.00 human work hours per kilogram (JKO/kg) to execute precise postharvest, extraction, and blending protocols. Operating at a standardized labor wage of IDR 15,000 per hour yields a direct labor remuneration of IDR 30,000 per kilogram of finished output. This structural wage allocation ensures fair compensation while maintaining operational cost control across processing units (Analianasari et al., 2024). Systematic labor accounting serves as a critical parameter for evaluating the socioeconomic distribution of value creation in smallholder-linked processing enterprises (Nurhaliza et al., 2024).

Raw material inputs reflect the combined economic value of raw coffee green beans and purified botanical adjuncts. Full-wash Pagar Alam Robusta coffee beans are valued at IDR 120,000 per kilogram, reflecting baseline agricultural production expenditures. Non-coffee inputs, including ethanol solvent, filtration materials, specialized packaging, and utility overhead, contribute an additional IDR 50,735 per kilogram. The addition of gambir crude catechin extract represents a major non-coffee cost driver necessary to achieve bioactive enrichment (Santoso & Pangawikan, 2022). Solvent extraction and rotary evaporation parameters determine the physical cost structure of the functional additive (Shiyan et al., 2025).

The economic value of the enriched functional coffee output reaches IDR 360,000 per kilogram based on market positioning for functional beverages. Deducting the combined raw material costs and auxiliary input contributions from output value yields a net value added of IDR 189,265 per kilogram. This transformation corresponds to a value-added ratio of 52.57%, demonstrating substantial economic surplus generation during processing. Such substantial value expansion confirms that chemical fortification provides far greater economic returns than raw commodity trade (Santoso et al., 2023). Value creation at this level surpasses traditional bean fermentation and simple roasting protocols (Ferreira et al., 2023).

The net processing margin created during the transformation equals IDR 240,000 per kilogram, calculated as the difference between gross output value and raw coffee input costs. Direct labor compensation accounts for 12.50% of the gross processing margin, representing a consistent reward for specialized human capital. Auxiliary input costs absorb 21.14% of the processing margin, reflecting the intensive resource utilization inherent in phytochemical extraction. The remaining 66.36% of the margin is captured as net enterprise profit within the Hayami value-added framework. This allocation profile highlights strong entrepreneurial returns while maintaining adequate budget coverage for operational consumables (Julianti & Pratama, 2024).

Table 1. Hayami Method Value-Added Analysis of Full-Wash Robusta Coffee Enriched with 4% Crude Catechin Extract

No.	Variable	Formula	Value
I	**Input and Output Parameters**		
1	Output Quantity	(1)	1.00 kg
2	Input Quantity	(2)	1.00 kg
3	Direct Labor Input	(3)	2.00 JKO
4	Conversion Factor	(4) = (1) / (2)	1.00
5	Labor Coefficient	(5) = (3) / (2)	2.00 JKO/kg
II	**Price and Cost Factors**		
6	Finished Product Price	(6)	IDR 360,000/kg
7	Direct Labor Wage	(7)	IDR 15,000/JKO
8	Raw Material Coffee Price	(8)	IDR 120,000/kg
9	Other Input Contributions	(9)	IDR 50,735/kg
III	**Value-Added and Revenue Distribution**		
10	Output Value	(10) = (4) × (6)	IDR 360,000/kg
11a	Net Value Added	(11a) = (10) - (9) - (8)	IDR 189,265/kg
11b	Value-Added Ratio	(11b) = [(11a) / (10)] × 100%	52.57%
12a	Labor Remuneration	(12a) = (5) × (7)	IDR 30,000/kg
12b	Labor Share of Value Added	(12b) = [(12a) / (11a)] × 100%	15.85%
13a	Hayami Enterprise Profit	(13a) = (11a) - (12a)	IDR 159,265/kg
13b	Profit Share of Value Added	(13b) = [(13a) / (11a)] × 100%	84.15%
IV	**Processing Margin Distribution**		
14	Gross Processing Margin	(14) = (10) - (8)	IDR 240,000/kg
14a	Labor Share of Margin	[(12a) / (14)] × 100%	12.50%
14b	Other Inputs Share of Margin	[(9) / (14)] × 100%	21.14%
14c	Enterprise Profit Share of Margin	[(13a) / (14)] × 100%	66.36%

Source: Primary empirical data processed by authors, 2025.

The net processing profit within the Hayami analytical framework reaches IDR 159,265 per kilogram of finished functional coffee. This profit represents 84.15% of total generated value added, proving that functional enrichment yields highly favorable economic efficiency. High profit retention stems from the premium valuation placed on health-promoting herbal coffee formulations (Purnawan et al., 2025). Extracting polyphenolic compounds from native gambier leaves offers a scalable mechanism for adding value to regional botanical resources (Arumsari, 2021). Such financial efficiency provides strong economic justification for scaling functional coffee processing at the enterprise level (Júnior et al., 2021).

Phytochemical fortification using Uncaria gambir catechin extract introduces functional properties that justify the premium market price. Catechin compounds exhibit exceptional antioxidant performance, neutralizing reactive oxygen species effectively (Wibowo et al., 2026). Molecular studies show that purified catechins demonstrate high bioactivity suitable for therapeutic and metabolic health applications (Aminah et al., 2025). Furthermore, gambier catechins maintain systemic glucose homeostasis, reinforcing the health claims of functional functional beverages (Rita et al., 2024). Combining coffee bioactive compounds with gambier catechins delivers synergistic metabolic benefits to consumers (Jannah et al., 2025).

Biochemical stabilization during full-wash processing prevents off-flavor development and maintains structural uniformities required for extract infusion (Várady et al., 2022). Wet processing controls sugar breakdown and organic acid concentrations within Robusta coffee beans (Wulandari et al., 2021). Clean bean surfaces facilitate uniform adherence of dried crude catechin extract during physical enrichment (Santoso et al., 2021). Controlled processing minimizes tannin precipitation while preserving the natural sensory profile of Robusta coffee (Sucipto et al., 2020). Maintaining biochemical integrity ensures that functional coffee products meet international specialty standards (Sucipto et al., 2020).

Beyond metabolic health, catechin enrichment provides antibacterial, oral microflora balancing, and pharmacological properties (Murad et al., 2022). Herbal formulations incorporating Uncaria gambir exhibit documented biological activity against pathogens and cellular degradation (Pramanik et al., 2024). Endogenous antioxidant activity is markedly enhanced when botanical polyphenols are introduced into daily dietary regimes (Utaminingsih et al., 2026). These multifaceted biomedical advantages substantiate the functional positioning of enriched Pagar Alam Robusta coffee (Kamal & Rusdi, 2018). Furthermore, botanical extracts from similar species show anti-hyperuricemic and tissue protective effects (Mulyani et al., 2025).

Integrative agroindustrial processing leverages native plant diversity, fungal biosecurity, and ecological suitability across Sumatran plantations (Waruwu et al., 2026). Natural phytochemical additives offer environmentally sustainable alternatives to synthetic food fortificants (Zaadah et al., 2020). In livestock and agricultural systems, gambier polyphenols even show efficacy in reducing rumen methane emissions and improving metabolic efficiency (Antonius et al., 2025). The value-added evaluation confirms that functional Robusta coffee processing creates substantial economic returns while advancing regional bioeconomy goals. Sustainable supply chain linkages between coffee growers and gambier harvesters enhance the overall resilience of the rural agroindustry (Analianasari et al., 2024).

Operational Cost Dynamics, Production Economics, and Capital Allocation Strategy

The operational cost dynamics of processing functional Pagar Alam Robusta coffee enriched with crude catechin extract require a structured economic framework to evaluate fixed and variable expenditures per batch. In a standardized production run scaled to a output volume of 270 kg per cycle, total variable expenditures reach IDR 29,440,000, encompassing raw coffee cherries, dried gambir leaves, extraction solvents, packaging materials, direct labor, and municipal utilities. Fixed cost allocations contribute an additional IDR 5,844,167 per cycle, which covers allocated asset depreciation and facility overheads to maintain operational continuity. Empirical assessments confirm that establishing fixed allocation ratios prevents cost underestimation in specialized agro-industrial processing lines. Consequently, combining variable operational inputs and allocated fixed overhead yields a comprehensive cost structure of IDR 35,284,167 for each 270 kg manufacturing cycle.

Establishing a reliable Unit Production Cost, commonly referred to as *Harga Pokok Produksi* (HPP), serves as the baseline for downstream commercial strategy and product positioning. Dividing the total cycle expenditure of IDR 35,284,167 by the finished product output of 270 kg establishes a unit production cost of IDR 130,682 per kilogram. Techno-economic analyses by Júnior et al. (2021)

demonstrate that specialized bio-fortification processes inherently elevate baseline production costs compared to conventional coffee processing due to multi-stage processing steps. The inclusion of solvent extraction and concentration stages introduces operational complexity that demands higher cost management protocols. Consequently, the derived unit cost reflects both raw commodity inputs and the specialized processing requirements necessary to produce high-value functional coffee.

To capture market value while ensuring corporate profitability, a strategic cost-plus pricing model is applied to the established baseline unit cost. Applying a targeted 165% markup over the base production cost establishes a retail unit price of IDR 347,000 per kilogram. This pricing structure aligns with empirical recommendations for value-added agricultural products, where premium margins compensate for initial research, equipment risk, and specialized formulation costs (Julianti & Pratama, 2024). The resulting retail price position enables the venture to capture premium market segments seeking functional health benefits from enriched beverage products. Furthermore, maintaining this price point ensures adequate gross margins to absorb potential market fluctuations and raw material price volatility.

Evaluating cycle revenues against total operational expenditures illustrates the primary financial throughput generated by the processing plant. Selling the 270 kg batch output at the established price of IDR 347,000 per kilogram generates gross cycle revenues of IDR 93,690,000. Subtracting total production expenditures of IDR 35,284,167 yields a net operational surplus of IDR 58,405,833 per production cycle. Financial evaluations in coffee agro-industries indicate that generating substantial operational surpluses per batch is critical for maintaining cash liquidity and supporting long-term asset renewal (Nurhaliza et al., 2024). This substantial cycle surplus validates the economic viability of transforming standard Robusta beans into high-value functional formulations.

To provide a clear, empirical overview of capital deployment, operational expenditures, and price derivation for a single 270 kg production cycle, the quantitative operational structure is synthesized in Table 2 below.

Table 2. Capital Expenditure Allocation and Operational Cost Structure for a 270 kg Functional Coffee Production Cycle

Category / Asset Description	Unit Cost (IDR)	Quantity / Scale	Total Outlay (IDR)	Operational Allocation / Cycle (IDR)
I. Capital Outlay (Fixed Assets)				
Solar Drying House (Dorm)	15,000,000	2 Units	30,000,000	Allocated Depreciation
Processing Facility Lease	25,000,000	1 Year	25,000,000	Allocated Depreciation
Mechanical Pulper Machine	8,000,000	3 Units	24,000,000	Allocated Depreciation
Coffee Huller Machine	9,000,000	1 Unit	9,000,000	Allocated Depreciation
Green Bean Size Grader	10,000,000	1 Unit	10,000,000	Allocated Depreciation
Moisture & Temp Analyzer	15,000,000	1 Unit	15,000,000	Allocated Depreciation
Fermentation Racks (5x5 m)	450,000	2 Units	900,000	Allocated Depreciation
Coffee Roasting Machine	12,000,000	1 Unit	12,000,000	Allocated Depreciation
Industrial Coffee Grinder	600,000	4 Units	2,400,000	Allocated Depreciation

Digital Scale (150 kg Capacity)	950,000	1 Unit	950,000	Allocated Depreciation
High-Speed Industrial Blender	20,000,000	1 Unit	20,000,000	Allocated Depreciation
Stainless Steel Sieve (60 Mesh)	700,000	2 Units	1,400,000	Allocated Depreciation
Industrial Rotary Evaporator	100,000,000	1 Unit	100,000,000	Allocated Depreciation
Subtotal Initial Capital Outlay			**250,650,000**	
II. Cycle Operational Economics (270 kg Output)				
Variable Production Expenditures	Variable Inputs	270 kg Scale	-	29,440,000
Fixed Cost Allocation	Fixed Overhead	Per Cycle	-	5,844,167
Total Production Cost per Cycle			-	**35,284,167**
Unit Production Cost (HPP)	Formula: Cost / 270 kg	Per kg Output	-	**130,682 / kg**
Retail Unit Price (165% Markup)	Formula: HPP × 2.65	Per kg Output	-	**347,000 / kg**
Gross Cycle Revenue	270 kg × IDR 347,000	Per Cycle	-	**93,690,000**
Net Operational Surplus per Cycle	Revenue - Total Cost	Per Cycle	-	**58,405,833**

Source: Primary empirical data processed by authors, 2025.

The initial capital outlay required to establish the operational infrastructure totals IDR 250,650,000 across primary processing and extraction hardware. Asset allocation involves acquiring post-harvest equipment including pulpers, hullers, drying structures, roasters, and quality measurement instrumentation. Technical literature emphasizes that investing in robust primary processing machinery is necessary to secure consistent green bean quality prior to bio-fortification (Bastian et al., 2021). The structured capital allocation ensures that all stages, from wet processing to final grinding, operate under controlled physical conditions. Consequently, the capital outlay provides the baseline infrastructural foundation required to maintain long-term production standards.

A critical feature of the initial capital deployment is the acquisition of an industrial rotary evaporator valued at IDR 100,000,000, representing 39.89% of the total investment. Solvent extraction technology is essential for isolating polyphenol-rich crude catechins from gambir leaves without thermal degradation (Santoso & Pangawikan, 2022). Empirical optimizations by Shiyan et al. (2025) confirm that efficient rotary evaporation is required to maximize polyphenol yield while enabling industrial solvent recovery. Allocating a major share of capital to extraction infrastructure ensures precise control over crude catechin concentration during batch preparation. Thus, the heavy investment in evaporation hardware directly enables the transformation of standard Robusta coffee into a high-value functional commodity.

The integration of botanical extracts into beverage matrices requires specialized secondary processing machinery to maintain standardized enrichment levels. The procurement of high-speed industrial blenders, precision mesh sieves, digital scales, and automated roasters accounts for IDR

36,750,000 of the capital budget. Modern processing frameworks indicate that precise particle size reduction and homogeneous liquid mixing are vital for uniform bioactive compound distribution in functional formulations (Santoso et al., 2023). Standardizing particle mesh sizes prevents precipitation during brewing while preserving sensory acceptability. Therefore, capital allocation toward secondary blending equipment ensures product consistency across sequential manufacturing cycles.

Facility leasing and post-harvest drying infrastructure require an initial capital commitment of IDR 55,000,000 to support primary processing operations. Constructing dedicated solar drying dormitories and securing processing facilities protects parchment coffee from environmental contamination and mold development (Wulandari et al., 2021). Controlled drying environments are documented to preserve natural antioxidants and volatile precursors prior to roasting (Várady et al., 2022). Maintaining strict moisture control prevents chemical degradation of added botanical compounds during subsequent storage and roasting. Consequently, infrastructure expenditures directly safeguard raw material integrity before secondary processing.

The operational cost dynamics demonstrate that high initial capital outlays are compensated by robust unit profit margins during operational cycles. With an initial investment of IDR 250,650,000, the enterprise generates an operational surplus of IDR 58,405,833 per 270 kg production run. Techno-economic literature indicates that agro-industrial processing lines exhibiting high gross surplus margins achieve rapid capital recovery and operational resilience (Analianasari et al., 2024). The substantial surplus generated per batch provides strong internal funding to service initial capital obligations and fund future operational expansion. Ultimately, the production economics confirm that the proposed functional coffee processing system achieves financial balance between asset expenditure and operational profitability.

Ex-Ante Capital Budgeting, Discounted Cash Flow Dynamics, and Multi-Year Feasibility Assessment

The ex-ante financial evaluation over a five-year operational horizon provides a robust analytical framework to assess long-term capital efficiency and economic sustainability. Capital budgeting models integrate initial outlay requirements with multi-year net cash flow projections to determine investment viability under dynamic market conditions. Financial metrics published by Nurhaliza et al. (2024) confirm that evaluating discounted cash inflows against upfront capital commitments is essential for capturing the true economic surplus of specialty coffee processing ventures. Incorporating time-value mechanisms ensures that future operating returns are rigorously adjusted for capital opportunity costs. Consequently, multi-year cash flow forecasting serves as the baseline for assessing long-term solvency and enterprise risk.

The structural capital commitment required to initiate operations is anchored by an upfront capital outlay of IDR 250,650,000 at Year 0. Operating revenues scale progressively from IDR 131,582,901.23 in Year 1 to IDR 192,218,262.50 by Year 5, reflecting market expansion and operational stabilization. Long-term business feasibility analyses by Analianasari et al. (2024) demonstrate that structured operational expansion enhances local agro-industrial development while generating strong socio-economic returns. The annual cash inflows successfully offset operational expenditures, generating positive net operating margins throughout the evaluation period. Thus, the enterprise maintains consistent internal liquidity to cover recurring expenditures and asset maintenance obligations.

To evaluate cash flow dynamics under rigorous economic standards, all projected cash streams are discounted at a baseline rate of $r = 4.75\%$. Applying this discount rate yields present value inflows ranging from IDR 125,616,134.83 in Year 1 to IDR 152,413,869.47 in Year 5. Supply chain sustainability studies by Aflizar et al. (2023) emphasize that establishing predictable discounted cash flows over multi-year horizons is vital for maintaining long-term agricultural processing viability. The cumulative discounted revenue streams exceed initial investment hurdles, confirming strong capital recovery potential. Therefore, the discounted cash flow structure demonstrates high capital efficiency and low long-term financial risk.

The comprehensive five-year discounted cash flow projection, ex-ante capital budgeting synthesis, and financial decision metrics are detailed in Table 3 below.

Table 3. Five-Year Discounted Cash Flow Projection and Ex-Ante Capital Budgeting Synthesis ($r = 4.75\%$)

Project Year (t)	Gross Benefit (IDR)	Total Cost / Outlay (IDR)	Net Cash Flow (CFt) (IDR)	Discount Factor (r=4.75%)	Present Value (PV) Cash Flow (IDR)
Year 0	-	250,650,000	-250,650,000	1.0000	-250,650,000.00
Year 1	131,582,901.23	83,000,000.00	131,582,901.23	0.9547	125,616,134.83
Year 2	153,041,191.36	83,000,000.00	153,041,191.36	0.9114	139,476,255.94
Year 3	146,893,310.49	112,752,000.00	146,893,310.49	0.8700	127,802,668.99
Year 4	168,347,761.54	117,262,080.00	168,347,761.54	0.8306	139,827,057.83
Year 5	192,218,262.50	121,952,563.20	192,218,262.50	0.7929	152,413,869.47
Cumulative Total	**792,083,427.13**	**768,616,643.20**	-	-	**NPV = 434,485,985.07**
Feasibility Metric	**Calculated Value**	**Target Criteria**	**Feasibility Decision**		
Net Present Value (NPV)	IDR 434,485,985.07	NPV > 0	Feasible		
Internal Rate of Return (IRR)	51.80% (≈ 52%)	IRR > 4.75%	Feasible		
Benefit-Cost Ratio (B/C)	1.031	B/C > 1.000	Feasible		

Source: Primary empirical data processed by authors, 2025.

The valuation analysis yields a Net Present Value of IDR 434,485,985.07, substantially exceeding the required decision threshold of $\text{NPV} > 0$. This positive metric confirms that the enterprise generates absolute wealth over five years beyond capital recovery obligations. Clinical and biochemical valuations by Utaminingsih et al. (2026) show that functional health products enriched with *Uncaria gambir* extracts command sustained consumer demand due to elevated antioxidant properties. Premium bioactive differentiation strengthens market competitiveness and stabilizes long-term product pricing. Consequently, strong product fundamentals directly drive net present value creation across multi-year operational cycles.

Evaluating the internal efficiency of capital deployment reveals an Internal Rate of Return of 51.80% ($\approx 52\%$), significantly surpassing the 4.75% baseline discount hurdle. High internal rates of return indicate that the enterprise possesses strong financial buffer capacity against operational shocks. Pharmacological and metabolomic assessments by Wibowo et al. (2026) validate that natural polyphenol fortification creates high added-value potential in consumer markets. High product efficacy supports strong sales price stability, preserving high internal profit rates. Thus, the derived IRR demonstrates exceptional investment returns relative to benchmark capital costs.

The cumulative financial performance registers a Benefit-Cost Ratio of 1.031, satisfying the fundamental economic criterion of $\text{B/C} > 1.000$. Total cumulative gross benefits reach IDR 792,083,427.13 against total lifetime outlays of IDR 768,616,643.20. Biomedical studies by Rita et al. (2024) confirm that purified catechin isolates provide valuable functional properties that justify premium consumer pricing strategies. Stable consumer willingness to pay protects gross operational receipts over extended planning periods. As a result, the positive B/C ratio validates overall financial efficiency and structural feasibility.

The functional beverage market positioning is further reinforced by the therapeutic and bio-fortification properties of botanical additives. Research by Aminah et al. (2025) highlights the enhanced biological stability of bioactive catechins, while Pramanik et al. (2024) confirm the therapeutic versatility of *Uncaria gambir* derivatives. Complementary findings by Jannah et al. (2025) and

Purnawan et al. (2025) demonstrate that integrating gambier extracts into specialty beverages significantly enhances radical-scavenging capacities without compromising organoleptic quality. Added functional benefits expand market potential beyond conventional beverage segments. Therefore, bio-fortification supports premium product positioning and safeguards long-term revenue streams.

Broadening the commercial scope of catechin-enriched formulations aligns with expanding industrial applications of bioactive compounds. Industrial studies by Kamal & Rusdi (2018), Zaadah et al. (2020), and Sucipto et al. (2020) demonstrate the functional versatility of gambier catechins across diverse consumer applications. In food systems, Mulyani et al. (2025) and Agustini et al. (2022) confirm that combining plant extracts with functional beverages delivers documented metabolic health benefits. Furthermore, antimicrobial research by Murad et al. (2022) and Waruwu et al. (2026) reinforces the biological stability of *Uncaria gambir* extracts. These multidisciplinary applications underline the robust market foundation supporting the long-term commercialization of enriched Robusta coffee.

Despite favorable baseline feasibility metrics, long-term operational continuity remains exposed to external market volatility and raw material cost fluctuations. Environmental studies by Antonius et al. (2025) and Arumsari (2021) indicate that natural catechin yields can vary depending on harvest quality and extraction efficiency. Variations in raw material costs require effective supply chain management to protect profit margins. Maintaining strict quality standards prevents cost overruns during secondary processing. Consequently, active operational monitoring is necessary to preserve long-term financial performance.

The ex-ante capital budgeting evaluation confirms that bio-fortified Pagar Alam Robusta coffee processing is a financially viable venture. All primary feasibility metrics, including NPV, IRR, and B/C Ratio, consistently meet their respective investment criteria. High internal returns provide strong capital protection against potential raw material price volatility. Strong product differentiation, grounded in verified bioactive properties, secures stable market demand over the five-year operational horizon. Ultimately, combining primary empirical processing parameters with formal discounted cash flow modeling establishes a reliable foundation for commercial scaling.

CONCLUSION

Integrated empirical transformation dynamics, operational economics, and ex-ante financial budgeting conclusively establish that enriching full-wash Pagar Alam Robusta coffee with a four percent crude catechin extract creates a highly viable functional enterprise. Utilizing the Hayami evaluation framework, the post-harvest bio-fortification process generates a positive value-added margin of IDR 189,265 per kilogram with a high value-added ratio of 52.57 percent, reflecting significant economic retention at the processing level. Cycle-level operational modeling demonstrates that an output capacity of 270 kilograms per run yields a cost-effective unit production cost of IDR 130,682 per kilogram, allowing a strategic cost-plus price point of IDR 347,000 per kilogram to secure a net operational surplus of IDR 58,405,833 per cycle. Over a five-year operational horizon discounted at a four point seven five percent baseline rate, the initial capital outlay of IDR 250,650,000 delivers a net present value of IDR 434,485,985.07, an internal rate of return of 51.80 percent, and a benefit-cost ratio of 1.031, validating enterprise solvency and structural feasibility. Consequently, combining controlled full-wash processing with functional polyphenol enhancement offers a sound agro-industrial strategy for escalating market competitiveness and securing long-term economic returns.

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