ISSN 2055-0286
Advances in Social Sciences Research Journal; Vol. 13 No. 01 (2026) (287-294)
https://doi.org/10.14738/assrj.1301.19935

Supply Chain Risk Management of Molded Palm Sugar at Besan Village, Dawan District, Klungkung Regency, Bali Province, Indonesia

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Abstract: The molded palm sugar processing business at Besan Village, Dawan District, Klungkung Regency in Bali, plays an important role in contributing to community's income. However, the sustainability of this business faces various risks along the supply chain, ranging from unstable palm sap supply to distribution and product quality issues. This study aims to identify actors and to analyze their level of risks, and to formulate appropriate risk mitigation strategies along the molded palm sugar at Besan village. The research involved actors in the molded palm sugar supply chain, including tappers, palm sugar producers, collectors, and retailers. Supply chain process mapping was conducted using the Supply Chain Operations Reference (SCOR) approach. Risk identification and assessment were conducted using the Failure Mode and Effects Analysis (FMEA) method. Finally, prioritization of risk mitigation strategies was analyzed by using the Analytical Hierarchy Process (AHP) method. The results of the study indicate that the risks of the molded palm sugar supply chain are spreading across all supply chain actors. Critical risks are primarily related to the instability of the sap supply in the plan and source processes, as well as the risk of damage and product quality degradation during delivery and return processes. FMEA mapping shows that risks in the red and yellow zones are spread throughout the supply chain, accordingly it requires coordinated risk management. The AHP results indicate that priority risk mitigation strategies include mechanization of climbing equipment, strengthening partnerships, implementing a quality-based pricing system, and increasing the number of business partners. Based on the research results, it can be concluded that risk management in the molded palm sugar supply chain requires a comprehensive and integrated approach across actors. It is recommended that stakeholders and related stakeholders prioritize mitigation strategies that focus on strengthening upstream aspects without neglecting risk control at the downstream stages of the supply chain.

Keywords: supply chain, risk management, molded palm sugar, SCOR, FMEA, AHP.

INTRODUCTION

The molded palm sugar business at Besan Village plays a significant role in the income of the local community [1], however in practice, various risks affect its sustainability. Decreasing availability of palm sap tappers at Besan Village has resulted in limited raw material supplies, while limited access to capital hampers smooth production. Furthermore, the implementation of product quality standards has not been optimal, resulting in varying molded palm sugar quality. Accordingly, these risks arise not only in the production process, but also in financing, quality, and marketing [2]. Furthermore, the palm sugar producers depend on collectors to facilitate sales, but by the same time producers face the risk of product damage during storage. These various obstacles indicate that the problems faced

by palm sugar producers do not only occur at the production stage, but also reflect problems in the supply chain system as a whole, from raw material procurement to product distribution to end consumers [2].

A study by Fausayana et al. (2018) at Konawe District, South-east Sulawesi also found that risk in the palm sugar processing business are distributed across all stages of activities, ranging from raw material procurement and processing to market. This condition indicates that risk management in the palm sugar cannot be conducted in a partial manner, but rather requires a comprehensive supply chain approach [3].

This study was conducted to identify the risks in the molded palm sugar supply chain, to analyze the level of risk faced by each actor, and to formulate risk mitigation strategies for molded palm sugar at Besan Village, Dawan District, Klungkung Regency, Bali, Indonesia.

RESEARCH METHODS

The research was conducted at Besan Village, Dawan District, Klungkung Regency from May to December 2025. The research subjects included all key actors in the molded palm sugar supply chain, namely palm sap farmers (tappers), palm sugar producers, collectors, and retailers. The data used in this study consisted of primary and secondary data. The primary data collection technique used in this study was interviews starting at the palm sugar producers, then using snowballing techniques to find other actors in the supply chain. Secondary data were collected from the past literature studies and Besan village administration for the number of producers. The samples in this study began with 49 palm sugar producers. Based on information obtained from the producers, other supply chain actors were then identified, namely palm sap farmers, collectors, and retailers. Eventually there were two palm sap farmers (tappers), three collectors, and six retailers selected who have a direct connection to the flow of raw materials and molded palm sugar products at Besan Village.

Risk identification was carried out by mapping the activities of the molded palm sugar supply chain based on the five main processes in the SCOR model, namely Plan, Source, Make, Deliver, and Return [4]. Risk level assessment is carried out using the FMEA method by assessing three main parameters, namely the severity of the risk impact (severity), the frequency of risk events (occurrence), and the ability to detect risks (detection) which will produce RPN [5]. The risk with the highest RPN value is then used as the basis for determining handling priorities. Further analysis using the Analytical Hierarchy Process (AHP) method was carried out to determine the priority of the most effective risk mitigation strategy. In the AHP analysis, it will present structured decision making process, as various strategic alternatives need to be prioritized based on their level of importance to business sustainability [6]

In determining the priority of risk mitigation strategies using the AHP method, this study involved five key informants who were selected purposively based on their experts in palm sugar knowledge. These key informants consisted of representatives of the main actors in the molded palm sugar supply chain, namely tappers, palm sugar producers, and collectors, as well as two representatives from the Agricultural Officers of Klungkung Regency.

RESULTS AND DISCUSSION

Actors and Activities along the Supply Chain of Molded Palm Sugar at Besan Village

Tappers

Tappers play a crucial role in the molded palm sugar supply chain due to their role in harvesting coconut sap, the primary raw material for making molded palm sugar. The tapper's work process begins with planning daily tapping activities (plan) based on the number of coconut trees and determining the tapping times, which are carried out in the morning and evening. In procurement (source), tappers prepare all the necessary equipment, such as tapping knives, ropes, natural preservatives, and sap collection containers. The activity continues with tappers climbing coconut trees, cutting coconut flowers, and collecting the sap in containers (make). The obtained sap is collected twice a day. The resulting sap is then filtered to reduce impurities before being sent to the palm sugar producers. After tapping, tappers will immediately deliver fresh sap to the craftsmen (deliver) to prevent the sap from spoiling.

Palm Sugar Producers

Palm sugar producers transform fresh coconut sap into molded palm sugar. In the planning stage, palm sugar producers plan production based on the availability of raw coconut sap. Palm sugar producers generally cook in the morning. Next, in the procurement stage (source), palm sugar producers ensure that production tools and materials are available and clean. In the production stage (make), the coconut sap is cooked in a pan for 3-6 hours until it thickens and turns brown. Next, the sugar liquid is poured into molds until it hardens into molded palm sugar. The sugar is then packaged in plastic to protect it from moisture and then distributed (deliver). Most palm sugar producers sell to collectors at Besan Village, while others sell directly to stalls around the village, Klungkung Market, and traditional cake sellers. Palm sugar that is not matching with the market demand will be returned to the palm sugar producers (return).

Collectors

Collectors act as a liaison between producers and retailers. During the planning stage, collectors estimate the volume of sugar purchased from producers based on market demand. Then they collect sugar from several producers at Besan village then later resale in large quantities to retailers (source). Collectors make contact with producers who are as regular suppliers based on trust and continuity of supply. This allows collectors to maintain product quality standards and consistency according to the market needs. Quality policies vary among collectors. Some collectors implement strict quality standards by rejecting adulterated sugar and others apply adjustable decision, to maintain their product's reputation in the market. Conversely, others are more flexible and accept all types of sugar, including mixed or impure sugar, to maintain supply volume. The purchased sugar is then delivered to retailers such as at Galiran Market in Klungkung, traditional cake shops in Denpasar City and Gianyar Regency, and coffee shops in Denpasar City. If the sugar does not meet the requirements, it will be returned to the producers.

Retailers

Retailers function at downstream parties on the supply chain that sell palm sugar directly to end consumers, both in traditional markets and cake shops. Activities at the retailers begin with planning (plan), where retailers estimate availability of sugar from collectors based on daily needs and demand trends. Next, retailers purchase sugar (source) from collectors. For retailers who resell molded palm sugar, such as to food stalls and sellers in traditional markets, the (make) activity only covers product storage before reselling to consumers. Meanwhile, retailers who also act as food processors, such as traditional snacks and beverages, carry out the (make) stage by directly utilizing sugar as a processed ingredient. At the (deliver) stage, retailers distribute molded palm sugar products directly to end consumers. The (return) stage at the retailer level is relatively rare because molded palm sugar products have a fairly long shelf life and a low risk of damage when stored in dry conditions. However, in certain cases, product returns can occur if the sugar received by the retailer is far from the specified level. These returns are made directly to the collector from whom the product was obtained.

Risk Mapping, RPN Calculation, and FMEA Level Map

A risk event is a risk occurrence, symbolized by Ei, calculated with a Severity scale of 1-10. Scale 10 reflects the most of severe a risk event. A risk agent is the cause of the risk occurrence, symbolized by Ai, calculated with an Occurrence and Detection score on a scale of 1-10. Scale of 10 implies the most occurrence and detection of risk agent. The RPN is the product of Severity, Occurrence, and Detection. Table 1 reveals the risk events, risk agents, and RPN scores of molded palm sugar supply chain at Besan village.

Table 1: Risk Event, Risk Agent and RPN Score

No	Actors	Ei	Risk Event	S	Ai	Risk Agent	O	D	RPN
1	Tappers	E1	Fluctuations in palm sap yield	9	A1	It is possible that the wiretapping was not carried out routinely.	7	2	126
					A2	Unstable supply of sap due to the nelon system	9	1	81
		E2	The quality of the sap is unstable	6	A3	Potential use of inappropriate preservative mixtures	6	3	108
		E3	Potential for work accidents during tapping	7	A4	The condition of the coconut tree is slippery and there is a lack of vigilance.	6	4	168
2	Palm sugar producers	E4	Fluctuating sugar production	9	A5	Unstable supply of sap due to the nelon system	9	1	81
		E5	Potential for sugar to solidify	6	A6	Poor quality of palm sap	7	3	126
		E6	Risk of sugar being damaged during	5	A7	Handling of products by palm sugar producers during	8	2	80

			the distribution process			transportation and unloading is less than careful.			
		E7	Possibility of product being returned by collector/retailer	6	A8	Damaged sugar (broken or soft)	8	7	336
					A9	The aroma/taste of sugar is not right	7	9	378
3	Collectors	E8	Uncertain availability of palm sugar	8	A10	The number of supplier palm sugar producers is decreasing	8	2	128
					A11	Fluctuating sugar supply	8	2	128
					A12	The product did not pass the quality selection	8	2	128
		E9	Risk of sugar being damaged during the distribution process	5	A13	Careless handling of products at the collector during transportation and unloading	8	3	120
		E10	The possibility of the product being returned by the retailer	6	A14	Damaged sugar (broken or soft)	8	7	336
					A15	The aroma/taste of sugar is not right	7	8	336
4	Retailers	E11	Difficulty obtaining sugar supplies	8	A16	Irregular supply from collectors/palm sugar producers	8	2	128
					A17	The amount of sugar delivered was less than ordered.	8	2	128
		E12	Potential to reject sugar	6	A18	Damaged sugar (broken or soft)	8	1	48
					A19	The aroma/taste of sugar is not right	7	3	126

Based on Table 1, risk levels will then be mapped to identify and prioritize risks that need to be addressed immediately in the molded palm sugar supply chain. Risk level mapping serves as the final stage in the FMEA analysis, determining the position and priority of each risk agent based on the RPN values. Through this mapping, all risks in the molded palm sugar supply chain can be viewed more systematically by considering two main indicators: impact severity and risk priority value (RPN). Risk level along the molded palm sugar supply chain based on the severity and Risk Priority Number (RPN) is presented in Figure 1.

Risk Level		RPN		
		1-71	72-391	392-1000
Severity	1-6	A18	A3, A6, A7, A8, A9, A13, A14, A15, A19	
	7-8		A4, A10, A11, A12, A16, A17	
	9-10		A1, A2, A5	

Figure 1: FMEA Level Map

Based on the mapping of RPN values against severity levels in Figure 1, three risk priority zones were determined, they are green, yellow, and red zones. The green zone, called the Broadly Acceptable (BA) category, represents a low risk level that requires routine monitoring without urgent mitigation measures. The yellow zone, called the As Low as is Reasonably Practicable (ALARP) category, indicates a moderate risk level that requires more attention because it has the potential to increase if not handled properly. The red zone, called the Intolerable (INT) category, describes a high risk level that requires immediate handling because it has the potential to have a significant impact on the continuity of the production and distribution process. Risk agents to be handled to formulate mitigation startegy is presented in Table 2. There agent were coming from yellow and red zones in Fugure1.

Table 2: Risk Agents That Need to be Handled

No	Actors	Code	Risk Agent	Category	RPN
1	Tappers	A1	It is possible that the wiretapping was not carried out routinely.	INT	126
		A2	Unstable supply of sap due to the nelon system	INT	81
		A4	The condition of the coconut tree is slippery and there is a lack of vigilance.	ALARP	168
2	Palm sugar producers	A5	Unstable supply of sap due to the nelon system	INT	81
3	Collectors	A10	The number of supplier palm sugar producers is decreasing	ALARP	128
		A11	Fluctuating sugar supply	ALARP	128
		A12	The product did not pass the quality selection	ALARP	128
4	Retailers	A16	Irregular supply from collectors/palm sugar producers (late or not sent)	ALARP	128
		A17	The amount of sugar delivered was less than ordered.	ALARP	128

Mitigation Strategies for Supply Chain Risks of Molded Palm Sugar at Besan Village

Results of the Analytical Hierarchy Process (AHP) processing using Expert Choice 11 software indicated the weights and priority mitigation strategies for the molded palm sugar supply chain at Besan Village. The structure of the molded palm sugar supply chain risk mitigation strategy is presented in Figure 2.

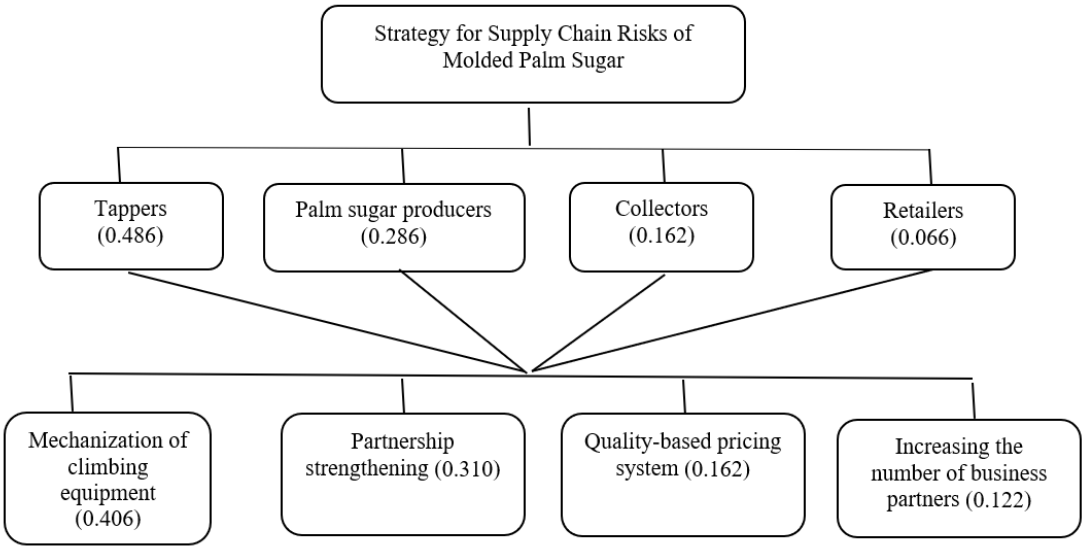

Figure 2: AHP Hierarchical Structure

Based on Figure 2, it can be seen that the climbing equipment mechanization strategy has the highest priority to conduct with the score of 0.406, making it the most recommended risk mitigation strategy. Climbing equipment mechanization can improve the efficiency and safety of tappers, ultimately contributing to the sustainability of the supply of sap, the primary raw material in molded palm sugar processing. The partnership strengthening strategy ranked second with a score of 0.310. This strategy demonstrates the importance of strengthening relationships between supply chain actors. Through sustainable partnerships, the risks of supply uncertainty, fluctuations in raw material quality, and dependence on specific suppliers can be minimized. Furthermore, the strategy of implementing a quality-based pricing system received a priority score of 0.162. This strategy has the potential to encourage improvements in the quality of the sap and molded palm sugar produced, while providing fair incentives for supply chain actors. The strategy of increasing the number of business partners ranked last with a weighting score of 0.122. The low priority score for this strategy indicates that adding partners is not yet seen as a primary solution in mitigating risks in the molded palm sugar supply chain. This is due to the potential for new risks, such as difficulties in quality control, increased coordination costs, and weak institutional ties between actors.

CONCLUSIONS AND SUGGESTIONS

This study shows that risks in the molded palm sugar supply chain at Besan Village are spread across all supply chain actors, from tappers, palm sugar producers, collectors, to retailers. Risks at the upstream level are dominated by instability in the supply and quality of the sap, while risks at the downstream level are primarily related to product availability and damage and deterioration in the quality of the sugar during handling and distribution. The FMEA analysis results in three risk classification zones with the most risks occurs in the red zone at upstream level of the supply chain. Nonetheless, there are several critical risks might occur at the yellow zone that require immediate, priority attention and coordinated

handling among supply chain actors. Based on the AHP analysis, the highest priority risk mitigation strategy is the mechanization of climbing equipment to reduce the risk of unstable sap supply and work accidents at the tappers level. Subsequent strategies include strengthening partnerships between supply chain actors and implementing a quality-based pricing system to control supply fluctuations and maintain product quality. These findings confirm that risk control in the molded palm sugar supply chain needs to focus on strengthening the upstream aspect as the main source of risk, while still paying attention to risk management at the downstream stage. Further research is recommended to integrate risk analysis with supply chain performance and sustainability measurements and utilize time series data to find out risk dynamics of the molded palm sugar.

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