The Potential for Value-Added Banana Production Waste under Circular Economy Concept

Cheerawit Rattanapan and Weerawat Ounsaneha

***Abstract*—The objective of this research was to identify the potential for value-added banana production by adopting circular economy concept. The resource utilization performance of a banana production factory in the middle part of Thailand was collected in 2020. The economic analysis and circular economy were used for developing the potential of banana production waste as value-added products. Finally, potential scenarios of value-added banana production were selected by brainstorming with the factory owner based on the circular economy approach. The result found four types of waste in banana production, including wastewater, rejected banana material, banana peel, empty banana bunch, and waste generated from the production process. Nine scenarios for value-added banana production were developed and proposed by the resource performance, economic analysis and circular economy implementation. After brainstorming with the banana factory owner, four potential scenarios for value-added banana production waste under circular economy concept were selected. The details of potential scenarios were as the following: banana powder form rejected banana, bio-compost from banana peels, re-use of wastewater, and sale of solid waste. From this finding, the circular economy concept should be recommended and implemented for enhancing the efficiency of the banana production process.**

***Index Terms*—Value-added product, Banana production, circular economy, Thailand.**

I. Introduction

According to the increasing world population and the different dietary habits, the demand for fruits has increased significantly over the past years. Banana is the one of most important fruits worldwide in terms of production [1]. Globally, banana is the eighth-most important food, with 148 million tons produced from 135 countries. It serves as a staple food for over 400 million people worldwide and is vital for food security [2]. These are commonly grown on a small scale by farmers throughout the tropics and sub-tropics in more than 150 countries, such as countries in Africa, Asia-Pacific and the Caribbean and Latin American regions [3]. Suvittawa [4] mentioned that there is a high demand for Thai bananas as agricultural products exports because they are perceived to be delicious and soft with high quality. The Department of Trade Negotiation, [5] identified Thailand as the second-highest banana exporter in the ASEAN, with 2,800 tons in 2020.

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However, the losses and waste can reach up to 35% in the supply chain for banana production [6]. During the past ten years, an increase in banana waste was recorded, with more than 353,443 tons per year. The natural biodegradation of banana waste produced foul odour, with the release of toxic gases to the environment [7]. Rattanapan and Ounsaneha [8], [9] mentioned that the supply chain for banana production in Thailand presented high environmental impact in the form of water and carbon footprints, with a high volume of banana waste production.

Alvarado-Herrera *et al*. [10] implied that scientific research on environmental issues has been proposed and developed by using the sustainable development concept. The relationship between the concepts of sustainability and circular economy has been increased for understanding and clarifying performance [11], [12]. Currently, the principle of circular economy concept has gained momentum as a perspective to tackle major global problems, such as resource scarcity and waste management [13]. It is seen as an alternative to the traditional linear economic model, contributing to environmental sustainability [14]. However, the concept of circular economy is relatively new, and the role of this approach in a future green transition is not yet fully defined nor exemplified at the local and regional levels [15]. For Thailand's situation, the concept of circular economy was applied to the cassava starch production process with the distribution process of rhizomes, sand, and peels [16]. Hence, the aim of this study was to assess the potential of value-added banana production waste under circular economy concept. The potential scenarios of sustainable banana production were developed by the concept of circular economy concept. Finally, the value-added banana production was recommended for waste minimization in Thai banana production.

II. Material and Methods

A. Goal and Scope Definition

The primary data for the factory case study was collected from a native banana production plant in the central of Thailand in 2020. The face-to-face interview and observation in the banana production factory were used as the data collection process. Gate-to-gate concept was implemented as the system boundary (Fig. 1). The production process was focused in this study. The volume of banana production of the case study was 21,352,500-32,850,000 kilograms/year. The banana factory was located in Pathum Thani province. The waste production performance and the economic feasibility of potential scenarios were determined.

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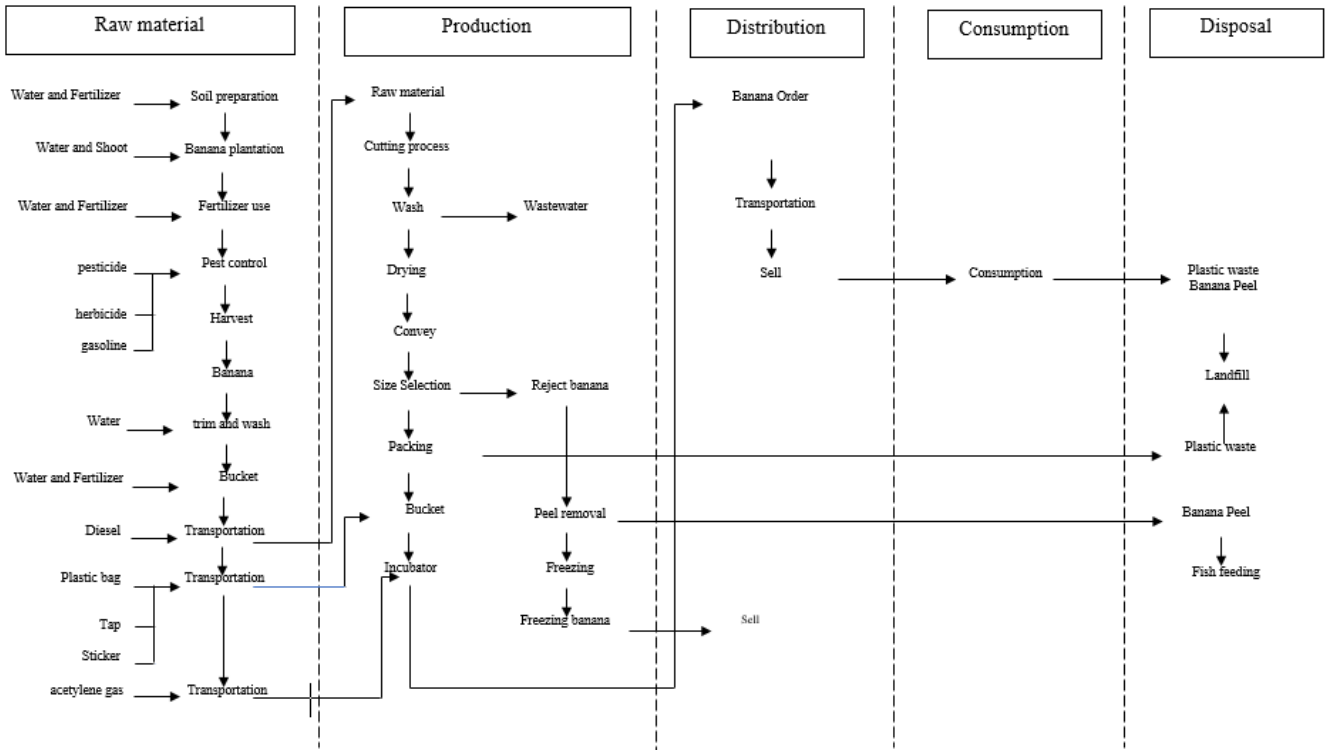

Fig. 1. Diagram of banana production.

B. The Potential Scenarios of Value-Added Banana Production

The process of banana production was designed by material flow concept. This concept can be used to identify the input and output streams of materials and energy and determined the possible cascading and coupling activities to apply [17]. The volume of waste generated from banana production was identified by the material flow analysis. Finally, the potential scenarios of value-added banana production were proposed and selected by literature review, the circular economy concept, and economic feasibility, followed by brainstorming with the company owner.

C. Economic Analysis

The income statement and payback period based on the data collection were used for economic analysis of potential scenarios of value-added banana production [18]. The operating costs consisted of costs of raw materials, labor, social fund, tax fund, and depreciation. The material cost was calculated directly from the price of materials used for manufacturing.

The income statement was used to assess the economic performance of the banana supply chain in terms of its present value. The income statement was calculated from Eq. (1):

$$\text{Revenues (Bath)} - \text{Expenses (Bath)} = \text{Benefit (Bath)} \quad (1)$$

The payback period is the time required to recoup the funds expended in the investment and was calculated from Eq. (2);

$$\text{Payback period} = \text{Cost of investment}/\text{Annual cash inflow} \quad (2)$$

III. Result and Discussion

A. Resource Performance

Fig. 2 and Table I presented the volume of resources and their performance in the production process of bananas, with input and output processes. The resources used in the banana production process consisted of banana raw material, water, acetylene gas, plastic tap, electricity and plastic bag in the production day. The output of the production process included banana products, wastewater and waste generated from the process.

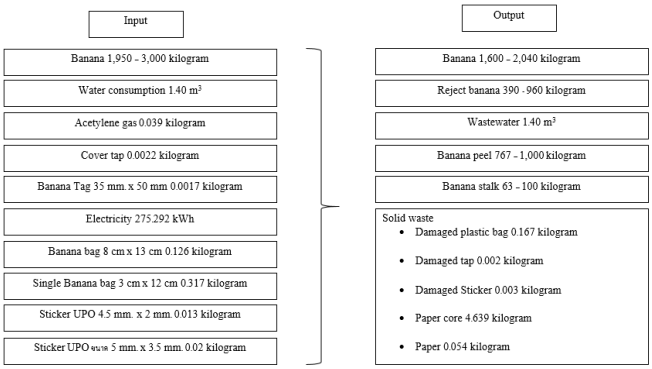

Fig. 2. Input-output resources of banana production.

B. Waste Production and Management

Fig. 3 presented the volume of waste production in each production process. The waste generated by banana production consisted of four groups including wastewater, the rejected banana material, banana peel, empty banana bunch, and waste from the production process. From the case study of the factory, the waste management of production process based on the waste type are the following: 1)

Wastewater: The main source of waste of banana production came from the cleaning process of raw material, with 511 m^3 of wastewater/year. The fish pond was used to treat the wastewater. 2) The banana raw material can be rejected due to unsuitable size, weight and skin. Around 131,400-350,400 kilograms of bananas/year were rejected from the selection process. The rejected banana materials (around 25,000 kilograms/month) were managed by the gas curing process within 24 hours, followed by the removal of peels by freezing process, and sent to the wholesale market. Moreover, more than 18,00 kilograms/week were directly sent to the retail seller. 3) Waste generated from the production process consisted of banana peel and empty banana bunch (276,000-360,000 kilograms/year). The banana peel and empty banana bunch from the factory were used in the fish feed and soil nourishing plants, respectively. From the observation of 400 rai of banana farms, 1.946 tons/rai of banana productivity was achieved.

TABLE I: RESOURCES PERFORMANCE OF THAI BANANA PLANTATION

items	Concentration			
	Per day	Per month	Per year	Unit
Wastewater	1.40	42	511	Cubic meter
Reject banana	350-960	0,800-28,800	131,400-350,400	Kilogram
Banana peel	767-1,000	3,000-30,000	276,000-360,000	
Banana bunch	63-100	1,890-3,000	22,680-36,000	
Solid waste				
-Damaged plastic bag	0.167	5	60	
-Damaged cover plastic bag	-	-	2,922-4,382	Kilogram
-Damaged cover plastic tap	0.002	0.053	0.636	
-Damaged sticker bag	0.003	0.082	0.984	
- Paper core	4.639	139.162	1,669.941	
- Paper	0.054	1.618	19.418	

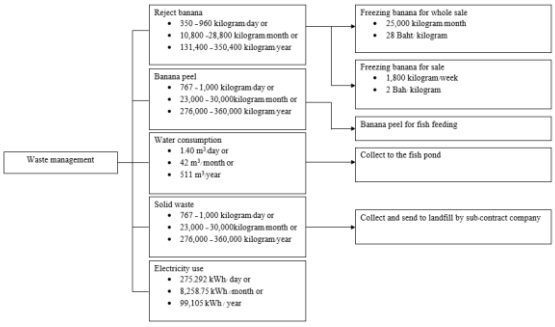

Fig. 3. Waste management in the banana production process.

C. Potential Scenarios

From the results of resources performance, waste production and management and circular economy were implemented for identifying potential scenarios for value-added banana production. Application of the circular economy concept to wastes and by-products from the agricultural production process can lead to sustainable development, higher economic profit and more efficient resource usage through waste minimization, as well as environmental benefits [16]. Nine scenarios for value-added banana production are shown in Table II. The potential scenarios consisted of 1) banana powder from rejected banana, 2) banana powder packed in capsules, 3) pasta from banana powder, 4) extra banana meatballs, 5) banana crackers from rejected banana, 6) bio-fermented juice from banana peels, 7) bio-compost from banana peels, 8) Re-use of wastewater, and 9) sale of solid waste. The output and the cost of the potential scenarios were developed and proposed to the factory owner. The benefits and limitations of potential scenarios for value-added banana production were identified by brainstorming with the factory owner, as shown in Table III.

TABLE II: POTENTIAL SCENARIOS FOR VALUE-ADDED BANANA PRODUCTION

No.	Scenarios	Output	Cost
1	Banana powder form rejected banana	40 kilograms	1,600 Baht
2	Banana powder packed in capsules	1,064 bowl	38,197.60 Baht
3	Pasta from banana powder	390 kilograms	27,555.33 Baht
4	Extra banana meatballs	344 kilograms	39,893.33 Baht
5	Banana crackers form rejected banana	484 kilograms	53,500 Baht
6	Bio-fermented juice from banana peels	2,150 kilograms	5,250 Baht
7	Bio-compost from banana peels	660 kilograms	1,118 Baht
8	Re-use of wastewater	0.7 m^3	-
9	Sale of solid waste	145 kilograms	+145 months

D. The Potential for Value-Added Banana Production Waste under Circular Economy Concept

After brainstorming with the factory owner, four potential scenarios for value-added banana production waste under circular economy concept were selected. From the factory owner's perspective, the financial support mechanisms are needed to progress from the early business-planning stage to the stage of operations and commercial sustainability [16]. The details of potential scenarios are presented in Table 4 and are as the following:

Scenario 1 Banana powder form rejected banana: 40 kilograms of banana powder was produced by 400 rejected bananas. 400 Bath per 1 kilogram of banana powder was charged by the sub-contract company. From the economic analysis, it was found that the revenue and payback period of this scenario were 14,000 Bath and 1.14 months, respectively.

Scenario 7 Bio-compost from banana peels: 500 kilograms of bio-compost was produced by 660 banana peels. 400 Bath per 1 kilogram of banana powder was charged by the sub-contact company. 41,782 Bath in revenue and a payback period of 0.03 months were found in this scenario.

Scenario 8 Re-use of wastewater: 1.14 m3 of wastewater was reused to water the plants, wash the floors and transport vehicles. Non-operational cost was found in this scenario with the reduction of water use costing 298.67 baht per month and a payback period within 0 months.

Scenario 9 sale of solid waste: Solid waste generated by month and year is presented as 145 and 4,670-6,130

kilograms, respectively. In this scenario, zero cost with the refund of 145 Bath per month and 298.67 Baht per year and a payback period within 0 months was found.

TABLE III: THE BENEFIT AND LIMITATION OF POTENTIAL SCENARIOS FOR VALUE-ADDED BANANA PRODUCTION

No.	Scenarios	Benefit	Limitation
1	Banana powder form rejected bananas	- Sub contract - Marketing - Value added product - New product for factory	- Staff number limitation
2	Banana powder packed in capsules	- Sub contract - Value added product - High volume of production - Short payback period	- Non marketing
3	Pasta from banana powder	- Novel product - Value added product	- High operation cost - Staff number and infrastructure limitation - Long payback period - Non marketing
4	Extra banana Meatballs	- High volume of production - Short payback period	- Complicated production process - Staff number and infrastructure limitation - Long payback period
5	Banana crackers form rejected bananas	- High volume of production - Short payback period	- Complicated production process - Staff number and infrastructure limitation - Long payback period
6	Bio-fermented juice from banana peels	- Value added product - Used within the factory	- Long production process - Non marketing
7	Bio-compost from banana peels	- Value added product - Used within the factory - Factory demand	- Staff number limitation - Non marketing
8	Re-use of wastewater	- Re-use process - Operation cost reduction	- Contamination
9	Sale of Solid waste	- Value added product	- Long process

TABLE IV: THE POTENTIAL FOR VALUE-ADDED BANANA PRODUCTION WASTE UNDER CIRCULAR ECONOMY CONCEPT

No.	Scenarios	Condition	Economic Analysis
1	Banana powder form rejected banana	400 kilograms of rejected banana = 40 kilograms of banana powder	- Revenue = 14,000 Bath - Payback period = 1.14 months
7	Bio-compost from banana peels	500 kilograms of banana peel= 600 kilograms of bio-compost	- Revenue = 41,782 Bath - Payback period = 0.03 months
8	Re-use of wastewater	1.14 m^3 of reuse wastewater	- Revenue = 0 Bath - Payback period = 0 months
9	Sale of Solid waste	145 kilograms of solid waste	- Revenue = 4,670-6,130 Bath - Payback period = 0 months

IV. CONCLUSION AND RECOMMENDATION

The objective of this study was to implement the circular economy concept in the waste management of banana production. Firstly, the resources utilized by a banana production factory were collected. Then, the economic analysis and circular economy concept were used to develop value-added banana waste management. The potential scenarios of value-added banana waste were selected and applied by brainstorming with the factory owner. The result showed four potential scenarios of value-added banana waste under the circular economy concept, which is as follows: Scenario 1 was banana powder from rejected bananas. With 40 kilograms of banana powder produced per 400 rejected bananas, the revenue and payback period of this scenario were 14,000 Bath and 1.14 months, respectively. Scenario 7 was bio-compost from banana peels. In this case, 500 kilograms of bio-compost per 660 kilograms of banana peels could be produced, with 41,782 Bath in revenue and 0.03 months of payback period. Scenario 8 was the re-use of wastewater. With 1.14 m^3 of wastewater reused per month, the reduction in the cost of water use was 298.67 baht per month and the payback period was within 0 months. Scenario 9 was the sale of solid waste. In this situation, 145 kilograms of solid waste were generated per month, with the refund of 145 Bath per month and payback period within 0 months. From the factory owner's perspective, financial support mechanisms are needed to progress from the early business-planning stage to the operations and commercial sustainability phase.

CONFLICT OF INTEREST

The authors declare no conflict of interest.

AUTHOR CONTRIBUTIONS

Conceptualization, and methodology, C.R., ;data collection and data analysis, W.O.; and writing, W.O.

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