

Sustainability Study by Mapping Risks Patchouli Supply Chain In Aceh Province

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Abstract: This study aims to identify and map risks in the patchouli supply chain in Aceh Province with the aim of improving supply chain conditions so that patchouli essential oil production becomes stable in terms of quantity and quality. This research uses a descriptive qualitative research design involving all patchouli supply chain actors, using in-depth interviews as the main technique, followed by participatory observation to validate the interview results. The research instrument includes all activities related to supporting facilities and infrastructure for upstream and downstream patchouli commodities. Through interviews with 38 supply chain actors, information was obtained on 32 risks that become obstacles to the development of increasing patchouli production. The obtained risks were then categorized into 5 areas of sustainability, namely ecological, economic, social, infrastructure, legal and institutional. The results show that there are 6 risks in the ecological dimension, 10 risks in the economic dimension, 3 risks in the social dimension, 10 risks in the infrastructure and technology dimension, 3 risks in the legal and institutional dimension.

Keywords: Supply Chain, Risk Management, Patchouli Sustainable

1. Introduction

Indonesia is one of the largest essential oil producing countries in the world. Atsiri oils in world trade are called “essential oils”. Patchouli (*Pogostemon cablin Benth*) is the main essential oil-producing plantation crop in Indonesia, namely crude patchouli oil. The quality of Indonesian patchouli oil is known to be the best and controls a 90% share of the world market (Ministry of Agriculture, 2020). Patchouli oil is needed by the world because it contains Patchouli Alcohol (PA) compounds that function as fixatives, this compound is not owned by other essential oil content. This compound gives patchouli oil a special identity that gives it its own export opportunities compared to other essential oils, thus ensuring that the world's demand for patchouli oil will continue. Patchouli oil is a renewable resource with a wide range of applications, making it economically important in the fragrance and herbal sectors (A Kumar, N Sharma, C.S. Chanotiya, 2024). The key to export success lies in the quality and quantity of patchouli oil products, which still needs to be improved.

Indonesia is a price taker in the patchouli oil trade, despite being the largest supplier of patchouli oil. The challenge is how to achieve production stability to create ideal conditions for production continuity. The activities of cultivation, processing into crude oil and then marketing to consumers can be described by a sequence of supply chains. Knowing the current state of the supply chain and assessing the constraints faced in it is expected to be a solution for the sustainability of the patchouli commodity in Aceh Province. Constraints that become barriers in the form of risks that occur in the trading system / patchouli oil supply chain should be immediately mitigated to reduce the problems that will arise.

There is limited empirical evidence of sustainability-focused risk mapping in the patchouli supply chain in Aceh Province. Although Indonesia is a major global supplier of patchouli oil, there is limited research that comprehensively identifies and categorizes risks in its supply chain. The lack of in-depth studies on the factors that hinder the stability of patchouli oil production and quality makes it difficult to design effective mitigation strategies. Therefore, this study aims to fill this gap by mapping risks in the patchouli supply chain and analyzing them in the context of sustainability in order to provide more appropriate recommendations to improve the resilience and competitiveness of the Indonesian patchouli oil industry.

2. Purpose of Study

Research on patchouli commodity in Aceh Province has been conducted, including: the market structure of patchouli oil in Aceh Jaya with its trade type (Vonna, Indra and Nugroho, 2020), analysis of the feasibility of patchouli farming in North Aceh (D. Nurulia, U. Mustafa, 2020), research on the conclusion that the goal of sustainable patchouli agricultural development is based on three main pillars: economic, social and ecological (Zikri et al., 2021). There is still no research that takes a risk perspective that patchouli farmers face in their business activities. This research discusses these risks starting from the risks that occur, the frequency of their occurrence to the risk category in the segmentation of the sustainability assessment.

The following is a question guide for the completeness of risk information to be known in this study is what are the risks in the patchouli supply chain in Aceh Province, causes of these risks in the patchouli supply chain in Aceh Province and risks based on the sustainability category of the patchouli supply chain in Aceh Province. By knowing and examining the answers to these questions, this study seeks to provide insights that can inform strategies for improving the patchouli supply chain in Aceh Province.

3. Riview of Literature

3.1 Nilam (*Pogostemon Cablin Benth*)

Pogostemon cablin Benth, commonly known as patchouli plant, belongs systematically (taxonomy) to the family Labiatae and is an aromatic herbal plant that grows commercially in India, Malaysia, Philippines, Indonesia and Singapore (Kumaraswamy and Anuradha, 2010). Patchouli plants grow naturally in several Southeast Asian countries with tropical climates such as Indonesia, the Philippines and India (Idris, Ramajura and Said, 2014). Patchouli plants are also known as patchouli oil has been widely known since the colonial era of the Dutch East Indies Government, where Aceh from that time until now is known as the largest patchouli producer in Indonesia. The name Patchouli comes from the abbreviation Nederlands Indische Land ook Acheh Maatzchappij (NILAM), a Dutch company that organizes the sales and trading system of Patchouli plants, which at first, around 1921, was cultivated in West Aceh and South Aceh Districts to Aceh Singkil, which is a climate type A area according to Schmidt and Ferguson, where rainfall is evenly distributed throughout the year so it is very suitable for Patchouli growth, so until now Patchouli is still cultivated in Aceh Province.

The fluctuating development of patchouli in Aceh Province has received several reinforcements, so that the amount of production and productivity should continue to increase in the future. However, Aceh is still experiencing productivity stagnation; low productivity is caused by a very simple cultivation system and technology, and is very susceptible to pest attacks. The average productivity value is around 280 kg/hectare per year from 2015-2020, or experienced negative growth of 28.05% in 2017-2018. Declining production quality and unstable prices are affecting farmers' interest in patchouli cultivation and shifting to other sectors (Atsiri Research Center Universitas Syiah Kuala, 2020).

Patchouli oil is an essential oil obtained from the distillation of the leaves, stems and branches of the patchouli plant. Patchouli oil is a type of essential oil that has various functions in the soap, cosmetics and perfume industry that cannot be replaced by synthetic substances, because it plays a role in determining the strength, properties and durability of fragrance. This is due to its ability to bind the fragrance of other fragrance ingredients (fixative) and at the same time form a harmonious odor in a mixture (Van Beek & Joulain, 2018).

The development of patchouli commodities in Aceh Province is not only of economic value, but also of social value, where its success will improve welfare at the same time. The results of the Patchouli Oil Farming An Alternative to Poverty Alleviation through Smallholders Business (Ernawati *et al.*, 2019), suggest that the patchouli plantation business is one of the good alternatives for poverty alleviation, where the results of the business sustainability study show very good calculation results in the form of verification that even at the lowest selling price farmers will still make a profit.



Picture 1. Crued Oil Nilam

3.2 Supply Chain

The supply chain is a system of coordinated flows from the organization of materials, information, payments, services, and resources involved in the supply of raw materials through factories and warehouses to end users. Supply chains encompass the organizations and processes that create and deliver products, information, and services to users. The supply chain also includes various activities such as purchasing, payment flow, materials management, production planning and control, logistics and inventory control, distribution inventory and delivery (Stolyarov *et al.*, 2022);(A Kumar, N Sharma, C.S. Chanotiya, 2024);(Mallesham, 2024);

The term supply chain was first used by some logistics consultants in the 1980s. In 1982, supply chain management began to be used, focusing on logistics systems that describe the logistics management between related organizations (Liu *et al.*, 2017). Academics further analyzed the supply chain in the 1990s, so the concept of supply chain management (SCM) was born. The concept of supply chain has become a concern due to global competition and increasing demand for customer value as companies strive to improve their industry performance in terms of cost, delay, adaptability, variety, and traceability (Sadraoui, 2014). Supply chain includes three parts: upstream supply chain, internal supply chain and downstream supply chain (Naseer *et al.*, 2019). Supply chain management is the management of upstream and downstream relationships with suppliers and customers to deliver superior customer value at lower cost throughout the supply chain, including distribution activities, production schedules, and logistics (Christopher and Holweg, 2011). Supply chain management is evolving and is a process of integrity of several business entities that includes the procurement of raw materials, processing into finished / semi-finished materials and the distribution process to the end user (Ahumada and Villalobos, 2009). The supply chain management process involves the flow of goods, information and money (Gumus and Guneri, 2009). The analysis and evaluation of supply chain activities are intended to minimize business risks.

The current status of patchouli cultivation by farmers in Aceh Province is still less than 1 hectare on average, based on land ownership, farmers are included in the smallholder category, namely farmers who own 0.51 to 1 hectare of land. Indonesia defines smallholders as farmers who own no more than 25 hectares of land per (Ministry of Agriculture, 2020) . The World Food and Agriculture Organization (FAO) reports that Indonesian smallholders generally own about 0.6 hectares of land per household (Samberg *et al.*, 2016). Based on their land tenure, patchouli farmers in Aceh are classified as smallholders who need special attention in their development.

The conditions of other factors of production are also very diverse, including: land area, capital, use of seeds, labor, level of technology use, fertilizers, medicines that cause high and low production yields. Analysis of production factors should be done to get an overview of the constraints faced by farmers. All agricultural activities are represented in the supply chain, sequencing and value assessment in the supply chain are carried out to reduce risk and can increase yield and production value (Paillin *et al.*, 2022)(Pardaev *et al.*, 2023)

SCOR analysis describes the actors in the supply chain into 5 core processes, namely plan, source, make, deliver and return. Plan is reviewed into source, make, deliver and return because planning exists in each of these activities. The five processes function as described below:

1. Plan includes the process of estimating distribution needs, inventory planning and control, material planning production planning.
2. Source is the process of procuring goods and services to meet demand.
3. Make is the process of transforming raw materials/components into products that customers want.
4. Deliver which is the process of fulfilling demand for goods and services, including order management, transportation and distribution.
5. Return, which is the process of returning or receiving product returns for various reasons. (Pujawan, I. N., & ER, 2010); (Septarianes, 2020);(Ntabe *et al.*, 2015)

By analyzing and decomposing processes, SCOR can objectively measure supply chain performance based on existing data and identify where improvements in the form of efficiency or development need to be made to generate profits and competitive advantage in production. Implementing SCOR requires considerable effort to describe current business processes and define desired processes (Ntabe *et al.*, 2015). Implementing SCOR in the Patchouli supply chain is expected to provide maximum results for improving the performance and results of each actor in the supply chain.

The supply chain constraints based on SIDA (Bappeda, 2015) 24 obstacles are as follows: Quality patchouli seeds are not readily available, and the seed certification process is not straightforward, difficulty in obtaining organic fertilizers and biopesticides, limited farmland, shifting cultivation, deforestation, soil fertility not well controlled, farmers do not focus on patchouli cultivation, traditional patterns of planting and harvesting, pest control is difficult, post-harvest drying conditions do not meet standards, storage of raw materials (dried plants) is not good and dirty, availability of raw materials is not stable, water used to produce steam contains many contaminants, traditional refineries from used drums produce low quality products, distillation boilers and extractors are still energy intensive, use of wood as the main fuel in the patchouli oil distillation process, raw materials are a mixture of stems and leaves with a disproportionate composition, the installation of piping is too long and has too many turns, so that the energy loss becomes higher, cooling unit is not optimized, oil and water separation unit needs to be modified, refinery waste utilization is not good, refining of raw patchouli and its derivative products has not been developed yet, start-up innovations for the local market of derivative products have not been developed, product certification to be obtained, new international buyers are available

3.3 Supply Chain Risk Management

Efforts to meet needs in general are always accompanied by uncertainty, the higher the uncertainty faced, the more disturbances or risks that may occur. The occurrence of risk can interfere with efforts to achieve goals so that for solutions it is necessary to carry out a mitigation to overcome the risks that become obstacles. (Jankelova, Masar and Moricova, 2017). Risks that occur cause supply chain performance conditions to be far from expected, risk management plays an important role in keeping the supply chain system uninterrupted. Risk management is part of a management process that runs continuously to minimize losses and increase opportunities. This risk management process starts from the process of risk identification, risk assessment, mitigation, monitoring and then evaluation (Hopkin, 2018).

The study of risk in the supply chain of patchouli oil products has received increasing attention from various parties. This is related to the increasing number of risks in the business world and the patchouli industry. The condition of patchouli oil prices has not been strengthened and tends to fluctuate from year to year. Various risks that occur in the patchouli oil supply chain include a decrease in the amount of production and a decrease in the

quality of patchouli oil. (Tahyat, Rosmawaty and Yusran, 2022). In preliminary observations, the researchers received information from patchouli export agents who concluded that sustainability is a major obstacle in the Aceh patchouli supply chain, namely that the amount of production has decreased due to the declining interest of the Acehnese people in growing patchouli plants. Sustainability on the part of the farmers/cooperatives as a source is a major obstacle to meeting the growing global demand for patchouli.

Research on the sustainability of risk management by (Rafi-UI-Shan *et al.*, 2018) concluded that it consists of 4 things: Problem definition must be explained in detail, in terms of organization and management, empirical research needs to be conducted that specifically addresses why risk management is not integrated to be sustainable and what hinders / supports the implementation of risk management, there are many factors influencing risk that need to be carefully identified, there is a need to propose a framework for managing sustainability risks in volatile and unpredictable demand situations.

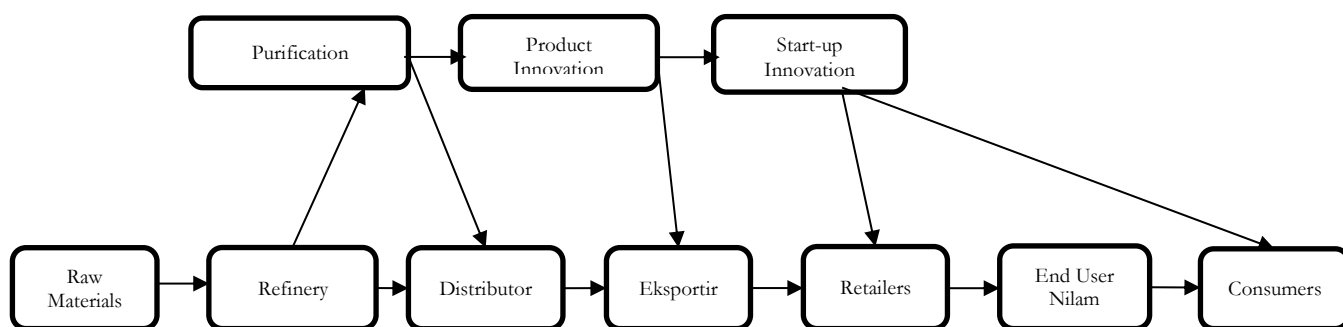
Management and calculation of risk levels based on the initial identification of the sequence in the supply chain known as SCOR (Chehbi-Gamoura *et al.*, 2020). The aspect of each actor in the supply chain is also a review of risk calculations, reference SCOR supply chain operations (source: farmers who are members of smallholder plantation cooperatives; make: business start-ups, industry; deliver: intermediary agents, large agents and exporters to return) all affect the level of supply chain success. The current innovation of business start-ups directly run by farmers and cooperatives has a positive impact on supporting price stability (Atsiri Research Center Universitas Syiah Kuala, 2020)

4. Research Methods

The first step of this research is to conduct a preliminary survey by observing the site and interviewing several cooperatives as research subjects. The purpose of the survey is to find out the state of the supply chain of smallholder patchouli plantations and the risks involved. Below is a summary of the research participants:

No	Position in the supply chain	Number of Respondents	Sample Collection
1	Farmer	27	Purposive Sampling
2	Cooperative Officer	7	Purposive Sampling
3	Agent	3	Snowball Sampling
4	Government	1	Snowball Sampling

The Atsiri Research Center has mapped the patchouli supply chain in Aceh Province and serves as a reference point for the development of activities in this study. Below is a picture of the patchouli supply chain in Aceh Province as mapped by ARC:



Supply Chain of Patchouli Industry ARC PUI-PT Nilam

The Aceh Province patchouli mapping supply chain formulated by ARC has described the basic supply chain and development in the form of purification, product innovation and start-up innovation carried out. The idea of renewal should be widespread, this research will examine the need for renewal in the field, as a whole will be implemented when production is stable. The main problem in the supply chain lies in the sustainability of Patchouli oil. Problems in the supply chain are analyzed by knowing the stages by mapping risk events and then

mapping risk causes (risk agents), both of which are assessed in terms of the highest risks that hinder the creation of sustainability patchouli oil in the patchouli supply chain in Aceh Province.

5. Result and Discussion

The results of the interviews and participatory observations show various risks in the patchouli oil supply chain, categorized based on the SCOR model, which includes the source, make, and deliver stages. These risks reflect the challenges faced by patchouli industry players, ranging from aspects of natural resources and production inputs, cultivation and processing, to distribution and marketing. Factors such as limited resources, low production quality, price fluctuations, and lack of regulation and oversight are the main obstacles that can affect the sustainability and competitiveness of the patchouli industry. By understanding and classifying these risks, it is hoped that more effective mitigation strategies can be designed to improve the efficiency and resilience of the patchouli supply chain, according to the risk event table of the research findings:

No	Kategori (SCOR Model)	Risk Event
1	Source	Low land fertility
2		Low water availability
3		Limited quality and number of seeds
4		Pests and diseases that often appear
5		Limited capital for farming/sales/forwarding business
6		No family support in patchouli cultivation
7		No support from village officials
8		Absence of institutions supporting patchouli farming (for example: farmer groups, cooperatives, etc.)
9		Conflict (internal farmers/security conditions)
10		Harvest Failure
11	Make	No managerial process of patchouli oil cultivation (planning, process, sales)
12		Patchouli farming income is low
13		No facilities to support patchouli farming (kettle, warehouse, etc.)
14		Low/poor quality of patchouli oil
15		Net product weight depreciation
16		Irregular refining activities
17	Deliver	Fluctuating price of patchouli oil
18		Limited sales market / Unstable demand for patchouli oil (supply and demand fluctuate)
19		Absence of price standardization rules
20		No regulation of patchouli sales market
21		Lack of government supervision of the patchouli supply chain
22		Delays in receiving patchouli oil to buyers

Based on the table above, it is known that the dominance of risk in the patchouli supply chain SCOR source lies in the procurement of raw materials & production factors, namely risks related to land, seeds, capital, institutions and external factors affecting production. The make category refers to the production & processing process, namely risks in refining, crop management and product quality. The deliver category refers to distribution & marketing, namely risks affecting sales, prices and product delivery. In the return category, there is no specific risk because it focuses more on production and distribution, there have been no returns of oil that does not meet quality standards or export contract discrepancies because samples were sent before the purchase transaction.

After 22 risk events were known, then analyzed what caused the emergence of these risk events, 32 risk agent were found that hindered and had to be mitigated, namely as follows: High temperature (heat), high rainfall, new land clearing (shifting cultivation), no fertilizer application during farming, no maintenance, inappropriate harvest procedures, expensive production facilities (seeds, fertilizers, pesticides), no organic fertilizer making process, low cultivation land area, land ownership status, limited farming capital, not joining farmer groups, low cooperation

between farmers, no supporting institutions (farmer groups, cooperatives), absence of supporting production facilities, patchouli oil mixed with other materials, water used for distillation is not sterile, distillation fuel uses wood (not environmentally friendly), oil storage/shipping packaging is not appropriate, the price of standard distillation equipment (stainless steel) is high, high distillation operational costs (fuel etc.), high costs (shipping, taxes, packaging), no work procedures are applied when distilling, distillation operational hours are uncertain, limited human resources / labor in farming / processing / shipping, delays in the refining process, no easy access to documents / files (assistance) for export, limited number of agents that accommodate patchouli, not maintaining cleanliness during the production, storage and shipping process, unavailability of international ports in Aceh, long distance (lading, warehouse, shipping place), no innovation in derivative products (making finished products, for example: dish cleaner made from patchouli oil, perfume etc.).

In analyzing the patchouli oil supply chain, identifying risks and sources of risk is a crucial step in understanding the challenges faced by industry players. The Risk Event (R1 - R22) reflect various constraints that can hinder the productivity and sustainability of the patchouli business, such as limited capital, low quality of raw materials, price fluctuations, and lack of institutional support. These risks arise as a consequence of various sources of risk agent (RA1 - RA32) rooted in ecological, economic, social, infrastructure, and regulatory factors. For example, low land fertility (R1) is caused by the absence of fertilizer application (RA4) and lack of maintenance (RA5), while limited capital (R5) is affected by high operational costs (RA22). By understanding the relationship between these risks and risk sources, more effective mitigation strategies can be designed to improve the efficiency and competitiveness of the patchouli oil industry. In more detail, the following is the relationship between the risk event and the risk agent that causes it

No	Risk Event (R)	Risk Agent (RA)
R1	Low land fertility	RA4 (No fertilizer application), RA5 (No maintenance)
R2	Low water availability	RA3 (Opening of new land), RA17 (Water is not sterile)
R3	Limited quality and number of seeds	RA7 (Expensive production facilities), RA10 (Low cultivation area)
R4	Pests and diseases that often appear	RA5 (No maintenance), RA6 (Harvesting procedures are not appropriate)
R5	Limited capital for farming/sales/forwarding business	RA11 (Limited farm capital), RA22 (High operational costs)
R6	No family support in patchouli cultivation	RA12 (Not joining a farmer group)
R7	No support from village officials	RA30 (No access to export documents)
R8	Absence of institutions supporting patchouli farming (for example: farmer groups, cooperatives, etc.)	RA14 (No supporting institution)
R9	Conflict (internal farmers/security conditions)	RA13 (Low cooperative relationship)
R10	Harvest Failure	RA1 (High temperature), RA2 (High rainfall)
R11	No managerial process of patchouli oil cultivation (planning, process, sales)	RA16 (No supporting production facilities)
R12	Patchouli farming income is low	RA11 (Limited capital), RA18 (Inappropriate storage packaging)
R13	No facilities to support patchouli farming (kettle, warehouse, etc.)	RA16 (No production facilities), RA20 (High price of refining equipment)
R14	Low/poor quality of patchouli oil	RA15 (Patchouli oil is mixed), RA18 (Storage packaging is not suitable)
R15	Net product weight depreciation	RA19 (Wood distillation fuel), RA18 (Storage packaging is not suitable)
R16	Irregular refining activities	RA26 (Uncertain operating hours), RA25 (No work procedures)
R17	Fluctuating price of patchouli oil	RA28 (Limited number of agents)
R18	Limited sales market / Unstable demand for	RA28 (Limited number of agents), RA31 (No

	patchouli oil (supply and demand fluctuate)	international port)
R19	Absence of price standardization rules	RA30 (No access to export documents)
R20	No regulation of patchouli sales market	RA30 (No access to export documents)
R21	Lack of government supervision of the patchouli supply chain	RA30 (No access to export documents)
R22	Delays in receiving patchouli oil to buyers	RA27 (Not maintaining cleanliness), RA29 (Long travel distance)

Based on the analysis of the relationship between risk events (R1-R22) and risk agents (RA1-RA32), it can be concluded that the main problems in the patchouli oil supply chain cover aspects of cultivation, production, marketing, and regulation and institutions. In terms of cultivation, low land fertility, limited water availability, and pest and disease attacks are caused by lack of maintenance, absence of fertilization, and inappropriate harvesting practices. Economic problems such as limited capital and high operational costs further worsen the condition of patchouli farming. In the production sector, the absence of adequate facilities and equipment, irregular distillation activities, and inappropriate storage contribute to the low quality and efficiency of patchouli oil production. From the marketing aspect, price fluctuations, limited markets, and lack of government supervision and regulation are major challenges in improving product competitiveness. In addition, infrastructure and institutional factors, such as the absence of an international port in Aceh and difficult access to export documents, further hinder the distribution and market expansion of patchouli oil. A holistic approach involving improvements in cultivation practices, strengthening access to capital, improving production quality and capacity, and developing regulatory and institutional support is needed to create a patchouli oil industry.

Furthermore, as efforts to improve the supply chain in a sustainable manner must involve the dimensions of sustainability, the analysis continues with these dimensions, which will present the main dimensions and attributes that contribute to various risks in the patchouli oil supply chain. These dimensions include ecological, economic, social, infrastructure and technology, and legal and institutional aspects. Each dimension has specific attributes that affect sustainability and efficiency in the cultivation, processing, and distribution of patchouli oil. The following is a table of Risk Agents with mapping according to the sustainability dimension:

No	Dimension	Attributes
1	Ecological	High temperature
		High rainfall
		Shifting Cultivation
		No fertilizer applied during cultivation
		No treatment applied during cultivation
		Inappropriate harvesting procedures
2	Economic	No manufacturing process for organic fertilizer
		Small cultivation area
		Land ownership status
		Business capital limitations
		Inappropriate oil storage/transport packaging
		High price and high operating costs of the appropriate refining technology (stainless steel)
		High operating costs for refining (fuel etc.)
		High costs (shipping, taxes, packaging)
		Lack of innovation in derivative products
3	Social	Expensive production inputs (seeds, fertilisers, pesticides)
		Low level of co-operation between farmers
		Limited human resources/labor in farming / processing / shipping
		Not a member of a farmer group / Lack of supporting institutions (farming groups, cooperatives)
4	Infrastructure and Technology	Absence of production support equipment such as boilers etc.
		Distillation water is not clean
		Wood fuel (not eco-friendly)

		No working procedures used in the distillation process
		Irregular distillery operating times
		Delays in the process of distillation
		Lack of hygiene during production, storage and shipping processes
		The non-availability of a public international port in Aceh.
		Distance between locations (loading, storage, shipping)
		No facilities and infrastructure / Absence of an institution to provide support
5	Legal and Institutional	No access / help with document / filing
		Limited number of major real buyers of patchouli
		Patchouli oil mixed with other substances

Based on the table, it can be concluded that various factors from the five dimensions of ecological, economic, social, infrastructure and technology, and legal and institutional play a crucial role in determining the success of the patchouli oil supply chain. Ecological factors such as high temperatures and extreme rainfall can affect crop productivity, while limited capital and high production costs are the main challenges in the economic aspect. On the social side, low cooperation among farmers and a lack of human resources in the cultivation to distribution process also worsen the condition of the patchouli industry. In addition, infrastructure and technology limitations, such as the unavailability of adequate production facilities and non-standardized work procedures, hamper the efficiency of the refining and distribution processes. Regulatory and institutional barriers, including difficult access to export documents and a lack of credible major buyers, further complicate the marketing of patchouli oil, requiring a comprehensive approach to address each risk factor.

Of particular note is the finding of Risk Agent 32 (No innovation of derivative products) related to the economic dimension, namely that there is currently no overall development of patchouli oil-based products in Aceh province, such as perfumes, cleaners, or other products with higher economic value. This can hinder business diversification, narrow market share, and make the patchouli industry more vulnerable to fluctuations in crude oil prices. Diversifying in agribusiness helps increase market share and stabilize revenue by introducing new products or services (Tomashuk, 2023);(Hochuli, Hochuli and Schmid, 2021). Therefore, efforts are needed to encourage research and development of innovative products to increase the competitiveness of the patchouli industry in domestic and international markets.

Conclusion

Analysis of the relationship between risk events (R1-R22) and Risk Agents (RA1-RA32), as well as their relationship to the dimensions of ecological, economic, social, infrastructure and technology, as well as legal and institutional sustainability, shows that the patchouli oil supply chain is faced with various complex and interrelated challenges, requiring an integrated strategy that includes improvements in all aspects of sustainability. Optimizing cultivation with more environmentally friendly agricultural practices, strengthening access to capital and market development, increasing cooperation between stakeholders, modernizing production and distribution infrastructure, and improving regulations and institutional support are important steps in building a more sustainable, efficient, and competitive patchouli oil industry in the global market.

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