J@TI JURNAL TEKNIK INDUSTRI UNIVERSITAS DIPONEGORO

Vol. 21, No. 1, Januari 2026

SUPPLY CHAIN TRANSPARENCY ANALYSIS OF PATCHOULI OIL INDUSTRY IN ACEH FROM SEED TO INTERNATIONAL MARKET

Zaudhatul Ulya*[1], Muhammad Haikal[2], Raihan Dara Lufika[1], Adinda Gusti Vonna[3], Ade Surya Mandira[3], Zikrina Melinda[4]

[1]*Industrial Engineering Department, Faculty of Engineering, Universitas Syiah Kuala, Banda Aceh*
[2]*Environmental Engineering Department, Faculty of Engineering, Universitas Islam Negeri Ar-Raniry, Banda Aceh*
[3]*Agribusiness Department, Faculty of Agriculture, Universitas Syiah Kuala, Banda Aceh*
[4]*Geological Engineering Department, Faculty of Engineering, Universitas Syiah Kuala, Banda Aceh*

Abstract

Patchouli is one of the most valuable export commodities in Aceh. Patchouli oil must meet several qualifications to obtain export eligibility certification, particularly in terms of its environmental impact, where an in-depth analysis of supply chain transparency is necessary, spanning from seed procurement to distribution and entry into the international market. Despite the large potential for patchouli oil production, industries in Aceh face critical challenges related to supply chain transparency and traceability, which undermine efforts to meet sustainability standards and global market requirements. This study analyzes the transparency of the patchouli oil procurement at the PP NILAS Cooperative and the distribution process through PT Ugreen to the buyer, two key institutions in the local value chain. This study use an exploratory case study approach, combining field observation, purposeful sampling, and semi-structured interviews with key stakeholders, including farmers, distillers, intermediaries, exporters, cooperatives, and Non-Governmental Organization (NGO)s. The study found traceability gaps across several elements of the supply chain, limited documentation practices among smallholders, and challenges in aligning local operations with global certification demands. The study highlights the need for supply chain digitalization, inclusive training, and multi-stakeholder collaboration to strengthen supply chain transparency and support sustainable export growth for the Aceh patchouli industry.

Keywords: *Patchouli Oil Industry; Supply Chain Transparency; SCOR Model; Sustainability*

1. Introduction

To meet international standards, the industry must ensure that its products meet relevant qualifications and certifications, which identify the quality of the product through supply chain transparency and traceability. The improvement of operations and supply chain functions in any industry has become a core of business operations and strategy (Anwar et al., 2025). To support effective supply chain decisions, firms require accurate, real-time information on inventory levels and material and product flows. Advances in Information and Communication Technologies (ICTs) enable organizations to collect, analyze, and utilize such data for timely decision-making and demand forecasting (Song et al., 2019). ICTs enable smooth information exchange among supply chain stakeholders, ensuring clarity and time efficiency. From a corporate perspective, embracing supply chain transparency has become a way to improve firm legitimacy (Dubbink et al., 2008; Egels-Zandén & Hansson, 2016).

Supply chain transparency refers to creating clear visibility and traceability across both upstream and downstream supply chain activities by actively communicating and engaging with stakeholders (Carter & Easton, 2011; Carter & Rogers, 2008). Supply chain transparency includes the disclosure of information such as suppliers' identities, the sustainability conditions at supplier sites, and buyers' purchasing practices (Egels-Zandén, N., Hulthén, K., & Wulff, 2015). With the growing influence of environmental issues, which pose significant threats to human lives, business organizations have a crucial role to play in making their organizational performance environmentally friendly. For agricultural activity, the environmental performance index measures several aspects that include the sustainable nitrogen management index, phosphorus surplus, pesticide pollution risk, and relative crop yield.

*Corresponding Author

E-mail: zaudatulya@usk.ac.id

This approach emphasizes the effect on nature only, while in the environmental sustainability pillars, the economic and social aspects are also assessed. Ensuring strong environmental performance in the supply chain requires the availability of transparent and accessible information (Galahitiyawe, 2020). There are several approaches used to enhance supply chain transparency, which also means as well as to improve environmental sustainability.

Sustainable performance is achieved once transparent information is generated (Gold, S., Seuring, S., & Beske, 2010). This information helps each element coordinate in the process. Also, the identification of environment-related requirements of stakeholders' fulfillment will lead to environmental performance (Schultze & Trommer, 2012). This helps to achieve sustainable performance. The transparency is required to sustain the economic, social, and environmental goals of the supply chain (Duan, Y., & Aloysius, 2019). This is because the information will help the decision makers to solve problems that might occur. Plus, supply chain transparency assists the achievement of the sustainability efforts of a firm in an effective way (Egels-Zandén, N., Hulthén, K., & Wulff, 2015). Supply chain transparency is becoming crucial for industries, especially the patchouli oil industry, which is marketed worldwide.

Essential oil derived from patchouli is an export commodity with the highest percentage. (Rahmayanti, Hadiguna, & Nazir, 2017). Patchouli oil is a key natural base ingredient in the perfume and cosmetics industry, as it provides a strong foundation that binds fragrances and enhances their longevity (Rinaldi et al., 2022; Robbins, 1982).

According to Dewan Atsiri Indonesia, patchouli is widely cultivated across Indonesia, from Aceh to Sulawesi. It holds a leading position in the global market, as Indonesia is a major exporter of patchouli oil, contributing significantly to economic growth and strengthening the national economy. Indonesian patchouli is estimated to account for 80–90% of the global market share, with the patchouli oil market projected to generate revenues of around US $86.6 billion by 2028 (Nurulia & Mustafa, 2020).

Based on data from the Directorate General of Estate Crops of Indonesia (2018–2020), patchouli is primarily cultivated in Southeast Sulawesi (7,644 ha), followed by West Sumatra (2,890 ha), South Sulawesi (2,108 ha), and Aceh (1,210 ha) (Crops, 2019). Despite having the smallest cultivated area, Aceh ranks first in patchouli oil production, outperforming other regions with larger patchouli plantations. As one of its leading commodities, patchouli oil contributes to Aceh Province's prominent role in the global supply chain, where the region functions not only as a supplier but also as a producer of high-quality patchouli oil (Adhayani et al., 2023; Ernawati et al., 2021). The data from 2015 to 2020 shows that 415 tonnes of patchouli oil were produced in Aceh, which contributed around 18,78% to the Indonesian economy. According to the Aceh government (2024), patchouli oil production in Aceh reached 1.27 tonnes by March 2024, generating a turnover of Rp 1.1 billion. Dewan Atsiri Indonesia also notes that Aceh patchouli oil is among the highest quality in the world, with an oil yield of around three percent and patchouli alcohol (PA) content exceeding 30%.

Aceh patchouli oil is exported to various countries such as France, Singapore, the United States, England, Germany, India, Spain, and the Netherlands. Patchouli oil has been a leading commodity of Aceh Province since 1998 and has been able to penetrate the international market. Aceh patchouli has obtained a Geographical Indication certificate (ID-G-000000021) from the Ministry of Law and Human Rights of the Republic of Indonesia. Aceh patchouli plants are cultivated, and their derivative products are developed with a research and technology approach through Atsiri Research Center (ARC) as the Center of Excellence for Higher Education Science and Technology (PUIPT) of Aceh Patchouli, Universitas Syiah Kuala (USK),

Patchouli is one of the traditional plantation commodities in Aceh Province, and it is cultivated fairly evenly across almost all regions. However, limited development and integration of the upstream and downstream aspects of the patchouli value chain have meant that local communities experience minimal positive benefits from this commodity (Salsabila & Nugroho, 2023). The current Aceh patchouli production business has high complexity. The production capacity and quality of patchouli oil produced are also relatively low. This condition is influenced by the accumulation of low performance of upstream input subsystems, cultivation and maintenance, harvesting and post-harvest handling, processing of products, and supporting institutions. Although the natural and geographical conditions have the potential to develop, the level of knowledge, skills, and behavior of patchouli farmers is still low and will have implications for the economy and community welfare.

Patchouli oil, derived from *Pogostemon cablin*, is a key export commodity for Indonesia, with Aceh Province. Lhoong District, Aceh Besar Regency, is one of the districts where some of the people have returned to planting patchouli, especially on dry, hilly land [16]. Lhoong District is ± 51.7 km from the capital of Aceh Province, Banda Aceh, and can be reached in ± 1 hour by two-wheeled and/or four-wheeled motorized vehicles. Currently, one of the production hubs of patchouli oil is produced in PP NILAS Lhoong.

In recent years, patchouli oil industry in Lhoong has been supported by institutional stakeholders such as BSI Maslahat and ARC USK, with the resulting oil processed at PP NILAS Lhoong and then channeled through PT Ugreen for export. Despite these promising developments, the patchouli oil industry in Aceh faces significant challenges related to the lack of transparency and traceability across its supply chain. These issues not only hinder the ability to meet international certification standards such as organic, fair trade, or sustainability certifications but also limit the industry's potential to build consumer trust and secure a competitive position in global markets.

In the case of the patchouli oil agroindustry, there is a tendency for the situation to change

frequently; for example, there are uncertain price changes that have an impact on the amount of patchouli oil produced (Rahmayanti, Hadiguna, Santosa, et al., 2017). Across Aceh, patchouli farmers share a strong commitment and determination to produce high-quality patchouli and maintain a stable supply chain in order to support consistent global prices. This motivation is further driven by their aspiration to improve living standards and reduce poverty among patchouli-farming communities (Zikri et al., 2021).

In the production process, the quality of patchouli oil depends on the method of extraction (Arliani et al., 2024). At present, Acehnese farmers rely on simple steam distillation methods using large drums heated by burning logs. To achieve export-quality standards, additional processing is needed, including purification and the reduction of impurities (Arliani et al., 2024). However, challenges related to Indonesia's regulations and policies, along with issues of quality and supply instability, limit the ability of Indonesian patchouli to compete more effectively in the global market. Decisions made to address these issues could significantly improve farmers' livelihoods, as higher quality standards would raise prices and enable Indonesian patchouli oil to better meet international market requirements (Silvia et al., 2023).

Due to the problems mentioned above, this paper investigates the transparency of the patchouli oil supply chain using the Supply Chain Operations Reference (SCOR) approach. The study aims to identify the current practices and existing transparency gaps, as well as to analyze the challenges faced by stakeholders in implementing a transparent supply chain system. Ultimately, the goal is to propose strategic recommendations to enhance supply chain visibility, support sustainability, and improve the long-term viability of the patchouli oil industry in Aceh. By strengthening transparency, the region's smallholder farmers and processors can unlock greater economic value, meet rising global expectations, and contribute to more sustainable agricultural development.

2. Material and Methods

Research Location and Objects

This study uses an exploratory case study approach that aims to analyze the transparency of the supply chain in the patchouli oil industry in Aceh, especially with the "seed to international market" approach. The study focuses on Perkumpulan Petani Nilam Lhoong Aceh Sejahtera (PP NILAS) cooperative located in Lhoong District, Aceh Besar Regency. This cooperative is a group of farmers assisted by BSI Maslahat that manages activities ranging from seeding, planting, to refining patchouli leaves into crude oil. The refined oil is then purchased by PT UGreen, a patchouli oil distribution company that has a network to the international market, including consumers from companies in France. Therefore, the object of the study covers the entire supply chain flow from production at the farmer level to distribution to the global market.

Data Collection and Analysis

Data collection was conducted through field observations to map the supply chain and the flow of product and information movement. Semi-structured interview techniques were applied to obtain qualitative data from various key actors, including the management of the PP NILAS cooperative and the management of PT UGreen. The sampling technique was carried out purposely, by selecting informants who were directly involved and had important roles in the patchouli oil supply chain. The inclusion criteria were as follows: (1) individuals who are actively involved in the patchouli oil supply chain within the PP NILAS cooperative or PT UGreen; (2) individuals who hold strategic roles or responsibilities related to production, processing, quality control, logistics, or marketing; (3) individuals who have a minimum of one year of experience in the patchouli oil supply chain; and (4) individuals who possess sufficient knowledge of supply chain processes and information flow relevant to transparency and traceability practices.

During the interviews, data were collected to explore key dimensions of supply chain transparency across the entire patchouli oil value chain. Specifically, respondents were asked to provide information related to: (1) production and sourcing practices, including seed selection, cultivation methods, harvesting procedures, and sourcing traceability at the farmer level; (2) processing and refining activities, covering distillation processes, quality control mechanisms, documentation of production batches, and consistency of product quality; (3) information flow and data recording, including how production, processing, and transaction data are documented, shared, and accessed among supply chain actors; (4) logistics and distribution transparency, such as storage practices, transportation processes, shipment tracking, and export documentation; (5) pricing, transaction, and contractual arrangements, including price-setting mechanisms, payment systems, and transparency in financial transactions between farmers, cooperatives, and distributors; and (6) traceability and digital system utilization, particularly the use of digital tools or platforms to support traceability, monitoring, and reporting from the seed stage to international markets.

Data were analyzed using a supply chain mapping approach based on the SCOR model, which includes five main elements: Plan, Source, Make, Deliver, and Return. This mapping allows the identification of critical points in the transparency and information flow aspects at each stage. In addition, a Strengths, Weaknesses, Opportunities, and Threats (SWOT) analysis was conducted to assess the strengths, weaknesses, opportunities, and threats to the current transparency system. The results of interviews and observations were analyzed theoretically to reveal patterns, challenges, and potential improvements that can support the strengthening of the traceability system in the Aceh patchouli oil industry.

3. Results and Discussion

Supply Chain Mapping

Mapping the supply chain of the patchouli oil industry is essential to understanding the structure,

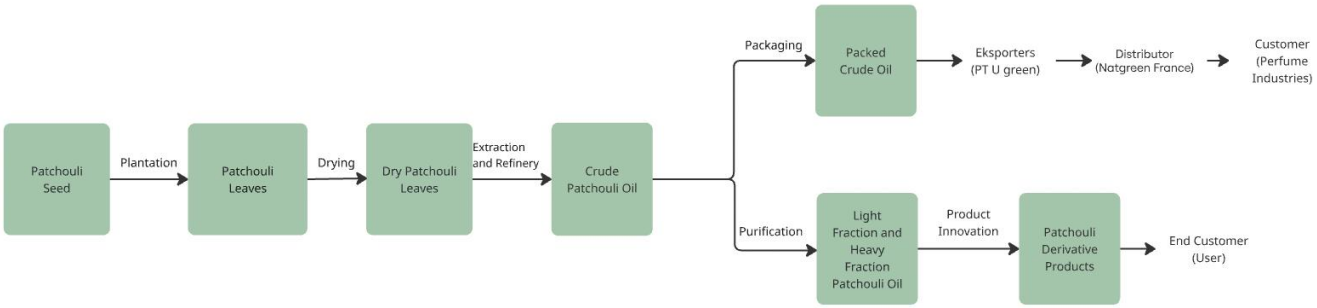

Figure 1. Patchouli Oil Supply Chain

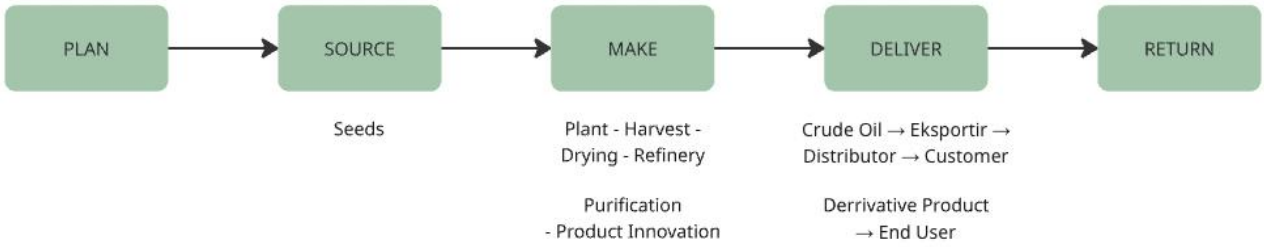

Figure 2. SCOR Model of the Patchouli Oil Supply Chain

Table 1. Issues Identification in the Patchouli Oil Industry Supply Chain

SCOR Key Processes	Activities	Current Practice	Issues/Needs
Plan	1. Demand forecasting for patchouli oil export. 2. Planning of planting and harvesting schedules. 3. Coordinating supply chain actors (coops, farmers, distillers, exporters).	Mostly informal, based on past seasons. Planning varies across farmers and distillers.	1. Need for a centralized data system. 2. Lack of long-term production planning. 3. Minimal market intelligence access.
Source	1. Sourcing patchouli seedlings and inputs (fertilizer, compost). 2. Procuring raw patchouli leaves from farmers.	Inputs are often self-supplied or bought from local vendors. Collection from dispersed smallholders.	1. No standardized input quality. 2. Lack of certified planting material. 3. Difficulty in traceability at source.
Make	1. Drying patchouli leaves. 2. Steam distillation to extract oil. 3. Filtering and basic quality testing.	Done in small-scale units or cooperatives like PP NILAS. Distillers vary in process quality.	1. Inconsistent oil quality. 2. Limited lab testing. 3. Manual recordkeeping. 4. Need for Good Manufacturing Practices (GMP)/ISO standards.
Deliver	1. Packaging for export. 2. Transport to exporters (through PT UGreen). 3. Documentation and certification.	Basic drums or canisters used. Paper-based documentation.	1. Lack of integrated logistics system. 2. Need for export-compliant packaging. 3. Weak digital traceability ("seed to seal").
Return	1. Handling rejected oils or failed certification batches. 2. Learning from customer feedback.	Rarely occurs in a structured way. Little feedback loop to upstream actors.	1. No formal product recall system. 2. Need for feedback channels to farmers/distillers.

dynamics, and critical points that influence both product quality and market access. The patchouli oil supply chain from seed to seal is shown in **Figure 1**.

SCOR Model for Patchouli Oil Supply Chain in Aceh

The SCOR Model consists of five key processes: Plan, Source, Make, Deliver, and Return. **Figure 2** is how each applies to the patchouli oil industry. From the mapping, then the detailed activities, current practice, and issues for the patchouli oil industry related to supply chain transparency are detailed in **Table 1** based on SCOR key processes, which are Plan, Source, Make, Deliver, and Return.

Table 2. Performance Attributes (aligned with SCOR KPIs)

Attribute	Performance Attribute Definition	Assessment	Gap
Reliability	Supply chain performance refers to the ability to deliver the right product to the right place, at the right time, in the right condition and packaging, in the right quantity, with accurate documentation, to the right customer.	Medium – dependent on season and weather.	Needs better planning and storage.
Responsiveness	The speed at which a supply chain provides products to the customer.	Low – lead times are unpredictable.	Need for faster coordination mechanisms.
Agility	The agility of a supply chain in responding to marketplace changes to gain or maintain competitive advantage.	Low – system is not flexible to sudden changes.	Introduce adaptive sourcing and processing capacity.
Cost	The costs associated with operating the supply chain.	Low input cost, but high inefficiency.	Improve cost-to-value ratio via efficiency.
Asset Management	The effectiveness of an organization in managing assets to support demand satisfaction. This includes the management of all assets: fixed and working capital.	Poor utilization of assets like distillers.	Investment in shared processing infrastructure.

Table 3. Transparency by SCOR Stage

SCOR Stage	Transparency Status	Key Challenges	Needs/Opportunities
Plan	Low	Lack of centralized planning data; no real-time forecasting.	Digital farmer databases; mobile apps for planting schedules and yield forecasting.
Source	Partial	Informal transactions; no documentation on input origin (e.g., seed quality).	Input traceability (certified seeds, fertilizer records); farmer ID system.
Make	Partial	Small-scale distillers lack SOPs; no batch records or quality logs.	Standardized processing logs; QR-coded batch IDs; basic lab testing trace.
Deliver	Partial	Exporters keep records, but upstream documentation is often missing; limited product labeling.	Full digital tracking ("seed to seal"); integrated producer–buyer platform.
Return	Low	No product recall or feedback loop; limited learning from product rejection.	Formal feedback and product grading; digital recall mechanisms.

Table 4. Traceability Gaps Identified

Area	Description
Farmer-level	No farmer registration system; difficult to verify cultivation practices or origin.
Processing	Distillers operate informally; limited records of batch origin or yield/output ratios.
Middlemen	Intermediaries' obscure visibility: oil may be mixed from multiple sources.
Certification	Organic or sustainable certification is often exporter-led; upstream actors are unaware or excluded from requirements.
Technology	Lack of digital tools (e.g., mobile tracking, barcoding, blockchain) among upstream actors.

From **Table 1**, performance attributes aligned with SCOR Key Performance Indicators (KPIs) are assessed, and the gaps are identified. The summary of assessment results and gaps is detailed in **Table 2**.

Transparency levels were categorized into three statuses: low, partial, and high. A low transparency status indicates limited or fragmented information, predominantly informal data recording, and minimal visibility across stakeholders. Partial transparency reflects the presence of basic documentation and selective information sharing, often constrained to specific actors or stages of the supply chain. High transparency denotes comprehensive, standardized, and digitally supported information flows that enable end-to-end traceability and real-time visibility. This correlation highlights the critical role of transparent information systems in enhancing supply chain performance from seed production to international market distribution. The results are shown in **Table 3**.

Table 4 presents the traceability gaps identified across key areas involved in the patchouli oil supply chain. These areas include the farmer level, processing,

Table 5. Risks of Low Transparency

Impact Area	Risk
Market Access	Risk of export rejection or price penalties due to lack of certification/compliance.
Farmer Inclusion	Smallholders risk being excluded from premium/value-added markets.
Reputation	Global buyers increasingly demand ethical sourcing—Aceh could be left behind.
Environmental/Social	Lack of data makes it hard to enforce sustainable land use or labor practices.

middlemen, certification, and technology, each representing critical points that influence the continuity and transparency of traceability from seed production to international markets. The table summarizes how limitations in documentation, information flow, and system integration within each area contribute to overall transparency challenges in the Aceh patchouli oil industry.

Institutional Dynamics for Patchouli Oil Supply Chain in Aceh

The institutional landscape supporting supply chain transparency in the patchouli oil industry in Aceh, particularly in Lhoong, reflects a mix of emerging initiatives and structural limitations. At the core of the value chain are PT UGreen and Koperasi Produsen Nilam Lhoong Aceh Sejahtera (PP NILAS), which have taken initial steps to formalize the procurement process and aggregate patchouli oil from smallholder farmers. These efforts mark progress toward a more structured supply chain, yet they remain largely semi-formal and non-digital, limiting their scalability and integration with international traceability standards. For instance, while batch documentation and cooperative-level aggregation exist, there is no end-to-end digital tracking system that allows seamless traceability from cultivation to export.

Institutions such as the Atsiri Research Center (ARC) at Universitas Syiah Kuala (USK) and BSI Maslahat have contributed to capacity-building for farmers and cooperatives, particularly in areas such as Good Agricultural Practices (GAP), sustainable cultivation, and cooperative governance.

However, these interventions tend to be project-based and externally driven, meaning they are not yet embedded in the daily operations or long-term strategic plans of the actors involved. This creates a gap between knowledge transfer and systemic adoption of transparency mechanisms in routine supply chain activities.

In this context, Non-Governmental Organization (NGOs) and donor agencies have a strategic role to play in piloting traceability technologies and supporting the development of farmer-facing systems that are both accessible and adaptable to the rural context. This includes the potential deployment of mobile-based apps, QR-coded batch tracking, or simplified digital recordkeeping that can empower smallholders while also meeting the demands of international buyers for transparency and sustainability assurance. The challenge, therefore, lies not in the absence of institutional actors but in the lack of coordination, digital infrastructure, and operational integration among them. A multi-stakeholder governance framework would be essential to harmonize efforts and ensure that transparency is institutionalized rather than project dependent.

Risks of Low Transparency for the Patchouli Oil Supply Chain in Aceh

The SCOR Model consists of five key processes: Plan, Source, Make, Deliver, and Return. **Table 5** is how each applies to the patchouli oil industry.

Despite growing interest in building a transparent and traceable supply chain for patchouli oil in Aceh, several persistent barriers continue to undermine these efforts, particularly at the upstream and midstream levels. One of the most fundamental challenges is the informality that characterizes transactions between smallholder farmers, collectors, and distillers. Most upstream exchanges are conducted without written agreements, standardized procedures, or reliable documentation of origin, quality, or quantity. This lack of formalization makes it difficult to establish traceability protocols, verify product authenticity, or enforce quality standards.

Compounding this issue is the limited adoption of digital infrastructure and poor recordkeeping habits across the supply chain. Many smallholders and processors operate with minimal technological support, and there is little to no use of digital tools for tracking production inputs, processing batches, or recording sales. This absence of reliable data hinders not only transparency but also restricts the ability of exporters and international buyers to conduct due diligence or comply with increasingly stringent sustainability and traceability requirements.

Economic volatility further exacerbates the problem. Fluctuating patchouli oil prices create incentives for opportunistic behaviors, such as the mixing of oils from various sources to meet volume demands or to maximize short-term profits. These practices severely degrade traceability and make it difficult to guarantee the origin, purity, or ethical sourcing of the final product. Inconsistent pricing and lack of value-chain incentives for traceable practices mean that farmers and middlemen often prioritize immediate market access over long-term transparency.

Lastly, the patchouli oil supply chain in Aceh is characterized by a fragmented stakeholder ecosystem, where coordination among cooperatives, processors, exporters, NGOs, and support institutions remains weak. While individual actors such as PT UGreen, PP NILAS, ARC USK, and BSI Maslahat have made positive contributions, there is no unified platform or governance structure to align transparency initiatives, set standards, or monitor compliance across the chain. Without stronger integration and institutional collaboration, transparency efforts are likely to remain siloed, inconsistent, and difficult to sustain.

Strengths (S)	Weaknesses (W)
1. Strong historical and cultural basis in patchouli farming, especially in Lhoong. 2. Existing cooperative models (e.g., Koperasi PP NILAS) that serve as entry points for traceability. 3. Active support from local institutions (e.g., ARC USK, PT UGreen, BSI). 4. Growing awareness among exporters of sustainability requirements.	1. Low documentation practices among smallholders and distillers. 2. Fragmented supply chain with many informal intermediaries. 3. Limited digital infrastructure and capacity for data management. 4. Lack of standardized processes for product tracking and quality verification.
Opportunities (O)	**Threats (T)**
1. Rising global demand for ethically sourced, traceable essential oils. 2. Potential integration with digital traceability platforms (e.g., blockchain, QR code tagging). 3. Government and donor interest in sustainable agriculture and green supply chains. 4. Certification schemes (organic, fair trade) offer market incentives.	1. High cost of implementing digital transparency systems for small-scale actors. 2. Risk of exclusion of smallholders if systems are overly complex. 3. Global competition from other traceable essential oil producers (e.g., India, Madagascar). 4. Supply chain disruptions due to climate, conflict, or infrastructure issues.

Figure 3. SWOT Analysis of Supply Chain Transparency in the Aceh Patchouli Oil Industry

SWOT analysis

To better understand the internal capabilities and external environment influencing the development of a transparent and traceable patchouli oil supply chain in Aceh, a SWOT analysis was conducted. This strategic tool provides a structured framework for identifying key enabling factors as well as barriers that affect the effectiveness and sustainability of supply chain interventions. **Figure 3** shows a strategic SWOT analysis for improving patchouli oil supply chain transparency.

The analysis captures the current landscape, where traditional strengths such as a robust cultural foundation in patchouli cultivation and cooperatives like Koperasi PP NILAS serve as valuable starting points for improvement. Local institutional support from organizations like ARC USK, PT UGreen, and Bank Syariah Indonesia (BSI) further bolsters the ecosystem. However, internal issues such as poor documentation practices, limited digital capacity, and a lack of standardized tracking systems continue to stall progress. Externally, global market trends show rising demand for ethically sourced, traceable essential oils, opening new opportunities for Aceh's patchouli sector. Innovations in digital traceability tools and certification schemes also offer pathways for added value and market differentiation. Nevertheless, the sector faces significant threats, including high costs of digital adoption, the risk of marginalizing smallholders, and competition from countries with more advanced traceability systems. This SWOT analysis underpins the identification of key actions and strategic recommendations to strengthen the patchouli oil supply chain and boost its readiness for sustainable, competitive global markets.

The SWOT analysis has been translated into strategic directions to improve supply chain transparency in the Aceh patchouli oil industry. Strength–Opportunity (SO) strategies leverage strong farming traditions, cooperative structures, and institutional support to tap into the growing global demand for traceable and certified essential oils. Strength–Threat (ST) strategies use cooperative governance and exporter awareness to reduce high implementation costs and improve competitiveness against global producers through collective digital efforts.

Weakness–Opportunity (WO) strategies aim to address limited documentation and digital capacity by utilizing government, donor, and technology-driven initiatives to standardize traceability practices. Weakness–Threat (WT) strategies focus on minimizing the risks of smallholder exclusion and supply chain disruptions by implementing simplified systems, phased approaches, and targeted capacity building.

The internal strengths and weaknesses identified reflect conditions within the Aceh patchouli oil supply chain. Notable strengths like the strong historical and cultural roots of patchouli farming in Lhoong and the presence of cooperatives such as PP NILAS were consistently observed during field visits and interviews. These structures support collective coordination and serve as institutional entry points for implementing traceability systems. Additionally, active support from universities, private companies, and Islamic social finance institutions indicates an enabling environment for supply chain improvements.

On the other hand, the main weaknesses involve operational and informational constraints. Low documentation standards, fragmented supply chain structures involving informal intermediaries, and limited digital capacity were frequently cited by farmers, distillers, and cooperative managers. The lack of standardized tracking and quality verification

processes further hampers transparency and traceability at various stages of the supply chain.

Strategic Recommendations

To enhance supply chain transparency in Aceh's patchouli oil industry, several strategic actions are recommended. First, developing a Farmer Traceability Registry is crucial, assigning unique IDs and profiles to farmers integrated with GPS data and planting histories to verify origins. This should be supported by digital batch tracking tools, such as mobile apps or QR codes at distillation points, to tag origin, processing dates, and cooperative affiliation. These initiatives should be integrated into a comprehensive "seed to seal" platform connecting all key players—farmers, distillers, cooperatives, and exporters—through a shared digital ecosystem. To promote adoption, transparency training and incentive schemes, such as access to quality inputs or premium prices for traceable products, must be established especially for smallholders. Additionally, creating a stakeholder governance model involving a local multi-actor steering group with entities like BSI Maslahat, PT U Green, ARC USK, and relevant NGOs will oversee traceability efforts and standard harmonization. This can be further supported by implementing simple technologies like QR code labeling, batch-level tagging, and mobile logbooks accessible to rural producers. For sustained long-term use, capacity-building programs and farmer incentives should be introduced to maintain accurate recordkeeping and ethical practices. Stakeholder integration should also be prioritized by embedding all supply chain actors into a unified data platform that addresses operational requirements and compliance. Finally, policy support from the Aceh provincial government is essential to institutionalize traceability frameworks and establish formal recognition or reward mechanisms for sustainable, transparent supply chain practices.

4. Conclusion

This research highlights the structural complexity and strategic potential of Aceh's patchouli oil supply chain, especially in areas like Lhoong. Supply chain mapping based on the SCOR framework reveals that while many actors, from smallholder farmers to exporters, are involved, the chain suffers from fragmented coordination, limited documentation, and inconsistent quality control. The SWOT analysis further indicates that despite strong cultural roots in patchouli farming and institutional support, the industry faces significant weaknesses in traceability infrastructure and standardized data systems. At the same time, rising global demand for transparent and ethically sourced essential oils offers a promising opportunity. Implementing inclusive digital traceability technologies with backing from government and donor initiatives can significantly upgrade the value chain. However, threats like exclusion, high adoption costs, and international rivalry demand careful strategy, stakeholder collaboration, and capacity building.

In summary, improving transparency and traceability in Aceh's patchouli oil supply chain is not just a technical task but a comprehensive effort that must integrate local knowledge, cooperative models, and appropriate digital innovations. Strengthening these areas is vital to boost sustainability, competitiveness, and equitable benefits for small-scale producers in the region.

5. References

Adhayani, L., Suhartono, S., & Amalia, A. (2023). Aceh patchouli oil (*Pogostemon cablin* Benth) as antibacterial and antibiofilm: Mechanism, challenges, and opportunities. *AIP Conference Proceedings, 2480*(1), 050005. https://doi.org/10.1063/5.0103567

Anwar, U. A. A., Rahayu, A., Wibowo, L. A., Sultan, M. A., Aspiranti, T., Furqon, C., & Rani, A. M. (2025). Supply chain integration as the implementation of strategic management in improving business performance. *Discover Sustainability*, *6*(1). https://doi.org/10.1007/s43621-025-00867-w

Arliani, R., Machdar, I., Kurnia, N. S., Bakar, A., & Husni. (2024). Extraction of patchouli essential oil using multi-injection steam distillation. *IOP Conference Series: Earth and Environmental Science*, *1356*(1). https://doi.org/10.1088/1755-1315/1356/1/012013

Carter, C. R., & Easton, P. L. (2011). Sustainable supply chain management: Evolution and future directions. *International Journal of Physical Distribution and Logistics Management*, *41*(1), 46–62. https://doi.org/10.1108/09600031111101420

Carter, C. R., & Rogers, D. S. (2008). A framework of sustainable supply chain management: Moving toward new theory. *International Journal of Physical Distribution and Logistics Management*, *38*(5), 360–387. https://doi.org/10.1108/09600030810882816

Crops, D. G. of E. (2019). *Tree crop estates statistics of Indonesia (2018-2020)*. https://satudata.pertanian.go.id/assets/docs/publikasi/Statistik_Perkebunan_Nilam_Tahun_2018-2020.pdf

Duan, Y., & Aloysius, J. A. (2019). Supply chain transparency and willingness-to-pay for refurbished products. *The International Journal of Logistics Management*, *30(3)*(797–820).

Dubbink, W., Graafland, J., & Van Liedekerke, L. (2008). CSR, Transparency and the role of intermediate organisations. *Journal of Business Ethics*, *82*(2), 391–406. https://doi.org/10.1007/s10551-008-9893-y

Ernawati, E., Masbar, R., Majid, M. S. A., & Jamal, A. (2021). Production and marketing efficiency of patchouli oil industry in Indonesia. *Regional Science Inquiry, 13*(2), 135–148

Egels-Zandén, N., Hulthén, K., & Wulff, G. (2015). Trade-offs in supply chain transparency: the case of Nudie Jeans Co. ,. *Journal of Cleaner Production*, *107,* 95–104.

Egels-Zandén, N., & Hansson, N. (2016). Supply Chain

Transparency as a Consumer or Corporate Tool: The Case of Nudie Jeans Co. *Journal of Consumer Policy*, *39*(4), 377–395. https://doi.org/10.1007/s10603-015-9283-7

Galahitiyawe, N. W. K. (2020). Role Of Supply Chain Transparency: Traceability And Visibility In Achieving Environmental Performance. *International Journal Management Dan Business*, *1*(December), 1–15. https://orcid.org/0000-0002-4815-8101

Gold, S., Seuring, S., & Beske, P. (2010). Sustainable supply chain management and inter-organizational resources: a literature review. *Corporate Social Responsibility and Environmental Management*, *17*(230–245), 4.

Nurulia, D., & Mustafa, U. (2020). ANALYSIS OF POTENTIAL AND PROSPECTS OF PATCHOULI BUSINESS DEVELOPMENT IN ACEH UTARA DISTRICT, INDONESIA. *Russian Journal of Agricultural and Socio-Economic Sciences, 108(12), 99-105*.

Rahmayanti, D., Hadiguna, R. A., & Nazir, N. (2017). *Model Konseptual Pengembangan Agroindustri Minyak Nilam di Pasaman Barat Menggunakan Sistem Dinamik Conceptual Model of Patchouli Oil Industry Development in West Pasaman Using Dynamic System*. *6*(3), 126–132.

Rahmayanti, D., Hadiguna, R. A., Santosa, S., & Nazir, N. (2017). Conceptual Model of Patchouli Oil Industry Development in West Pasaman Using Dynamic System. *Industria: Jurnal Teknologi Dan Manajemen Agroindustri*, *6*(3), 126–132. https://doi.org/10.21776/ub.industria.2017.006.03.3

Rinaldi, R., Indra, I., Syaifullah, M., Sriwati, R., Douma, B., Zulfahrizal, Z., & Ar Rasyid, U. H. (2022). The effect of intercropping and different dose of goat manure application on growth of Pogestemon cablin Benth. *Journal of Patchouli and Essential Oil Products*, *1*(1), 5–10. https://doi.org/10.24815/jpeop.v1i1.23745

Robbins, S. R. J. (1982). *Selected markets for the essential oils of patchouli and vetiver*. Tropical Products Institute (TPI).

Salsabila, B., & Nugroho, A. (2023). Strategi Pengembangan Agribisnis Nilam Di Desa Teungoh Geunteut Kecamatan Lhoong Kabupaten Aceh Besar. *Jurnal Ilmiah Mahasiswa Pertanian*, *8*(3), 114–125.

Schultze, W., & Trommer, R. (2012). The concept of environmental performance and its measurement in empirical studies. *Journal of Management Control*, *22*(4), 375–412. https://doi.org/10.1007/s00187-011-0146-3

Silvia, V., Sartiyah, & Fitra, M. R. (2023). Demand for Indonesian Patchouli Oil Exports: the Panel Autoregressive Distributed Lag (Ardl) Approach. *Revista de Gestão Social e Ambiental*, *17*(2 SE-), e03090. https://doi.org/10.24857/rgsa.v17n2-021

Song, J. M., Sung, J., & Park, T. (2019). Applications of Blockchain to Improve Supply Chain Traceability. *Procedia Computer Science*, *162*(Itqm 2019), 119–122. https://doi.org/10.1016/j.procs.2019.11.266

Zikri, I., Agussabti, Indra, Kamaruzzaman, S., Susanti, E., & Mujiburrahmad. (2021). Study on sustainable agriculture and dimension of needs: A case study patchouli farming in Aceh Jaya. *IOP Conference Series: Earth and Environmental Science*, *667*(1). https://doi.org/10.1088/1755-1315/667/1/012038