The Analysis and Design of FFB Supply System from Independent Smallholders for Production food-grade CPO and High Acid CPO

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The Analysis and Design of FFB Supply System from Independent Smallholders for Production food-grade CPO and High Acid CPO

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Abstract. The mandatory biodiesel program in Indonesia requires more High Acid Palm Oil Mill (HACPO). Some Palm Oil Mill (POM) that are part of the biodiesel supply chain need more FFB to produce more HACPO. Despite the increasing demand for HACPO, POM must maintain food-grade CPO production. POM requires more FFB from independent smallholders to maximize two types of CPO production. POM needs to redesign the FFB supply system from independent smallholders by building a different delivery system to produce food-grade CPO and HACPO. This study aims to analyze and design an FFB supply system from independent smallholders at PT.RSI. The FFB supply system design consists of an FFB delivery system to make food-grade CPO from trusted farms belonging to partnered farmer groups and an FFB delivery system to make HACPO from independent smallholders not partnered with POM. The FFB Delivery system for food-grade CPO production consists of various services run on the cloud platform; truck allocation, weigh scheduling, weighing, and sorting. The Method for developing FFB delivery service using a system approach and System Development Life Cycle (SDLC). This research only discusses the analysis and design phase. The research output only focuses on designing a delivery system of FFB from partner farmers to support food-grade CPO. The simulation of FFB truck scheduling to control the queue at the weighing terminal to understand how the Block Appointment Scheduling (BAS) works in the FBB delivery system. With the support of two different delivery systems, POM easier develop a food-grade traceability system of CPO for export and HACPO for biodiesel.

1. Introduction

Crude Palm Oil (CPO) is vegetable oil from palm oil used by various types of industries. Good quality CPO for the food industry, while low-quality CPO for the non-food. The food industry uses 80% of world CPO production while the remaining 20% is for non-food industries with high value, such as biodiesel [1]. In Indonesia, the demand for CPO for the biodiesel industry has increased dramatically since the government expanded the mandatory biodiesel program for non-PSO (Public Service

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Obligation), industrial and commercial. In 2017 Indonesia's biodiesel production was 3.4 KL. In 2020, it increased to 8.59 KL[2].

Some Palm Oil Mill (POM) is part of the biodiesel supply chain that produces CPO for biodiesel feedstock. These POM previously made a lot of low Free Fatty Acid (FFA) CPO with < 3.5% FFA content and standard grade CPO with < 5% FFA content, now producing more High Acid CPO (HACPO) for the biodiesel industry. HACPO for biodiesel requires Fresh Fruit Bunch (FFB) with high oil content, made from overripe fruit with high FFA content. In contrast, CPO for food with low FFA content.

Currently, Indonesia's mandatory biodiesel program has reached 30% mix of biodiesel (B30). CPO demand for biodiesel will continue to increase, along with the government's program to increase the biodiesel mix. The high demand for HACPO for biodiesel requires more FFB. The challenge faced by POMs, which are part of the biodiesel supply chain, is separating and maximizing CPO production for food and HACPO for biodiesel. POM cannot rely solely on FFB from its plantations. To maximize these two types of CPO production, POM relies on FFB supply from independent smallholder's farms.

The characteristics of independent smallholder farms include; the location is far from POM, not in the same area, and the palm fruit sells through intermediaries. The remote location of the farm causes more frequent loading and unloading. Independent smallholders who do not form partnerships cannot directly sell FFB harvests to POM. The obstacles faced by independent smallholders include; they do not have private transportation and do not have a Fruit Delivery Letter (SPB) as a requirement for FFB to be accepted by POM [3]. The small FFB harvest has caused independent smallholders to sell FFB to middlemen, from middlemen to Peron, wholesalers, and finally to POM. The long independent smallholder FFB supply chain, causing a high risk of physical damage to oil palm fruit. Physical treatment of FFB during loading and transport by truck can cause injury [3]. Physical damage to palm fruit increases CPO FFA levels and decrease the quality.

On the other hand, many independent smallholders produce good quality FFB. These independent smallholders work together to manage oil palm plantations by forming farmer groups. They received Good Agriculture Practices (GAP) training from NGOs and CSR programs from POM. This farmer group agree in the form of a contract or MoU with the POM to supply FFB. Based on the agreement or MoU, they send FFB directly to POM. The quality of FFB from this partner farmer group is more controlled because the supply chain is shorter.

To maximize CPO production for food and HACPO production for non-food, POM needs to redesign the FFB supply system. The current supply system does not separate FFB for a different type of CPO production. The quality of CPO is not optimal because there is no FFA control in the supply chain. POM can utilize FFB from independent smallholder farms in partnership to maximize low FFA CPO for food. POM can use FFB from non-partnered independent smallholders to optimize the production of HACPO for biodiesel. POM and independent smallholders will get higher added value supported by two different delivery systems. However, the FFB delivery system for low FFA CPO production has several challenges in the field that need attention.

The challenge faced in developing an FFB delivery system from independent smallholders to produce food-grade CPO effectively is how to build a transportation system that facilitates the coordination between independent smallholders and farmer groups/cooperatives and between cooperatives and POM. Cooperatives as intermediaries play an important role in providing independent smallholder FFB transportation. Based on research [4], traders and independent smallholders in Riau and Jambi areas have low performance. One of the reasons is the unresponsive transportation system. They can achieve responsive transportation if the FFB transportation is on time and quickly. A responsive FFB delivery system will support FFA control throughout the FFB supply chain. Harvesting and transportation are activities that determine the quality of CPO products. The proper harvest method will affect the production quantity (extraction), while the correct delivery time will affect the production quality (FFA content).

Transportation is the largest source of expenditure for the entire operational process in the palm oil industry. Transportation costs account for about two-thirds of the total logistics costs, agroindustry transportation costs are approximately 45.81% of the total logistics costs [5]. Transportation has a direct relationship with the harvest schedule and quality assurance of FFB palm oil harvested. Therefore, FFB delivery is a critical activity because the quality of FFB is highly dependent on its short lifespan. High priority monitoring at harvest and delivery FFB is needed to produce low FFA CPO.

The FFB supply system is the delivery process of FFB from the farm, the weighing and sorting FFB at POM. Queues during weighing often occur at POM, especially during the harvest season. Transportation using trucks with a small capacity is one of the causes of long queues during weighing. Congestion due to truck queues increases truck cycle times, truck engines generate harmful emissions and lower terminal efficiency[6]. A truck is better to wait for departure than to queue at POM to maintain the quality of FFB [7]. POM can use scheduling at the truck weigh terminal to support low FFA CPO production. Scheduling can avoid fluctuations in truck arrivals. Fluctuations at certain times cause many service requests at the weighing terminal, which is the cause of the queue. FFB transport times shorter by scheduling the truck arrival, helping to maintain FFB quality.

The complex supply system of FFB has prompted researchers to design a better supply system Several studies on FFB transportation have been carried out, such as; establishing land planning and transportation network in Thailand [8]. Builds the FFB transport model in Kalimantan, Indonesia [9]. Makes a calculation model for FFB truck departure management by minimizing truck queues at PT. IGP, West Kalimantan and PT. LTW in West Sulawesi [10]. This study further develops an application for monitoring truck transportation to POM [11]. Some researchers also use ICT (Information and Communication Technology) to support delivery operations, including; Putro developed a production management information system to make sure delivery data in the form of a real-time sorting weighing process is accessible directly by management[12]. Nursyanti developed a desktop application for weighing data processing for recording the FFB weighing process [13]. From the studies above, there is no research focus on discus FFB delivery operations from independent smallholders. One of the studies on independent smallholder supply systems supported by purchasing services for the production of High acid CPO, biodiesel feedstock [14]. Research to improve the supply chain performance of independent smallholder FFB needs more attention because the Indonesian government relies on independent smallholders to develop mandatory biodiesel programs, but the attention of government institutions towards independent smallholders is deficient [15]; [16].

This study aims to analyze and redesign the FFB supply system for independent smallholders for POM that are part of the biodiesel supply chain. The design FFB supply system to POM consists of two FFB delivery systems. First, the FFB delivery system for the production of CPO for food. Second, the FFB delivery system for the production of HACPO for non-food, especially biodiesel. This research only focuses on analyzing and designing an FFB delivery system for independent smallholders to maximize the production of food-grade CPO. This delivery system provides weighing scheduling services, weighing recording services, sorting and low FFA CPO production planning services. These services support by cloud service technology and are accessible anytime and anywhere. This FFB delivery system aims to improve the coordination of FFB transportation to avoid long queues during weighing. Direct delivery support by the Block Appointment Scheduling (BAS). With BAS, weighing FFB trucks for low FFA CPO production is prioritized to maintain quality until the truck reaches POM. The research object is PT. RSI (Rohul Sawit Industry) in Rokan Hulu. Riau Province, Indonesia. PT. RSI has its plantation but also receives FFB from independent smallholders. Currently, three independent smallholder's groups are in partnership supplying FFB based on MoU to PT. RSI. The size of the plantation area of the farmer group in partnership with PT. RSI around 200 Ha. Farms from the groups will be selected to support the production of food-grade CPO.

2. Research Method

Analysis and design of new independent smallholder supply systems are using a systems approach [18]. The first step in the systems approach is to analyze the system and identify the components that interact.

2.1. Component Analyst

System analysis is the first stage in the design with a systems approach and System Development Life Cycle (SDLC). The system components are analyzed, starting from the actors involved and the roles of each actor. Next, identify the input data to the system, the rules that bind each actor, the resources needed and finally, the system's output, namely food-grade CPO products. The research object is POM owned by PT. RSI in Rokan Hulu, Riau Province. POM production capacity is 90 Ton FFB/hour, support by two terminals. The research focus is to design an FFB supply system for food-grade CPO production (Fig.1).

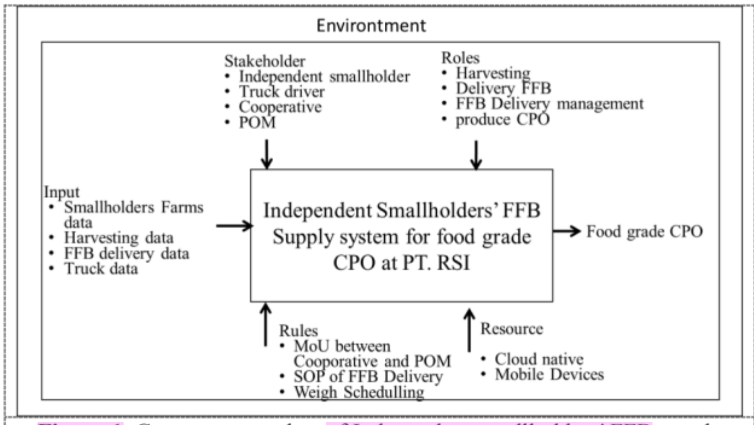

Figure 1. Component analyst of Independent smallholders' FFB supply system for food-grade CPO.

Cloud services will support the FFB Supply System. Analyst and design using System Development Life Cycles (SDLC). This study only discusses the analysis and design phase. Analysis of user requirements based on the SOP Delivery FFB book at PT. RSI. User requirements and system requirements model created using Unified Modelling Language (UML). The UML diagram consists of use case diagrams to describe user requirements and Business Process Modelling Notation (BPMN) 2.0 to define business processes of independent smallholders FFB supply to PT. RSI. The FFB delivery system's requirements for food-grade CPO are extracted based on the identification of business processes FFB supply at PT. RSI.

2.2. Truck queue model using Block Appointment Scheduling

The FFB truck weighing system at POM uses the conventional first in-first out (FIFO) method. To support the production of CPO for food, POM needs to develop a Terminal Appointment Scheduling (TAS) queue model to replace conventional weighing services. TAS is a method of scheduling truck arrivals that researchers widely discuss to avoid extreme conditions caused by fluctuations in arrivals at the container terminal [17]. Extreme conditions at the weighing terminal, cause by transportation from the farm that is not in sync with the production schedule. This harsh condition cause queues when many trucks request service; on the contrary, there is a vacancy in weighing services when trucks requesting weighing services are few. An important component in scheduling the arrival of trucks at the service terminal is the scheduling rule [17]. There is two type TAS based on scheduling rules. First, Individual Appointment Scheduling (IAS) and Block Appointment Scheduling (BAS). BAS Queue allocation is terminal oriented. Weighing terminal operators control the arrival rate of users effectively, keeping their resources operating at maximum levels while ensuring timely truck weighing service. BAS provide several block allocations times of queue in the terminal.

Krisdiarto [11] proposed a truck departure arrangement model to minimize queues in the weighing process. The model will be used to build BAS at the PT. RSI for CPO production for food. The truck arrival schedule synchronizes with the production schedule of CPO for food. The truck scheduling model is as follows

$$J_t = (J_l * K_l) / K_t \quad (1)$$

J_t is the number of trucks scheduled to depart from the plantation (units), J_l is the number of lorries containing FFB entering the boiling station (units), K_l is the lorry capacity (tonnes), and K_t = truck capacity (tonnes).
The scheduling time for weighing at the weighing terminal is:

$$tl = tb + ts \quad (2)$$

tl is the time the FFB truck is scheduled to arrive at the weighing terminal, *tb* is the time the truck departs from the farm, and *ts* is the cycle time (duration) of truck transportation from a particular farm to the POM.

3. Result and Discussion

3.1. User Requirement Analyst

The FFB delivery business process change follows the MoU between POM and cooperatives. All of the group farmer's trucks already register in BAS service. When harvesting at partner farmers' farms, the cooperative officers allocate registered trucks to transport FFB. After weighing the FFB at the farm, the cooperative officers then schedule this FFB truck to BAS service. The truck gets a weighing schedule. The POM weighing time (tl) must be greater than the truck transport cycle duration (ts). The truck departure time (tb) is adjusted by the driver so that the truck is not late at the weighing terminal. The delivery of FFB accomplishes with a Fruit Delivery Letter (SPB) document from a farmer group/cooperative. (Fig 2).

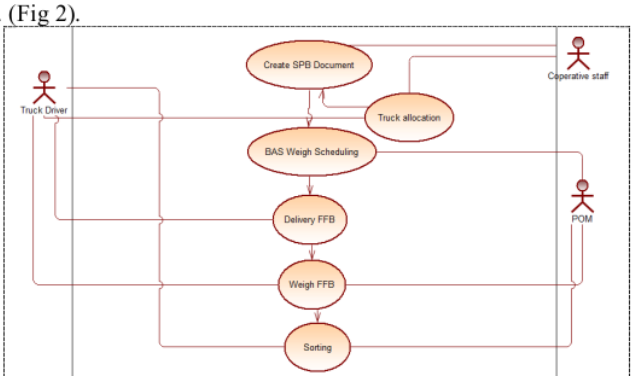

Figure 2. Use case diagram of FFB delivery for production food-grade CPO

The independent smallholder FFB delivery system has three main actors; cooperative officers, truck drivers, and POM. Each of them has a different role and carries out various business activities. Cooperative officers play a role in allocating trucks to the farm that are harvesting, ensure all harvested FFB is sent on time to POM. Cooperative officers also issue a Fruit Delivery Letter (SPB) for FFB shipments as a condition for fruit to be accepted at POM.

Drivers play a role in transportation, responsible for picking up FFB on the farm after receiving notification for delivery of FFB. The trucks consist of several types with different capacities (Table 1). Drivers are important actors ensuring FFB is delivered on time and overseeing the weighing and sorting process.

The manager production department arranges the production schedule for CPO for food. POM also ensures that the supply of FFB from company plantations, plasma farmers, and partner independent smallholders is maintained to maximize food-grade CPO production. POM activates TAS service when POM schedule the production of CPO for food. With the support of the TAS Service, the food-grade CPO production schedule will be in sync with the FFB truck delivery schedule. After weighing, this truck unloads for sorting the FFB. After the sorting process, the FFB send to the lorry for the boiling process.

Table 1. Truck Capacity

Truck Type	Capacity
Carry Pick Up	1.2 Ton
Cold Diesel	2 Ton
Cold Diesel Double Truck	4 Ton
Fuso Truck	7 Ton
Wooden Truck	10 Ton
Dump truck hydraulic	10 Ton

3.2. System Requirement Analyst

The existing condition of the Independent smallholder FFB supply system is running without schedule weighing and FFB Segregation. The FFB supply system starts when independent smallholders sell FFB to the middlemen/cooperative, then the middlemen collect the FFB and sell it to Peron. Next, FFB sells to wholesalers that have Delivery Order (DO) documents. Based on the DO document, the wholesaler sent FFB to POM. FFB from a group farmer/cooperative with an MoU or contract sends directly to the POM. After arriving at the POM, the truck waits in line to enter the weighing terminal. The weighing terminal controls the management of incoming fruit as the basis for calculating payments for harvesters and third parties and recording the production of supply farms. The truck unloads the FFB on the loading ramp for sorting processes. The loading ramp is a place for unloading FFB and serves as a temporary stockpile—the FFB Sorting ensures that the incoming fruit is in optimal conditions for oil extraction. Sorting results will reduce the number of FFB paid by POM. FFB from the loading ramp transport by lorry to boiling machine using the FIFO (first in-first out) Method.

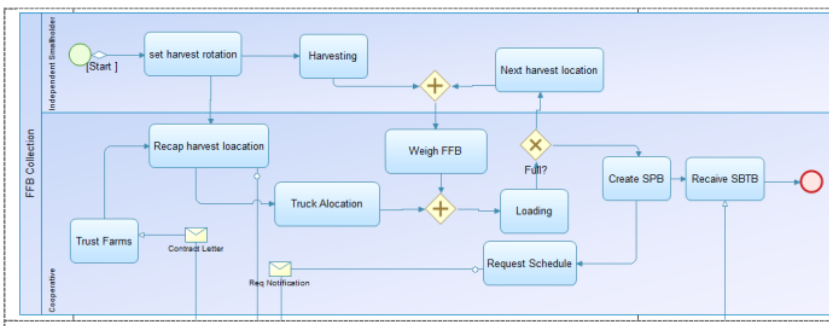

Figure 4. Business Process of FFB collection

POM redesigned the conventional FFB supply system by separating FFB delivery from trusted farms from smallholder's groups partner with FFB from independent smallholder farms. The FFB delivery system from trust farms starts with a harvest location recap by cooperative officers (Fig 4). Farmers Harvest FFB based on a predetermined crop rotation. Cooperative officers recapitulate the data on the plantations that are harvesting. From the recap, the Cooperative officer predicts the total harvest yields will ensure that the supply of FFB fulfils the FFB procurement contract with POM. Cooperative officers then allocate trucks with the appropriate capacity to transport the FFB. The Cooperative officer assigned the truck through a web-based delivery service. Truck drivers receive notification of FFB transportation from cooperative officers to transport FFB from TPH locations on the appointed harvest day. Cooperative officers input harvest data, including; harvest date, number of FFB, and weight of FFB. For each FFB delivery truck. The cooperative officer issues an SPB as a required document for receiving FFB at the weighing terminal. After record harvesting data using a mobile application, cooperative officers check the queue schedule for food-grade CPO production. Through online service, the cooperative officer asks for a schedule of trucks that have collected FFB.

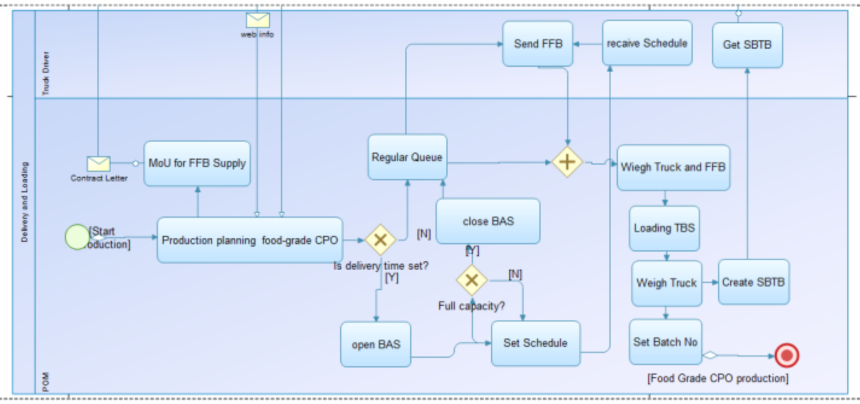

Figure 3. Business Process of delivery and loading FFB.

POM opens BAS weighing schedule service based on food-grade CPO production scheduling. After the BAS queue service open, the truck to be weighed asks for a weighing schedule. POM publishes the weighing schedule based on the availability of truck queue slots in the Block Appointment System (BAS) queue system. Trucks that register then get a weighing schedule at a predetermined time block. POM determines the weighing schedule for independent smallholder FFB trucks based on available weighing time blocks. The time block for weighing FFB trucks from independent smallholders open after the time blocks for weighing FFB trucks from company plantations and FFB trucks for plasma farmers are complete. Food-grade CPO production using batch number. The batch number base on the FFB block number. After the truck fills the BAS slot, POM will close the weighing service, indicating that the POM fulfils the food-grade CPO production.

3.3. BAS Simulation

The simulation of BAS truck queues is important to understand how this service works. In this simulation scenario, PT. RSI POM produces 900 Tons of FFB for food-grade CPO production. With a factory capacity of 90 tons/hour. To process 900 FFB with a total production time of 10 hours. In this simulation, POM allocates 180 tons FFB from partner group farmers. The time allocation for processing the partner farmers' FFB is two hours. In one hour of CPO production, the total FFB loads in the queue equal the POM production capacity, 90 tons. The production of food-grade CPO from partner farmers is carried out after POM process 820 Tons of FFB from the company's plantations and from plasma plantations which takes 8 hours. In the 1st block, there are 4 types of trucks scheduled to weigh at 16:00 – 18:00. 2 Cold diesel trucks (2 Tons), 4 Dump Trucks (10 Tons), 3 Fuso trucks (7 Ton), 2 Wooden Truck (10 Tons). The total number of queues is 11 trucks in 1st block (table 1). In the next block, the queue arrangement is 9 truck to reach of 90 Tons FFB.

Table 1. BAS simulation

No.	Asked for schedule	ts (hour)	tl (time)	tb (time)	Truck Capacity (ton)	+50% (ton)	∑ FFB 1st block	∑ FFB 2nd block	Batch number
1	10:20	3	13:00	16:00-17:00	4	6	6		9
2	10:30	4	12:00	16:00-17:00	4	6	12		9
3	10:50	2	14:00	16:00-17:00	2	3	15		9
4	11:10	4	13:00	16:00-17:00	4	6	21		9
5	11:50:	4	12:00	16:00-17:00	2	3	24		9
6	11:55	2	14:00	16:00-17:00	7	10.5	34.5		9
7	12:00	2	14:00	16:00-17:00	4	6	40.5		9
8	12:10	1	15:00	16:00-17:00	10	15	55.5		9
9	12:10	1	15:00	16:00-17:00	7	10.5	66		9
10	12:20	3	13:00	16:00-17:00	10	15	81		9
11	12:20	4	12:30	16:00-17:00	7	10.5	**91.5**		9
12	12:25	3	14:00	17:00-18:00	7	10.5		10.5	10
13	13:10	3	14:00	17:00-18:00	4	6		27	10
14	13:40	2	15:00	17:00-18:00	2	3		30	10
15	14:20	2	15:00	17:00-18:00	10	15		45	10
16	14:30	1	16:00	17:00-18:00	4	6		51	10
17	14:50	2	15:00	17:00-18:00	10	15		66	10
18	15:10	2	15:30	17:00-18:00	7	10.5		76.5	10
17	15:15	2	15:30	17:00-18:00	7	10.5		**86.5**	10

FFB delivery system for HACPO production without BAS service support. FFB quality control is not necessary. Independent smallholders send FFB through intermediaries. The delivery time for FFB longer because many parties trade the FFB before arriving at POM. FFB for HACPO production weighs at different terminals. FFB truck delays for HACPO production are tolerable. FFB from independent smallholder's farms stacks at the loading ramp. The POM processes the FFB from independent smallholder after the production of food-grade CPO finish.

4. Conclusions

FFB truck delivery service for food-grade CPO production support by BAS weighing scheduling. BAS controls arrivals and avoids queues at the weighing terminal. FFB trucks from trusted farms get priority service at the weighing terminal. This service also makes FFB delivery more effective, helping to coordinate FFB quality control. This cloud-based delivery service can ensure that FFB trucks deliver farmers' crops directly to POM. There is no accumulation of FFB on the loading ramp for food-grade CPO production because the FFB delivery and CPO production process are sync. On the other hand, HACPO production is not a priority, POM tolerates FFB accumulation for HACPO production.

Simulation of FFB delivery for food-grade CPO production helps to understand how BAS works. Time blocks provide to make FFB delivery operations more effective. A batch number also supports the production system. This batch of numbers uses for developing a traceability system for food-grade CPO for export purposes and HACPO for biodiesel.

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