

A model framework for coordinating the upstream supply chain of sago-based food MSMEs

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Abstract. The micro, small, and medium enterprises (MSMEs) engaged in sago-based food production have not been running optimally. One concern is related to the management of raw material procurement (sago starch), which involves relationships with suppliers. This study aims to build a model framework for coordinating sago food MSMEs and sago starch suppliers. First, identification and analysis were conducted on the sago food MSME supply chain in Kepulauan Meranti, Riau, Indonesia. Second, the required coordination between MSMEs and suppliers was discussed using optimization models that incorporated assumptions, parameters, and decision variables. The model framework can assist sago food MSMEs in planning related to coordination with suppliers. Thus, it is expected that optimization of the coordination system can lead to increased performance and competitiveness of the MSMEs sago food supply chain.

1. Introduction

Sago is the main commodity in Kepulauan Meranti Regency, Riau, Indonesia. The production of Meranti's sago reached 351,967 tons in 2020, contributing approximately 74.43% of the national sago production [1]. Most of the produced sago starch is shipped to Cirebon as a gate to consumers on Java island. The remainder is intended to meet the demand of local consumers, including sago food MSMEs. Currently, various types of sago food products are produced by MSMEs, as can be found in Kepulauan Meranti, e.g., sago noodles, fat sago, sago rendang, shogun, sago crackers, sago cendol, sago cake, sago sugar, and sago rice [2], [3]. The development of sago products in the form of product diversification and improved product quality will contribute to the development of the agricultural and industrial sectors, which will ultimately have an impact on improving the local economy [4], [5]. However, [3] reported that 70% of sago food business owners still have low incomes and do not show an increasing trend each year. Moreover, the number of sago food MSMEs has fluctuated. In line with this, [6] stated that the sago industry development was slow. From the initial observations of Meranti sago food MSMEs, there has been a decrease in the supply of sago in recent years due to natural factors. This makes the competition in obtaining sago starch quite tight and the price of sago flour is increasing. Therefore, this condition requires attention because it can affect the competitiveness of sago food MSMEs.

Problems faced by sago food MSMEs could be seen as the ineffectiveness of supply chain management (SCM). [7] shows that MSME's business performance of MSME could be increased by implementing appropriate SCM strategies. Furthermore, [8] showed that the collaborative capability of MSMEs with supply chain members can improve operational performance and gain mutual benefits. [9] revealed that among the non-financial indicators that can be used as a measure of SME performance is the form of collaborative relationships with suppliers regarding customer service (e.g., demand fulfillment and fast product delivery). [10] identified key

measures for increasing the competitive advantage of MSMEs, including aspects of SCM, namely, minimizing operational costs, producing within capacity limits, maintaining affordable prices, and improving customer service. Therefore, to be competitive, SMEs must find effective strategies to implement SCM [11]. Therefore, all entities involved in a supply chain must be coordinated to increase the profitability of the system [12]. Furthermore, coordination can help manage interdependence and reducing uncertainty [13].

Several studies have discussed the SCM perspective on MSMEs. [14] studied the optimization of the MSME supply chain using a multi-objective approach for sustainability purposes in the textile industry sector. [15] conducted resource optimization in the MSME supply chain in India for the tiffin industry sector by applying integer linear programming. [16] developed a strategy for banana chip food MSME supply using a qualitative approach. [7] conducted an empirical study with linear regression to examine the effects of implementing supply chain management, competitive advantage, and innovation on improving MSMEs' performance. In the case of sago MSMEs, [17] developed a responsive supply chain system for the micro and small sago food industry. From the results of the review of these studies, it was found that there were no studies that examined the coordination aspect in a real MSME supply chain. As reported in [11], one of challenges for SMEs how to coordinate their operations with other members in a supply chain.

Based on the problems discussed previously, this study aimed to develop a model framework for coordinating the upstream supply chain of Sago Food MSMEs. The current Sago food MSME supply chain was analyzed as a basis for developing a framework model for coordinating MSMEs and Sago-starch suppliers. The model framework proposed in this study could assist related actors in making tactical decisions to improve the sago food MSME supply chain performance.

The next section of this article will sequentially presents the methods used in this study. [1 The results of this study are presented along with a discussion. Finally, the conclusion summarizes the results of the research objectives, in addition to conveying the limitations of the study and suggestions for future research.

2. Research Methods

2.1 Research stages

To achieve the study objectives, descriptive analysis was applied to analyze the existing sago food MSME supply chain, and mathematical models were used to describe the coordination system between the MSME and its raw material supplier. This study follows the stages as presented in Figure 1.

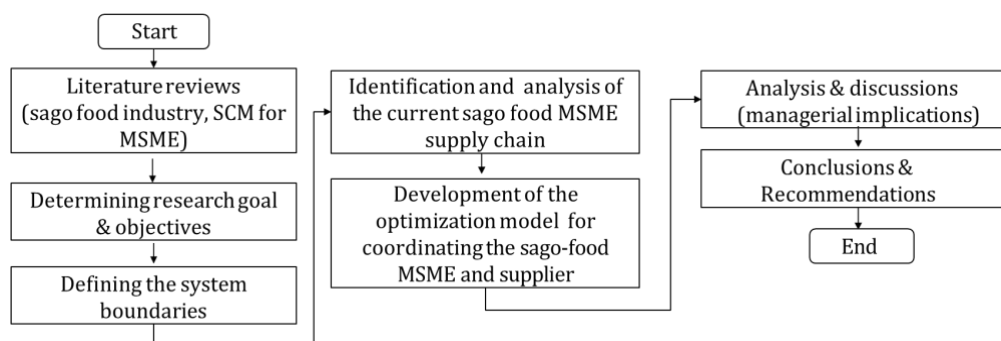


Figure 1. Research stages

2.2 Data type and data collection

The study object was the sago food MSME supply chain selected by purposive sampling. This study examined the case of the sago food MSME supply chain in Kepulauan Meranti Regency, Riau Province, Indonesia. Both primary and secondary data were required for this study. The first type of data included field observations and semi-structured interviews with

representatives of sago food MSME and sago mill (as a supplier). The secondary data type that supported the analysis in this study was obtained from article journals and proceedings.

2.3 Techniques of analysis

This study employed Linear Programming (LP), a popular technique in Operations Research, to model the problem. Readers can refer to [18] for a detailed explanation of the LP technique. The LP and its variants have the ability to analyze problems logically. Similar techniques have also been applied by [15], [19], and [20] in the logistics and supply chain management.

3. Results and Discussion

3.1 Identification and analysis of the existing supply chain system

The results of direct observations of the sago food MSME supply chain in Kepulauan Meranti and considering the findings of [21] and [22], a description of the sago food MSME supply chain is presented in Figure 2. The upstream MSME supply chain involves sago starch suppliers (i.e., sago mills, agents, stores). On the downstream side, there are several types of buyers or consumers (i.e., agents, stores, and household consumers).

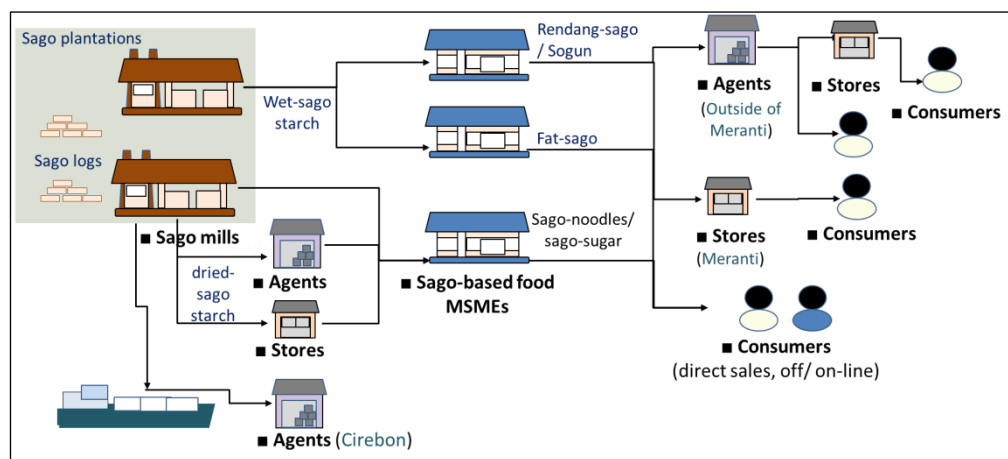


Figure 2. Structure (raw material and product flows) of the sago food MSME supply chain.

Overall, it can be seen in Figure 2, where MSMEs are in the center position and have various forms of networks, both to raw material sources and for their marketing networks. It can also be seen on the upstream side that MSMEs buy dried sago starch through agents or shops because the purchase rate is still low, and the distance is relatively far from the sago mill location. Whereas the diversity of marketing networks is considered quite effective in facilitating consumers in obtaining the products. This practice is in line with the suggestion of [3] that marketing capabilities and business networks are factors driving the success of sago-based MSMEs.

3.2 The optimization planning models for the sago-food MSMEs and supplier (sago mill)

Before designing a coordination system between MSME and supplier (this paper is limited to sago mills that produce wet-sago starch), an optimization planning model must first be developed for both actors.

To develop the sago-food MSME optimization planning (MOP) model some components including the indices, decision variables, and parameters must be listed and defined. For indices, i indicates the type of sago food product and t indicates a period. Both indices were placed as subscripts attached to variables or parameters. The index attached as a superscript indicates the owner of the decision model. The notations used for the MOP model are listed in Table 1.

Table 1. The notations for MOP model

Notation	Definition	Type*	Notation	Definition	Type*
Z_t^M	Total profit of MSME in periode t (in IDR)	V	L_i^M	Delivery cost of product i (in IDR/km)	P
$Y_{i,t}^M$	Quantity of delivered product i by the MSME to customers in period t (in kg)	V	d^M	Distance of MSME to customer location (in km)	P
$X_{i,t}^M$	Production quantity of sago-food product i in period t (in kg).	V	R_s^M	Purchasing cost of sago-starch s (in IDR/km)	P
$O_{s,t}^M$	Order quantity of sago-starch s to supplier in period t (in kg).	V	H_i^M	Inventory cost of food product i (IDR/kg/period)	P
$I_{i,t}^M$	Inventory of sago-food products i at the end of period t (in kg).	V	$v_{i,s}^M$	Conversion ratio of product i to sago-starch s	P
$D_{i,t}^M$	Demand of food product i in period t (in kg)	P	K_i^M	Production capacity of product i (kg/period)	P
p_i^M	Sales price of product i to customers (in IDR/kg)	P	W_i^M	Warehouse capacity for product i (kg)	P
C_i^M	Processing cost of product i (in IDR/kg)	P			

* V: decision variable, P: parameter

The LP-based MOP model has an objective function to maximize total profit by considering several constraints as presented in equations (1)–(7).

Objective function:

$$\begin{aligned}
 & \text{Max. } Z_t^M = \\
 & \sum_{i,t} (p_i^M \cdot Y_{i,t}^M) - \sum_{i,t} (C_i^M X_{i,t}^M) - \sum_{i,t} (R_s^M \cdot O_{s,t}^M) - \sum_{i,t} (d^M \cdot L_i^M Y_{i,t}^M) - \sum_{i,t} (H_i^M I_{i,t}^M) \dots\dots\dots (1) \\
 & \text{Total profit} = \text{Total sales revenue} - \text{total processing cost} - \text{total purchasing cost of wet-sago starch} - \text{total delivery cost of (sago-food) products} - \text{total holding cost}
 \end{aligned}$$

Constraints:

$$Y_{i,t}^M \leq D_{i,t}^M \dots\dots\dots (2)$$

Quantity of sago food products shipped to meet customer demand

$$X_{i,t}^M + I_{i,t-1}^M - Y_{i,t}^M = I_{i,t}^M \dots\dots\dots (3)$$

Product flow balance

$$X_{i,t}^M \leq K_{it}^M \dots\dots\dots (4)$$

Product quantity limits for each product type

$$O_{s,t}^M = \sum_{i,t} (v_{i,s}^M \cdot X_{i,t}^M) \dots\dots\dots (5)$$

Requirement level of raw material, i.e., wet-sago starch

$$I_{i,t}^M \leq W_i^M \dots\dots\dots (6)$$

Product inventory level at the end of each period

$$Y_{i,t}^M, X_{i,t}^M, O_{s,t}^M, I_{i,t}^M \geq 0 \quad \forall i \in I, \forall t \in T, \forall s \in S \dots\dots\dots (7)$$

Requirements of variable values

While to develop the sago mill optimization planning (SOP) model, indice m denotes an unit of MSME and t denotes a period. The required notations as presented in Table 2.

Table 2. The notations for SOP model

Notation	Definition	Type*	Notation	Definition	Type*
Z_t^{Sw}	Total profit of sago-mill I in period t (in IDR)	V	L_m^{Sw}, L_o^{Sw}	Delivery cost of wet-sago starch to MSME m and to overseas marketing agency (in IDR/km)	P
$Y_{m,t}^{Sw}, Y_{o,t}^{Sw}$	Quantity of wet-sago starch delivered successively to MSME m and overseas marketing agency in period t (in kg)	V	d_m^{Sw}, d_o^{Sw}	Distance of sago mill to MSME m and to overseas marketing agency (in km)	P
$X_{i,t}^{Sw}$	Production quantity of wet-sago starch by the sago-mill I in period t (in kg).	V	R^{Sw}	Purchasing cost of raw material (sago log) from suppliers (in IDR/kg)	P
O_t^{Sw}	Order quantity of sago logs from the the sago-mill I to supplier in period t (in kg).	V	H_i^M	Inventory cost of food product i (IDR/kg/period)	P
$D_{m,t}^{Sw}, D_{o,t}^{Sw}$	Demand of wet-sago starch from MSME m and overseas customer in period t (in kg)	P	v^{Sw}	Conversion ratio of wet-sago starch to sago log	P
W^{Sw}	Wholesale price of wet-sago starch by the sago-mill (in IDR/kg)	P	K^{Sw}	Production capacity of sago-mill I (kg/period)	P
C^{Sw}	Processing cost of wet-sago starch (in IDR/kg)	P			

* V: decision variable, P: parameter

Similar to the previous model, the LP-based SOP model has an objective function to maximize total profit by considering several constraints as presented in equations (8)–(15).

Objective function:

$$Max. Z_t^{Sw} = \sum_{m,t} (W^{Sw} \cdot Y_{m,t}^{Sw} + W^{Sw} \cdot Y_{o,t}^{Sw}) - \sum_t (C^{Sw} X_t^{Sw}) - \sum_t (R^{Sw} \cdot O_t^{Sw}) - \sum_{m,t} (d_m^{Sw} L_m^{Sw} Y_{m,t}^{Sw}) - \sum_t (d_o^{Sw} L_o^{Sw} Y_{o,t}^{Sw}) \dots \dots \dots (8)$$

Total profit = Total sales revenue – processing cost – purchasing cost of sago logs – delivery cost of wet-sago starch to MSMEs – delivery cost of wet-sago starch to overseas marketing agency

Constraints:

$$Y_{m,t}^{Sw} \leq D_{m,t}^{Sw} \dots \dots \dots (9)$$

Quantity of wet-sago starch shipped to meet MSME demand

$$Y_{o,t}^{Sw} \leq D_{o,t}^{Sw} \dots \dots \dots (10)$$

Quantity of wet-sago starch shipped to meet overseas customer demand

$$X_t^{Sw} - Y_{m,t}^{Sw} - Y_{o,t}^{Sw} = 0 \dots \dots \dots (11)$$

Product flow balance

$$X_t^{Sw} \leq K^{Sw} \dots \dots \dots (12)$$

Product quantity limits for wet-sago starch

$$O_t^{Sw} = \sum_t (v^{Sw} \cdot X_t^{Sw}) \dots \dots \dots (13)$$

Requirement level of raw material, i.e., wet-sago starch

$$Y_{m,t}^{Sw}, Y_{o,t}^{Sw}, X_t^{Sw}, O_t^{Sw} \geq 0 \quad \forall m \in M, \forall t \in T \dots \dots \dots (15)$$

Requirements of variable values

To obtain a cheaper price of dried sago starch and with more efficient logistics cost, this study proposes MSMEs to accumulate their demands in an order directly to sago-mill. This refers to [11], where the existence of intermediaries is one of the obstacles SMEs face in coordinating supply chains. The decision model for sago mill that produces dried-sago starch is

not shown in this paper because it only requires some modification from the previous SOP model. Some of these adjustments include adding product inventory cost variable to the objective function and replacing customers from overseas marketing agencies with customers from marketing agents in Cirebon.

3.4 The coordination mechanism for the MSMEs and sago mill (supplier)

After each MSME and supplier (sago mill) decision optimization model is obtained, a coordination mechanism must be implemented for both parties. This coordination mechanism was performed in two steps.

In the first step, MSMEs, who assumed applying the make-to-order (MTO) system, would plan for the demand for sago food products from various customers. In this case, the MOP model requires input values of all parameters and can then be run to obtain solutions (values of decision variables) that can provide the maximum total profit for MSMEs. These decision variables include the amount of production, amount of delivered products, amount of inventory at the end of the period, and level of demand (order) for raw materials (sago starch) for each type (i.e., wet and dried sago starch).

In the second step, the supplier (sago mill) manages the sago starch demand from MSMEs together with other customers (i.e., overseas marketing agencies). This requires the SOP model to be run by inputting the parameter values termasuk demand dari MSME ($Y_{m,t}^{Sw}$) yang merupakan luaran dari MOP model ($O_{s,t}^M$). This obtains the value variables that can provide the maximum total profit for the sago mill. These decision variables include the amount of production and the amount of sago starch delivered to customers (for example, MSME) and the level of demand or marketing of sago logs (raw materials).

From the running results of the two models, the performance measurement of coordination level will be assessed from several measures. The first measure is the service level, which refers to the level of fulfillment for both the sago-food demand from downstream customers ($\frac{Y_{l,t}^M}{D_{l,t}^M}$) and the sago-starch demand from MSME ($\frac{Y_{O,t}^{Sw}}{D_{O,t}^{Sw}}$). The second measure is the profit level that could be achieved by both actors or supply chain profit ($Z_t^M + Z_t^{Sw}$) and the profit distribution between actors ($\frac{Z_t^M}{Z_t^M + Z_t^{Sw}}; \frac{Z_t^{Sw}}{Z_t^M + Z_t^{Sw}}$).

This study developed a coordination model that is also necessary for MSMEs in general [11]. Thus, the coordination model presented in this study can be used in other sectors with some adjustments to suit the characteristics and requirements of the supply chain system.

4. Conclusions

Currently, sago food MSMEs are not running optimally, so they require in-depth improvement efforts, including analysis of the current supply chain system. This study developed a coordination model framework for coordinating sago-based food MSME and sago starch suppliers. The coordination system required between the two parties is analyzed through an optimization model. This study has several limitations including only a coordination model between two actors and a generic model. Future works will include numerical analysis using real data and considerations of various supply chain risks as previously identified in [23].

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