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Supply Chain Model, Business Feasibility Analysis, and Business Model Canvas of Organic Food Waste Processing In the Perspective of Circular Agriculture

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ABSTRACT:

The research aims to design a supply chain model for processing organic food waste; calculate costs and benefits, and design a business model canvas. The research was conducted at Rumah Magot Komunal, Gunungpati District, Semarang City, involving various stakeholders. The results showed that the main products are fresh maggot and dry maggot with prices of Rp. 6,000.00/kg and Rp. 40,000.00/kg, respectively, while the derivative products are solid organic fertilizer and liquid organic fertilizer. Processing organic waste is feasible because it has a B/C ratio of 1.23 and a Payback Period of 17.6 years with an investment value of Rp. 16,440,000.00. The utilization of maggots as an alternative feed source can save animal feed costs up to 24.31%. The organic waste supply chain involves (1) households, restaurants, and shops as raw material suppliers; (2) Zero Waste Community as a processor of organic waste into animal feed & fertilizer; and (3) farmers, breeders, and the community as users of processed products. Cooperation is carried out with farmer and livestock groups, animal feed stores, related agencies, and social media to reach the customer segment. The advantages of maggot are its high protein and fat content. The main resources that need to be considered are (1) continuity of organic waste; (2) production facilities including maggot cultivation media, drying and flouring machines, compost houses, knowledge of effective production processes and the latest processing technology will help improve efficiency, product quality, and competitiveness in the market; (3) competent labor is needed so that the production process runs smoothly, and customers get satisfactory service. Relationships with farmer/breeder groups can be built through education, training, and social media.

Keywords: Supply Chain Model; Business Feasibility; Business Model Canvas; Organic Waste Processing; Circular Economy.

1. Introduction

Climate change raises the potential for food insecurity and water resource scarcity, which in the long term will threaten the achievement of the *Sustainable Development Goals (SDGs)* (McKinsey Global Institute, 2020; Gourdji et al. 2015; Craparo et al., 2015). The current climate change adversely affects the agricultural system and results in a decrease in food productivity. The application of integrated organic agriculture based on circular economy can help reduce emissions and increase crop productivity and resilience. On the other hand, about one-third of the food consumed by humans (1.3 billion tons) experiences *Food Loss and Waste (FLW)* throughout the supply chain each year (Abiad, M. G., & Meho, L. I, 2018); (Gustavsson, et al., 2011); (Ishangulyyev, R., et.al. 2019).

Climate change can adversely affect natural resources, biodiversity, and environmental services, and contribute to a 5-20 percent decline in agricultural productivity (Van Wijik et al., 2020). As in most developing countries, agriculture plays an important role in the Indonesian economy. The agricultural sector in Indonesia contributes 13.28% to the Gross Domestic Product (GDP) and can absorb a workforce of 38.7 million people.

One of the efforts that can be made to anticipate the negative impacts of climate change on the agricultural sector is to implement climate smart agriculture or commonly called *Climate Smart Agriculture* (CSA) (Azadi et al., 2021; Barasa et al., 2021). The implementation of climate-smart agriculture has three main pillars, namely productivity, adaptation, and mitigation. By implementing climate-smart agriculture, it is expected to increase agricultural productivity, reduce greenhouse gas emissions and also improve environmental sustainability.

The results of a study by the National Development Planning Agency, together with several institutions show that Indonesians throw away 23 to 48 million tons of food waste per year in the period 2000-2019, equivalent to 115-184 kilograms per capita per year (Bappenas. 2021). The economic loss caused by this *food loss* is equivalent to IDR 213 to 551 trillion per year or 4 to 5% of Indonesia's GDP per year. Socially, this loss is equivalent to the energy content of the meal portions of 61-125 million people per year. Types of food waste include vegetables (31%), rice (20%), meat (11%), dairy products (10%), and fish (10%) (Kata Data, 2021). Therefore, the issue of food waste needs to receive great attention from the entire community so that the economic losses caused by this sector can be minimized.

In general, the composition of organic waste in the form of household food waste, or also known as Kitchen Processed Waste (SOD), is proven to have a greater amount than inorganic waste, which ranges from 60% to 73% of the total household waste generation [Brigita, G., & Rahardyan, B. 2013) (Khasanah, F. N., Rofiah, S., & Setiyadi, D. 2019) (Widiarti, I. W. (2012) (Rahmasary, A. N., Koop, S. H. A., & van Leeuwen, C. J. 2021).

A circular economy is a system that can address global challenges such as climate change, biodiversity loss, high waste and pollution through economic activities that minimize waste and pollution, circulate products and materials at their highest value, and regenerate nature (Ellen MacArthur Foundation, 2021). Circular economy is an alternative to the concept of linear economy. A linear economy is a system of economic activity that is implemented with a '*take-make-use-dispose*' cycle, where resources are extracted from the earth (*take*)*,* then processed into a product (*make*)*,* then consumed (*use*) and immediately disposed of when the product no longer has a*use* value (*waste*) (Ritchie, H., & Roser, M. 2020). While the concept of circular economy recognizes the '*take-make use-return*' cycle, where resources are taken responsibly (*take*), then processed into a product (*make*)*, the* product is used by continuing to maintain its value (*use*) and at the end of its life the product is processed into a new product (*return*) (K. Shirvanimoghaddam, B. Motamed, S. Ramakrishna, and M. Naebe, 2020).

The circular economy is known to use the 5R principle, which consists of five elements, namely: *Reduce, Reuse, Recycle, Refurbish,* and *Renew* (Rieke D. Negro, et.al. 2022) (Morceletto, P. 2020). The circular supply chain implements a *closed-loop* system*,* which is to *recover* materials that can be reused. The research aims to create a supply chain through cooperation with farmers, ranchers, and restaurants, calculate the costs & benefits the value of the supply chain, and develop a canvas business model.

2. Research Methods

The research was conducted at “Rumah Magot Komunal” which is a zero-waste community group located in Cepoko Kel. Semarang City. The research used an *action research* approach. Komunals Nol Sampah is trying to save kitchen waste through the cultivation of *Black Soldier Fly* (BSF) maggot.

To optimize waste utilization, SOD is also processed into Maggot, solid organic fertilizer (Kasgot), and liquid organic fertilizer (POC). Kasgot is the residue/remaining product of biotransformation. SOD is supplied by households, restaurants/canteens, and once a month, the Komunals Team receives *food loss* product grants from the *Food Bank of Indonesia* (FOI) in the form of liquid milk in 1-liter containers, canned sweetened condensed milk, soft drinks and packaged tea drinks, snacks, imported chocolate, pasta, sauces, various chili sauce, herbal drinks, and snacks.

For the purpose of developing a supply chain model of waste treatment, interactive analysis is used (Miles & Haberman, 2014), while to calculate the value of the supply chain using percentage descriptive analysis. As for calculating costs and benefits using *B / C ratio* analysis *and Payback Period* as follows.

2. *Net benefit cost ratio* (Net B/C)

$$\text{Net B/C} = \frac{\sum_{t=0/1}^{n} \frac{B_t}{(1+i)^t}}{\sum_{t=0/1}^{n} \frac{C_t}{(1+i)^t}} \quad \text{.......(2)}$$

Description:
Bt = Gross benefit (gross income) in year t
Ct = Gross costs (total business costs) in year t
I = The prevailing interest rate
If Net B / C> 1 then the project / business is feasible, and vice versa

4. *Payback period* (PP)

$$\text{PP} = \frac{I}{Ab} \text{ (4)}$$

Description:
I = Investment cost required (Rp)
Ab = Net benefits obtained per year
If PP < business life, then the business is feasible, and vice versa.

Meanwhile, to build a canvas business model using nine variables, including main partners, main activities, main resources, value proposition, customer relationships, channels, customer segments, cost structure, and revenue streams (Osterwalder and Pigneur, 2012)

3. Results and Discussion

The research results show that the management of organic food waste processing starts from household Kitchen Waste (SOD), restaurants, rotten vegetable and fruit leftovers, and food loss sourced from the Food Bank of Indonesia (FOI), where in 1 month, it reaches a nominal of IDR 15,553,367.00. Organic waste is managed by the "Communal Maggot House," which consists of young people who care about the environment.

The supply chain for organic waste processing managed by the Communal Maggot House can be described as follows:

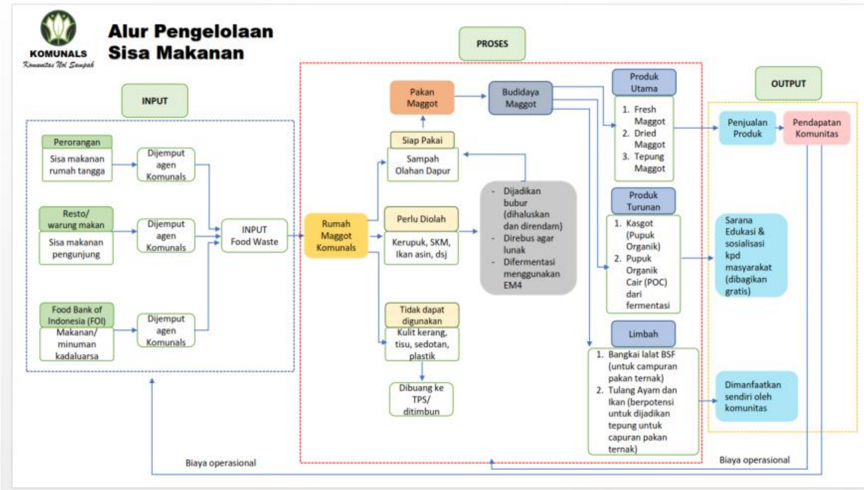

Figure 1: Organic Waste Processing Supply Chain Model

Implementing a circular supply chain, it is necessary to involve all stakeholders in the product/service life cycle, such as: suppliers, manufacturers, distributors and consumers (Batista L, Gong Y, Pereira S, Jia F, Bittar A. 2018). Collaboration between suppliers, manufacturers, customers and other *stakeholders* can keep the products in use moving in circles (M. Farooque, A. Zhang, M. Thürer, T. Qu, and D. Huisingh, 2019).
The value chain of each activity can be explained as follows:

Table 1. Cost Components of Sewage Treatment Supply Chain Activities

No	Activity	Cost Component	Cost	Total Cost	Percentage
1	**Garbage collection from the restaurant to the Maggot house**	**Operating Costs**			
		- Communication	5.000		
		- Transportation	300.000		
		Consumable Costs			
		- Plastic trash	10.000	315.00	19,295
2	**Waste management**	**Consumable Costs**			
		- Gloves	10.000		
		- Face Mask	5.000		
		- Stationery	5.000		
		Depreciation of Equipment			
		- Trash can	5.000		
		- Plastic Bucket	2.000		
		- Scales	200	27.200	1,67%
3	**Maggot Cultivation**	**Consumable Costs**			
		- Bran	20.000		
		- Tissue	8.000		
		Depreciation of Equipment			
		- Large Biopond	5.000		
		- Small Biopond	2.000		
		- Technical Equipment	1.000	36.000	2,20%
4.	**Main Products**	**Operating Costs**			
	a. Fresh Maggot	Water charges	25.000		
	b. Dry Maggot	Electricity cost	50.000		
		Labor costs	150.000		

	c. Maggot Flour	Electricity cost	50.000		
		Machine Depreciation	100.000		
		Labor costs	150.000	525.000	32,15
5	**Derivative Products**	**Operating Costs**			
	a. Solid Organic Fertilizer	Labor costs	50.000		
		Consumable Costs	20.000		
	b.Liquid organic fertilizer	**Operating Costs**			
		Labor costs	50.000		
		Consumable Costs	10.000	130.000	7.96
6	**Maintenance**	**Operating Costs**			
		Tool Care	50.000		
		Vehicle Maintenance	200.000	250.000	15,31
7	**Transportation**		50.000	50.000	3,06
8	**Training**		300.000	300.000	18,37
	Total cost			**1.633.000**	**100**

Source: Data Processed, 2024

Maggot cultivation has the potential to be one of the *waste* cultivations because the residue from this cultivation can be reused. BSF maggot is a larva with a high protein content that is good for livestock. With the same level of protein, maggot has a price that is about 50% lower than the price of animal feed such as chicken pur and catfish pellets. By utilizing maggot as an alternative feed source, farmers can save up to 24.31% on feed costs. Materials containing crude protein of more than 19% are considered good protein sources, 30% of fishmeal used for feed can be replaced by maggot (Murtidjo, B. A., 2001). (Ogunji, J. O., et.al., 2007). The protein content of maggots is quite high, which is about 40%. Maggot in dry form contains 41-42% crude protein, 14-15% ash, 31-35% ether extract, 0.60-0.63% phosphorus, and 4.8- 5.1% calcium (Newton, G. L. et.al, 2005). (Sogbesan, O. A., et.al, 2006) (Bondari, K., & Sheppard, D. C., 1987). Furthermore, compost made from organic waste has a high selling value. The benefits obtained by plants treated with compost are that they can grow well, and the processed organic waste can create a cleaner and healthier environment for the surrounding community (Slamet Priyanto et.al, 2023). Furthermore, sustainable supply chain management will maintain the food self-sufficiency of the nation and family as well as the semi-commercial needs of the community (Margunani et. all, 2018) (Soesilowati, et al., 2016).

Maggot cultivation residues and how to utilize them, among others, can be used as: (1) BSF fly carcasses can be added to *attractant* media because the smell *attracts* flies to lay eggs around it and can be given directly to chicken livestock or used as a mixture of chicken pellets because it still has a high protein content; (2) Kasgot or peeling maggot skin can be used as an organic fertilizer that increases soil fertility or planting media (**Alberta, Sartono Joko Santosa, and Siswadi**, 2024); (3) Kasgot residues can be in the form of animal bones that cannot be consumed by maggots, such as: Chicken bones, fish bones, rib bones, dried vegetables and hard fruit skins that cannot be decomposed by maggots can be processed into a mixture of pellets; (4) BSF fly cocoons can be utilized so that they are not wasted as organic waste and can be decomposed into chitosan to neutralize various industrial wastes; (5) Food ingredients that cannot be consumed by maggots directly such as broccoli are composted so that they become solid compost and liquid organic fertilizer.

The investment cost of maggot cultivation can be shown in Table 1 below:

Table 2. Investment Cost of Maggot Cultivation

No	Item	Quantity	Unit	Price (Rp)	Amount (Rp)
1	Maggot House	15	M2	1.000.000	15.000.000
2	Large Biopond	11	Unit	55.000	605.000

3	Small Biopond	6	Unit	20.000	120.000
4	Ladder	1	Unit	350.000	350.000
5	Large Plastic Barrel	1	Unit	110.000	110.000
6	Small Plastic Barrel	1	Unit	60.000	60.000
7	Plastic Bucket	2	Unit	25.000	50.000
8	Maggot Filter	5	Unit	15.000	75.000
9	Short Chair	2	Unit	35.000	70.000
Total Investment Cost					**16.440.000**

Source: Data Processed, 2024

The price of fresh adult maggot for animal feed ranges from Rp 6,000 to Rp 8,000 depending on the location of cultivation and market supply at the location concerned. On the other hand, the price of dried maggot can reach Rp 40,000 or more depending on the *treatment* added to the dried maggot product. With the previously described specifications of the Komunals Maggot House and ten adult maggot bioponds, as of August 2023, Komunals can achieve a production of 50 kg of fresh maggot in one month. In terms of business units, the Benefit/Cost Ratio calculation can be calculated as follows:

Benefit Cost Ratio = Total revenue / Total cost

= 413.000/ 335.000

= 1,23

The B/C ratio of more than 1 indicates that the investment in BSF maggot cultivation is feasible because the revenue earned is greater than the costs incurred in running daily operations. The time required for the Payback Period to recoup the investment is as follows:

Payback Payback Period = Initial Investment Value / Net Cash per Year

= 16.440.000 / (78.000 x 12)

= 17.6 years

The long payback period can be overcome by reducing investment costs, especially in the specification of Maggot Houses, which can be modified so that the required costs can be reduced. In addition to investment costs, BSF maggot cultivation also requires monthly expenditures for equipment such as bran (rice bran), chicken pur, plastic gloves, plastic waste, and daily mobility transportation costs for Communal Agents. Therefore, a monthly cost allocation of approximately IDR 345,000 is required.

This amount is certainly not an absolute number so it can be adjusted to the financial capabilities of the farmers. Assuming a stable maggot production of 50 kg per month, it is projected that by the fifth month (September 2023 in the case of the Communals), the cultivation of BSF maggots can run independently without additional personal costs from the Communals Team and can reimburse the transportation costs used for the mobility of the Communals Agent in picking up waste and transportation costs to the Communals Maggot House.

In addition to the main income from the sale of fresh maggots, Komunals also earns additional income from the sale of *food loss* packaging in the form of paper and plastic packaging. There are still many other potential additional incomes from BSF maggot cultivation besides the sale of inorganic waste.

Komunals data shows that in a month, the average segregated SOD collected from 2 restaurants and 1 warung alone reaches 584.2 kg/month. If this figure is averaged, then every day food places throw away 19.5 kg of SOD that will end up rotting in the landfill. This number does not include food loss in the form of expired and unsalable food from supermarkets. In a month, Komunals data recorded economic losses from food loss reaching around 15.5 million rupiahs, consisting of dairy products, sauces, packaged drinks, snacks, chocolate, and other food ingredients.

Organic waste processing as a substitute for imported animal feed can be built through a canvas business model using the following variables:

1. Customer Segments

Maggot has a lot of total fat content of 41.04% and protein of 36.05%, ash content of 5.70%, energy from fat of 369.32 Kcal/100 g, water content of 7.23%, total energy of 553.46 Kcal/100 g, and carbohydrates of 9.985%. At the same time, the results of the kasgot analysis show that the largest content owned is the water content of 55.10% and carbohydrates of 19.09%. The fat content and protein content contained in maggot are greater than commercial feed, so maggot and kasgot can replace concentrate feed, which is relatively expensive on the one hand and on the other hand, create a circular economy. With the benefits it has, the main customer segment for maggot products and their derivatives are farmers and breeders.

2. Value Propositions

The unique value offered by maggot products and their derivatives is in the aspect of nutritional content that can be used as feed for fish, ducks, and mammals, practically easy to produce and transport, economical because raw materials are easy to obtain and even abundant through waste utilization. Derivative products can be used for solid organic fertilizer and liquid organic fertilizer, thus creating a circular economy.

3. Channels

To reach the customer segment, maggot products and their derivatives can be through cooperation with farmer and livestock groups, animal feed stores, related agencies, and social media. The product has received a positive response from the community, with many farmers and breeders and local governments visiting the cultivation site to order feed through local delivery services and marketplaces. Starting from seeing the production process, trying feed and fertilizer can reduce costs to increase the income of farmers and breeders.

4. Customer Relationships

The relationships that need to be built with customers include several important aspects, including responsive customer service over the phone and social media, where consumers can ask questions and provide feedback; education and information through blogs, social media, and newsletters can help consumers make better decisions and maximize the benefits of the product; and loyalty programs through offering training programs to customers who continue to support the product. This can improve long-term relationships and encourage repeat purchases.

5. Revenue Streams

The main source of revenue comes from: First, direct sales to local farmers and ranchers through online and retail channels that enable direct consumer outreach and create a steady cash flow; Second, bulk wholesale sales to animal feed stores. These wholesale sales enable large-scale production and increase overall sales volume. Third, derivative products from the sale of processed products such as solid organic fertilizer and liquid organic fertilizer.

6. Key Resources

The key resources required include: First, organic waste supplied by households, canteens/stalls/restaurants, and vegetable farmers, where a stable and quality supply is essential to ensure continuity of production; Second, production facilities include maggot growing media, drying, and flouring machines, compost houses, which are required for processing, where to meet hygienic standards and efficient production processes. Knowledge of effective production processes and the latest processing technologies will help improve efficiency, product quality, and competitiveness in the market. Third, a highly competent workforce comprising production, marketing, and customer service teams. A well-trained and experienced team will ensure that the production process runs smoothly and customers get satisfactory service.

7. Key Activities

The key activities that need to be carried out include, First, the processing of organic waste into maggots and its derivatives. This process must be done well to ensure the quality, quantity, and continuity of the products produced. Second, research and development (R&D) plays a role in new product development. R&D enables continuous innovation, introducing new variants of feed products that are nutritious and meet feed requirements. Thirdly, marketing is a key activity to increase product sales. Finally, supply chain management ensures that maggot products and their derivatives are available in various locations, both through online channels and physical retail, making them easily accessible to consumers.

8. Key Partnerships

Key partnerships that need to be built include First, partnerships with food stalls/restaurants, food stores, and vegetable/fruit farmers to ensure the availability of organic waste. Second, partnerships with farmer/livestock groups, distributors, and retailers to distribute the products effectively. By establishing partnerships, animal feed, and fertilizer products can reach a wider market and be available in various locations that are easily accessible to consumers. Third, collaboration with related agencies and research institutions for product development. This is in line with the research of Odi Andanu et al. (2021) related to the factors that affect the chain are increasing the ability or skill of each actor (0.25), having a contract agreement between actors regarding clear product quality (0.21), structured farmer group institutions (0.13), optimizing local wisdom (0.10) and the role of the government in assisting the development of farmers and industry (0.08).

9. CostStructure

The main costs that need to be considered are: First, the cost of cultivation. Second, production costs include operational costs, machinery, and maintenance. Efficiency in the production process can help reduce these costs. Third, distribution costs include shipping and product distribution costs. Good distribution management will help reduce logistics costs. Fourth, labor costs include salaries and employees. These costs are important to maintain a competent and solid team in various aspects of operations, including production, marketing, and customer service.

Based on the explanation above, the BMC can be depicted in the following figure:

Table 3. Business Model Canvas for Organic Waste Processing

Key Partners	**Key Avtivities**	**Value Propotitions**	**Customer Relationships**	**Costomer Segments**
1. Farmer 2. Breeder 3. Distributor 4.Household, Restaurant, Canteen 5. Retailer	1.Maggot Cultivation 2. Wet Maggots, Dry Maggots 3. Fertilizer 4. R & D 5. Marketing	1. Nutrition 2. Cheap 3. Practical 4. Zero waste	1.Customer Service 2. Education & Information	1. Farmer 2. Breeder 3.Animal Feed Store
	Key Resources		**Channel**	

<table>
<tr><td></td><td>1.Organic Food Waste
2. Labor
3.Production Facilities
4.Science and Technology</td><td></td><td>1.Farmers & Livestock Group
2. Distributor
3. Relevant agencies</td><td></td></tr>
<tr><td colspan="2">Cost Structure</td><td colspan="3">Revenue Streams</td></tr>
<tr><td colspan="2">1. B. Raw material
2. B. Labor
3. B. Production
4. B. Distribution
5. B. Marketing</td><td colspan="3">1. Direct Sales
2. Wholesale Sales
3. Sales of Derivative Products</td></tr>
</table>

Source: Data Processed, 2024

Business Model Canvas (BMC) analysis has various benefits for Rumah Maggot Komunals to comprehensively understand the entire business model, facilitate communication and collaboration, and enable early identification of risks and challenges that may arise, such as dependence on certain partners or resources. Overall, BMC makes it easier to understand, develop, and make business decisions more quickly and effectively.

4. Conclusion

The research results show that the organic waste supply chain involves (1) households, restaurants, and shops as suppliers; (2) Zero Waste Community as organic waste processors into animal feed & fertilizer; and (3) farmers, livestock breeders, and the community as users. The main products are fresh maggots, dry maggots, and maggot flour, with prices of Rp. 6,000.00/kg, Rp. 40,000.00/kg, and Rp. 50,000.00/kg, respectively, while the derivative products are solid organic fertilizer and liquid organic fertilizer. Organic waste processing is feasible because it has a B/C ratio of 1.23 and a Payback Period of 17.6 years with an investment value of Rp. 16,440,000.00. Utilization of maggots as an alternative feed source can save animal feed costs by up to 24.31%. The main consumers of maggot products are farmers and livestock breeders. Business partners are households, restaurants as suppliers of raw materials, farmer and livestock groups, animal feed stores, and related institutions as distributors. The advantages of maggots are that they have high protein and fat content. Reduce dependence on imported feed and increase the added value of waste on the one hand, and on the other hand, increase food security and create a circular economy.

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