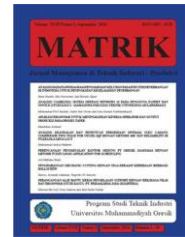




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Full Costing Analysis of Oil Palm Frond Waste Egg Trays

Salwa Adisa Putri¹, Arief Suardi Nur Chairat^{2*}, Adilla Khairani³, Nazwa Adelia Syahputri⁴,
Diego Kevin Pangaribuan⁵

^{1,2,3,4}Department of Industrial Engineering, Faculty of Energy Technology and Business – Institut
Teknologi PLN

⁵Department of Environmental Engineering, Faculty of Infrastructure and Regional Development –
Institut Teknologi PLN

Jalan Lingkar Luar Barat, Jakarta Barat 11750, Indonesia

Email : arief.suardi@itpln.ac.id

*Corresponding Author

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ABSTRACT

Indonesia, as one of the largest palm oil producers, generates large amounts of biomass waste including oil palm fronds. This waste has the potential to be utilized as an alternative raw material for environmentally friendly packaging products such as pulp-based egg trays. This study aims to analyze the cost of goods manufactured (COGM) of egg trays made from oil palm frond waste using the full costing method. The calculation includes direct raw material costs, direct labor costs, variable manufacturing overhead costs, and fixed manufacturing overhead costs. The results show that the COGM of egg trays made from oil palm fronds is Rp1,050 per unit. The largest cost component comes from direct labor, indicating that the production process is still semi-manual and labor-intensive. Compared with the indicative market price of conventional cardboard egg trays, which ranges from Rp800 to Rp1,000 per unit, the product cost is slightly higher. However, market prices may vary depending on purchase scale, product quality, and specifications. This study indicates that egg trays made from oil palm frond waste have promising potential, particularly through improvements in productivity, process efficiency, and larger-scale production.



1. Introduction

Indonesia is the world's largest palm oil producer, with approximately 40% of the 14.60 million hectares of plantation areas managed by smallholders [1]. Palm oil plantation activities not only produce crude palm oil (CPO) but also generate large amounts of biomass waste, particularly oil palm fronds [2]. Routine pruning activities conducted every two weeks produce approximately $\pm 4,500$ kg of oil palm fronds per hectare [3]. Without proper waste management systems, the accumulation of oil palm fronds in plantation areas may disrupt operational activities and contribute to environmental pollution.

The mechanical properties of oil palm fronds, such as being lightweight, easily shaped, and relatively resistant to moisture, are influenced by their high lignocellulosic content, consisting of 40% cellulose, 30% hemicellulose, and 25% lignin [4]. These characteristics make oil palm fronds highly potential as raw materials for pulp-based products [5]. Lignocellulosic waste from organic materials can be processed into value-added pulp products, including the utilization of used egg tray cardboard to produce nanocellulose [6]. Mujtaba also reported that lignocellulosic biomass waste from plantations can be utilized as a raw material source for pulp and bioplastics [7]. However, these studies did not comprehensively analyze production costs, making the economic feasibility of the products difficult to evaluate. On the other hand, Marliyah & Lubis applied the variable costing method to calculate the production cost of crude palm oil (CPO) [8]. Nevertheless, the method was unable to represent total production costs because it excluded fixed manufacturing overhead costs. Consequently, the study could not effectively support product pricing decisions and competitiveness analysis.

Cost of Goods Manufactured (COGM) refers to the total cost incurred in producing finished goods, including direct material costs, direct labor costs, and manufacturing overhead costs [9]. In determining COGM, the full costing method allocates all production costs, both variable and fixed, into the product cost so that

each product unit absorbs all manufacturing expenses incurred [8]. In contrast, the variable costing method only includes variable production costs in the COGM calculation, while fixed costs are treated as period costs and directly charged to the income statement. Differences in the treatment of fixed costs may result in different COGM and profit calculations, making the selection of costing methods important depending on reporting objectives and managerial decision-making needs [9].

Based on previous studies, oil palm fronds can be utilized as pulp-based raw materials. This material is considered suitable for egg tray production because it is lightweight, inexpensive, and resistant to moisture, allowing it to protect eggs during distribution [10]. The selection of egg tray material is important because it can affect egg quality, including egg pH, Haugh unit, and nutritional contents such as protein and fat [11]. Changes were observed in eggs stored in plastic-based containers for 28 days, where protein and fat contents decreased significantly. In addition, longer storage duration increases bacterial activity in metabolizing egg proteins, resulting in a greater reduction of protein content. Therefore, selecting appropriate egg tray materials can help minimize nutritional degradation in eggs.

The increasing consumption of chicken eggs in Indonesia, which reached 6.92 kg/capita/year in 2020 [12], indicates a stable and sustainable demand for egg trays. This condition creates promising market opportunities for environmentally friendly egg tray products. Moreover, the production process utilizes relatively simple technology, making it suitable for implementation by small and medium enterprises (SMEs), particularly those operating in the agricultural waste processing sector, eco-friendly packaging production, and community-based manufacturing industries located around palm oil plantation areas [13]. These SMEs generally face challenges in creating value-added products from abundant oil palm biomass waste, including oil palm fronds, which are often

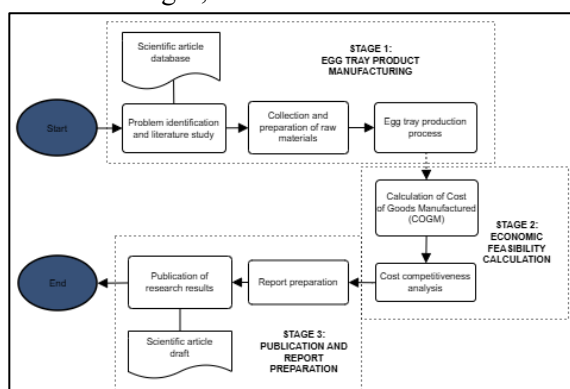
underutilized or left to decompose in plantation fields.

Through the conversion of oil palm frond waste into egg tray products, SMEs can transform low-value biomass residues into marketable packaging products with economic value. In addition to reducing waste accumulation, this business model can provide alternative income sources for local communities while supporting sustainable production practices and circular economy implementation. However, information regarding the production cost structure of oil palm frond-based egg trays remains limited. Therefore, comprehensive cost analysis using the full costing method is necessary to provide SMEs with accurate information for determining production costs, setting competitive selling prices, and evaluating business feasibility [14].

Based on these considerations, this study aims to analyze the Cost of Goods Manufactured (COGM) of egg trays made from oil palm frond waste using the full costing method. The results are expected to serve as a reference for SMEs interested in developing environmentally friendly packaging products from palm oil biomass waste.

2. Methods

To achieve the research objectives, this study was conducted through several systematic and structured stages, as illustrated in Picture 1.



Picture 1. Research Flowchart of COGM Analysis for the Development of Egg Tray Products from Oil Palm Fronds

The study began with problem identification and a literature review aimed at exploring the potential utilization of biomass, particularly oil palm fronds, as raw materials for environmentally

friendly packaging products [15]. This stage strengthened the scientific foundation by referring to databases of articles related to agricultural waste utilization. Furthermore, raw material collection and preparation were carried out. Oil palm frond waste was collected from local plantations and then selected based on quality criteria such as dryness and cleanliness from contaminants. The fronds were then cut, dried, and processed into chemical-free pulp, which was subsequently used in the egg tray production process through manual molding and drying until the product was ready for testing [16].

After the products were completed, the Cost of Goods Manufactured (COGM) was calculated. The calculation used the full costing method, which includes all costs directly and indirectly related to the production process [17]. Production costs were classified into direct material costs, direct labor costs, and manufacturing overhead costs [18].

2.1 Production Cost Data Collection

Production cost data were collected from the egg tray manufacturing process and classified as follows:

1) Direct Material Costs (DMC)

Direct material costs included the costs of oil palm fronds, water, and adhesives. These costs represent materials directly incorporated into the final product.

2) Direct Labor Costs (DLC)

Direct labor costs were calculated based on working hours and labor wages involved in each production stage, such as pulping, molding, and drying/finishing. Since the production process remains semi-manual, direct labor costs potentially become the dominant cost component.

3) Variable Manufacturing Overhead Costs (VMOH)

Variable manufacturing overhead costs included electricity consumption, equipment usage and depreciation, and packaging costs. These are indirect manufacturing costs that vary according to production volume, such

as electricity consumption for processing equipment and consumable utilities [19].

4) Fixed Manufacturing Overhead Costs (FMOH)

Fixed manufacturing overhead costs are indirect manufacturing costs that remain relatively constant in the short term, particularly equipment depreciation and maintenance costs. Equipment depreciation was calculated using the straight-line depreciation method based on the economic life of the equipment.

2.2 Full Costing Method Calculation

The collected cost data were processed to determine the total production cost and the COGM per unit of egg tray. The COGM per unit was calculated using the following formula:

$$\text{COGM} = \text{DMC} + \text{DLC} + \text{VMOH} + \text{FMOH}$$

Alternatively, the COGM per unit can be calculated by dividing the total production cost by the number of units produced in one production cycle:

$$\text{COGM/Unit} = \frac{\text{DMC} + \text{DLC} + \text{VMOH} + \text{FMOH}}{N}$$

Where N is number of units produced.

2.3 Equipment Depreciation (Straight-Line Method)

Equipment depreciation was calculated using the straight-line depreciation method:

$$\text{Depreciation per Year} = \frac{\text{Acquisition Cost} - \text{Residual Value}}{\text{Economic Life}}$$

The depreciation value was then allocated to the unit cost based on the production output within the same period. This approach is important to ensure that equipment investment costs are reflected in the COGM, enabling more realistic pricing decisions.

2.4 Cost Competitiveness Analysis

The cost competitiveness analysis was conducted by comparing the COGM of egg trays

made from oil palm fronds with the production cost of conventional egg trays available in the market, which range from approximately Rp800–Rp1,000 per unit. This comparison was used as an initial overview of the product's cost competitiveness while considering equivalent product specifications such as egg capacity, dimensions, and load-bearing capability of the oil palm frond-based egg trays.

3. Results and Discussion

The full costing method considers all production costs, including direct material costs, direct labor costs, variable manufacturing overhead costs, and fixed manufacturing overhead costs. This cost classification is carried out to ensure that the Cost of Goods Manufactured (COGM) reflects total production costs comprehensively and accurately [20].

Table 1 presents the direct material costs used in the egg tray production process. Although the main raw material comes from oil palm frond waste, which is relatively easy to obtain and low-cost, supporting costs such as water and additional materials required for the pulp formation process still exist. This indicates that utilizing waste materials does not entirely eliminate raw material costs, but it can reduce costs compared to conventional raw materials.

Table 1. Direct Material Costs

Component	Unit	Requirements per Tray	Unit Price (Rp)	Cost/Tray (Rp)	Notes
Dried oil palm fiber	kg	0,060	3,000/kg	180	Waste handling cost
Tapioca adhesive (solid equivalent)	kg	0,020	10,000 /kg	200	Plant-based adhesive
Water (distilled/clean water)	L	0,30	50/L	15	Can use PDAM water/well water
Direct Material Subtotal				395	

Furthermore, Table 2 shows the direct labor costs incurred during the production process. The high labor cost is caused by the semi-manual

nature of the egg tray production process, starting from raw material processing, molding, to the drying process. This condition indicates that labor cost efficiency can still be improved through better work methods or the implementation of simple technologies suitable for small and medium enterprises (SMEs).

Table 2. Direct Labor Costs

Activity	Time/tray (minutes)	Wage (Rp/hour)	Cost/tray (Rp)	Notes
Sorting & initial cutting	0,10	25	42	Fast work, batch-based
Drying (handling)	0,05	25	21	Only lifting/arranging
Crushing & grinding	0,25	25	104	Mechanical process
Pulping & mixing	0,15	25	63	Stirrer
Molding	0,35	25	146	Core process
Finishing & inspection	0,15	25	63	Trimming/checking
Packing	0,03	25	12	Simple packaging
Total effective working time	1,08			
Direct Labor Subtotal			450	(rounded)

The variable manufacturing overhead costs presented in Table 3 include electricity expenses and other supporting materials whose amounts depend on production volume. The greater the production volume, the higher the variable overhead costs tend to be. However, increasing production volume also has the potential to reduce unit costs if fixed costs can be distributed optimally.

Table 3. Variable Manufacturing Overhead Costs

Component	Basis	Rate	Cost/tray (Rp)	Notes
Crusher machine electricity	0,020 kWh/tray	1.700/kWh	34	Estimated consumption
Stirrer electricity	0,005 kWh/tray	1.700/kWh	9	
Additional water/cleaning	0,20 L/tray	50/L	10	
Consumable materials	Rp/tray	—	15	Gloves, etc.
Simple packaging/binding	Rp/tray	—	22	Plastic/strap
Variable Manufacturing Overhead Subtotal			90	

Table 4. Fixed Manufacturing Overhead Costs

Component	Value (Rp/month)	Output (tray/month)	Cost/tray (Rp)	Notes
Crusher machine depreciation	120	2	60	Equipment price/economic life
Stirrer depreciation	30	2	15	
Mold depreciation	40	2	20	Mold wears out quickly
Fixed rent/utilities	20	2	10	Workspace/supporting equipment
Equipment maintenance	20	2	10	Blades, minor servicing
Fixed Manufacturing Overhead Subtotal			115	

$$\begin{aligned}
 \text{COGM} &= \text{DMC} + \text{DLC} + \text{VMOH} + \text{FMOH} \\
 &= \text{Rp}395 + \text{Rp}450 + \text{Rp}90 + \text{Rp}115 \\
 &= \text{Rp}1050/\text{tray}
 \end{aligned}$$

Meanwhile, Table 4 presents fixed manufacturing overhead costs derived from equipment depreciation and maintenance. These costs are relatively constant in the short term and are not influenced by production volume. The existence of fixed overhead costs is one of the main reasons for applying the full costing method, as this method incorporates all production costs comprehensively, resulting in a more representative COGM[21].

Based on the calculation results using the full costing method, the COGM obtained was Rp1,050 per egg tray unit. This value reflects the actual total production cost because it includes all raw material, labor, and manufacturing overhead costs, both variable and fixed. These results can serve as a strong basis for determining selling prices, calculating profit margins, and evaluating production process efficiency in reducing the 1.08-minute effective processing time per tray and minimizing non-value-added activities during molding and finishing, both of which directly determine the direct labor cost share of COGM.

From the cost structure perspective, the largest cost component was direct labor cost, accounting for 42.86% of the total COGM. This component was followed by direct material costs at 37.62%, fixed overhead costs at 10.95%, and variable overhead costs at 8.57%. These findings indicate

that the production cost of oil palm frond egg trays under the current research conditions is more influenced by labor intensity than by raw material or utility costs.

Conceptually, product COGM is highly sensitive to three main factors: output quantity per production cycle, labor time, and fixed cost allocation. If output increases while maintaining a relatively constant cost structure, fixed costs per unit will decrease. Likewise, if working time per unit can be reduced through improved work methods or more efficient tools, the direct labor cost component will decrease significantly.

The COGM of oil palm frond egg trays at Rp1,050 per unit is higher than the reference cost of conventional egg trays. This difference indicates that under current process conditions, the product is not yet competitive purely from a cost perspective. However, the labor costs are the dominant component, accounting for 42.86% of total COGM, indicating opportunities for cost reduction through work-time reduction in the molding stage and standardization of production procedures (SOPs), rather than through material substitution or overhead cuts alone.

Nevertheless, egg trays made from oil palm fronds still offer added value from a sustainability and circular economy perspective. The utilization of biomass waste as a raw material can reduce waste accumulation in plantation areas, decrease dependence on conventional raw materials, and create opportunities for local value-added production. Previous research has demonstrated that oil palm biomass can be converted into various value-added products through appropriate processing technologies, supporting the potential for waste-to-wealth applications in the palm oil sector [1]. In addition, research on pulp-moulded products from oil palm fibre indicates that this biomass has potential for environmentally oriented packaging applications [5]. These findings support the feasibility of further developing oil palm frond-based egg trays, although their economic competitiveness depends strongly on improvements in production efficiency which means narrowing the current

cost gap primarily through labor-time reduction and higher production volume prevent the product from matching conventional egg tray pricing.

The COGM result of Rp1,050 per unit provides an important basis for determining the improvement priorities of SMEs. As shown in the cost structure, direct labor represents the largest component at 42.86% of total COGM, followed by direct material costs at 37.62%, fixed manufacturing overhead at 10.95%, and variable manufacturing overhead at 8.57%. Therefore, the most immediate opportunity for cost reduction is improving labor productivity. The current production process requires approximately 1.08 minutes of effective working time per tray and remains semi-manual, particularly in molding and finishing activities. This condition indicates that reducing processing time per unit can directly reduce labor cost and increase production capacity without requiring major capital investment.

One strategy that can be implemented by SMEs is work method standardization through the development of Standard Operating Procedures (SOPs) for each production stage, including raw material preparation, crushing, pulping and mixing, molding, drying, finishing, inspection, and packaging. Standardized work methods can reduce variation in processing time, minimize unnecessary activities, and establish a consistent production sequence. This approach is particularly relevant for SMEs because it can improve productivity while requiring relatively limited investment compared with full production automation. In the present study, the largest labor contribution suggests that even a modest reduction in labor time per tray could have a meaningful effect on COGM.

Process efficiency should also be supported by simple and appropriate production technologies. Based on the current process, activities such as crushing, pulping, mixing, and molding can be improved through the optimization of machine utilization and simple auxiliary tools. Rather than immediately adopting high-cost automation,

SMEs can prioritize low-cost interventions such as improved molding fixtures, batch-based material handling, standardized pulp quantities, and improved workstation arrangements. These measures can reduce non-value-added activities and increase the number of trays produced within each production cycle. The use of appropriate processing equipment is also consistent with previous research showing the importance of processing technology in increasing the value obtained from oil palm biomass [4], [16].

Increasing production volume is another important strategy because the COGM calculation includes fixed manufacturing overhead costs. Under the current production conditions, fixed overhead is allocated to each tray based on production output. Consequently, an increase in output while maintaining relatively stable fixed costs will reduce the fixed cost burden per unit. For SMEs, production expansion should therefore be conducted after establishing a stable and standardized production method. Increasing output without controlling process variation may instead increase material waste, rework, and labor requirements. Therefore, production scale expansion should be combined with capacity planning, standardized work procedures, and quality control.

Based on these findings, the implementation strategy for SMEs can be divided into three stages. First, SMEs should standardize the production method by establishing SOPs, standard processing times, material quantities, and quality criteria for each production stage. Second, SMEs should improve labor productivity by eliminating non-value-added activities and introducing simple supporting equipment, particularly in molding, material handling, and finishing operations. Third, after process stability has been achieved, SMEs can increase production volume to distribute fixed manufacturing overhead over a larger number of units. This sequence is important because COGM reduction should not rely solely on increasing production volume; it must be accompanied by improvements in productivity and process control.

The relationship between these strategies and COGM can be explained through the cost structure obtained in this study. Labor efficiency primarily affects the direct labor component, while production scale primarily affects the allocation of fixed manufacturing overhead. Meanwhile, standardized work methods can improve both factors by reducing processing time and increasing output consistency[22]. Therefore, the combination of work method standardization, labor productivity improvement, appropriate technology utilization, and production volume expansion provides a more realistic pathway for SMEs to reduce COGM and improve the competitiveness of oil palm frond-based egg trays.

To ensure long-term business sustainability based on these COGM results, SMEs must implement a dual strategy focusing on strategic market positioning and continuous operational reinvestment. From a financial sustainability perspective, knowing the exact COGM of Rp1,050 per unit allows SMEs to determine a safe and profitable selling price threshold. Because this production cost is slightly higher than the indicative market price of conventional egg trays (Rp800-Rp1,000), SMEs cannot compete purely on a low-price strategy. Instead, they must adopt value-based pricing by highlighting the eco-friendly and circular economy aspects of the product. SMEs can target niche markets, such as organic egg producers or premium eco-conscious supermarkets, that are willing to pay a premium for sustainable packaging. Furthermore, for operational sustainability, SMEs must use the identified cost structure as a baseline for continuous improvement. With direct labor being the largest cost component at 42.86%, SMEs should strategically allocate a portion of their initial profits to reinvest in simple automation technologies, particularly to assist the manual molding process. This step-by-step capital reinvestment will gradually lower the labor cost per unit over time, widen the profit margins, and ultimately ensure that the business remains financially viable and scalable in the long run.

Although the current COGM of Rp1,050 per unit remains slightly above the indicative cost range of conventional egg trays, the relatively small difference does not eliminate the product's market potential. The product offers additional environmental and circular economy value that is not reflected solely in the COGM calculation. Therefore, the development of oil palm frond-based egg trays still has promising prospects, particularly if SMEs implement continuous process improvement and gradually increase production capacity. Future studies should quantitatively evaluate the effect of reduced labor time, increased production volume, and alternative equipment utilization on COGM to identify the production scale at which the product can achieve greater cost competitiveness.

4. Conclusion and Recommendations

Based on the research results, the Cost of Goods Manufactured (COGM) of egg trays made from oil palm frond waste, calculated using the full costing method, is Rp1,050 per unit. When compared indicatively with the market price range of conventional cardboard egg trays, which is approximately Rp800–Rp1,000+ per unit, the product still shows a relatively slightly higher cost. This indicates that under the current process conditions, the product does not yet have a cost advantage compared to conventional products. Nevertheless, since the cost difference is not significantly far from part of the market price range, the development of this product is still worth considering especially through improvements in process efficiency, reduction of working time per unit, and increased production scale. Therefore, egg trays made from oil palm fronds still have promising prospects as environmentally friendly packaging alternatives that support biomass waste utilization and the circular economy.

Further research and development that can be conducted include improving process productivity through better work methods and process standardization, evaluating production scale expansion scenarios to reduce the proportion of fixed costs per unit, and

complementing the study with cost sensitivity analysis (such as variations in output per cycle, changes in labor wage rates, and energy consumption) so that recommendations for reducing the COGM can be presented quantitatively.

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