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Increasing the Added Value of Environmentally Friendly Fish Processing Utilizing a Dynamic System Model

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Abstract. This paper demonstrates the use of dynamic simulation of fish processing to increase added-value and environmentally friendly fish processing. However, the existing fish processing is limited and traditional even though the yield of marine commodities remains high, additionally contributing to environmental pollution. The object of this research is Sumber Pangan Group, a business engaged in the processing of *pindang* fish (smoked fish) located on the Prigi Coast. Efforts to identify factors that influence the fish processing system include designing a dynamic fish processing system using Powersim software and providing proposed solutions to fish processing problems. Then fish processing is evident to increase the added value of income, providing an environmentally friendly means. The applied scenario utilizes the waste products and maximizes fish yields by increasing the production of liquid-based smoked fish and processing the waste into *petis* using a simulation based on a dynamic system approach. Attempts also include the scenario of decreasing production costs and increasing demand. Based on the study results, it was found that the best fish processing was 70% removal, 30% liquid smoking, and the total added value of IDR. 11,819,500 waste treatment. The added value is obtained from the difference in profits from fish processing, upon the completion of profit margin improvement

INTRODUCTION

The demand for fish consumption of the Indonesian population continues to increase by the increasing population, for example, it was 47.12 kg/capita in 2017, 50.69 kg/capita in 2018 was, and 55.95 kg/capita in 2019. Thus, the demand for fish as consumption would annually increase. Fish as perishable food requires a proper fish processing method for product safety, providing benefits by consistently maintaining the nutrition and quality contained in fish.

System dynamics is defined as a field for an understanding of how things change over time. Meanwhile, in Forrester's writing entitled System Dynamics and 35 Years of Experience, the meaning of dynamic systems includes: "System dynamics combines the theory, methods, and philosophy needed to analyze the behavior of systems in not only management. Additionally, in environmental change, politics, economic behavior, medicine, engineering, and other fields" [1], the development of a dynamic simulation model defines, simulates, analyzes and describes desertification in terms of equality, feedback loops and graphics [2]. Several previous studies discuss dynamic systems. Sujandari et al. analyzed the dynamic system model of waste management to reduce the burden of waste accumulation in DKI Jakarta Province [3]. Indayani et al.'s research analyzed the dynamic model of the banana waste availability system in Bali Province [4]. The dynamic system is also utilized in research to determine competitive strategies in small industries in Yogyakarta [5]. Another research is conducted to increase productivity [6].

Furthermore, another study discusses the analysis of the new method in social impact assessment [7]. Simulation of demand growth scenarios in the Colombian electricity market, entitled: An integration of system dynamics and dynamic systems, was also conducted by Morcillo, et al. [8]. Min-Kyung Lee and several authors conducted a study in a journal regarding the Dynamic modeling of the pellet production process for the pellet injection system [9]. The paper by Anne Senkel, Carsten Bode, and Gerhard Schmitz demonstrates the use of dynamic simulation to model and assess an integrated energy system [10]. Finally, a study by Louise et.al. compares cost-effectiveness results from two models of maternal immunization to prevent pertussis in infants in Brazil, one static, one dynamic, by exploring when static models are adequate for public health decisions and when dynamic models essentially require the extra effort is worthwhile [11].

One of the fish processing businesses is Sumber Pangan Group, situated in the coast of Prigi Beach, Trenggalek Regency. In January and February 2021, fish catches were recorded high of reaching 1400 tons, in March was 1800 tons, and in was April 1700 tons. However, the fish industry players do not maximize high fish catches since the types of fish processing available are minimal and still traditional. Sumber Pangan Group becomes the largest fish processing business, with up to 10 tons of production capacity. In addition, this processing business has fish storage of up to 160 tons, with a large capacity that should be utilized to maximize production results. However, the lack of

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variety of fish processing hinders the expected maximum added value. In addition, the result of *pindang* waste presents a problem because the wastewater is directly discharged into the river, polluting the environment.

Based on the notion as mentioned earlier, the researchers are interested in conducting research based on the problems faced by the fish industry center to increase the added value of income by utilizing waste products and maximizing the production of fish harvests by utilizing simulations based on a dynamic system approach. Attempts include identifying influencing factors, making causal loop diagrams, constructing stock and flow diagrams, further simulated, verified, and validated by considering several scenarios of decreasing production costs and increasing demand to get max production yield and profit projections. Therefore, this study is expected to obtain the advantages as the added value generated by the industry for various scenarios, thereby generating the best scenario to add value-added to fish processing using simulation. Furthermore, apart from the economic aspect, waste is also expected to be environmentally friendly.

METHODS

The research was conducted at Sumber Pangan, regarded as a conversion industry. The research combines causal research and secondary analysis to comprehend the situation and problems of fish processing. Causal research is generally conducted through experiments to determine the relationship between phenomena. This study applies a dynamic system modeling approach to select the best decision of environmentally friendly fish processing and increasing the added value. Data were collected by interviewing business owners and data historical. The method utilizing modeling of dynamic systems with software Powersim 10 consists of dynamic systems, which are: 1) Problem Formulation and Definition; 2) Conceptual System Development; 3) Model Formulation; 4) Model Verification Simulation and Validation; and 5) Policy Analysis or Decisions and Improvements.

1. Identification of Environmentally Friendly Fish Processing System Variables

There are seven sub-systems in the fish processing system: the production sub-system, expense sub-system, income sub-system, value-added sub-system, demand sub-system, fish supply sub-system, and sewage treatment sub-system. Some variables have altered according to time from each sub-system and are more specific so that the fish processing industry system has a dynamic system.

2. Stock and Flow Diagrams (SFD)

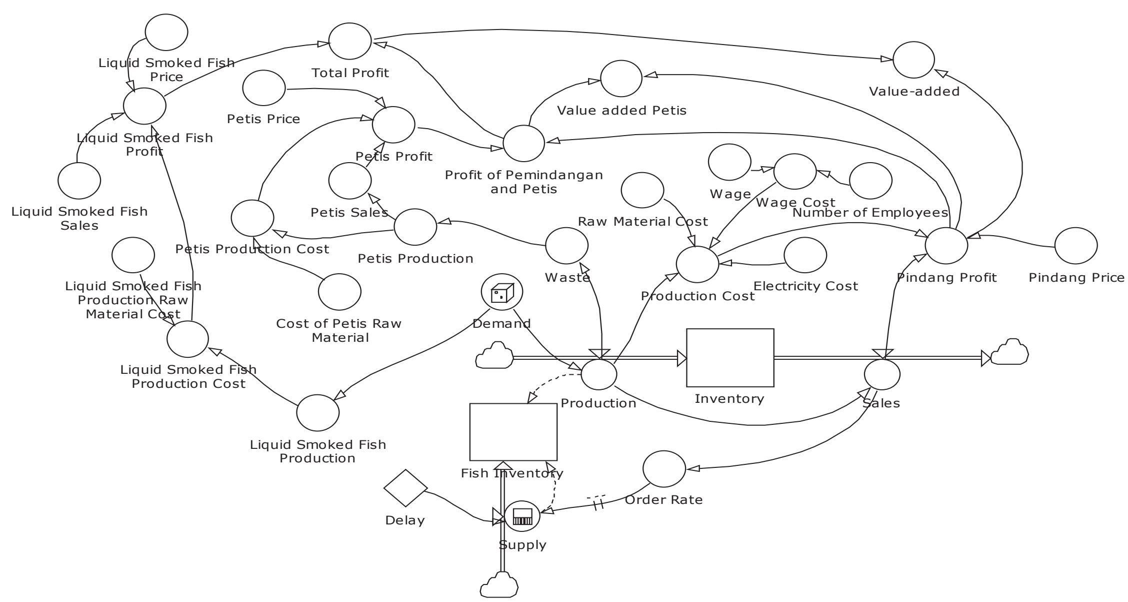

FIGURE 1. Stock and Flow Diagram

SFD describes the relationship between variables with the flow of information and material transfer. SFD contains the levels and rates; the level indicates a value that accumulates over the simulated period, while the rate indicates an altering value per unit and simulation. The fish processing system is divided into processing, processing of *petis*, and liquid smoking. The SFD is illustrated in Figure 1, which applies the Powersim.

Pindang Fish Processing

The fish processing system is divided into several sub-models: the cost burden sub-model, the production sub-model, the income sub-model, and the fish stock sub-model. The production sub-model describes the conditions of the production of the Sumber Pangan, in which the products will depend on the demand and supply of raw materials, daily fluctuating Based on the simulation results, the production is similar to the demand, which indicates similar fluctuation because the company applies to make to order, in which higher production will also affect the waste results. There are several variables related to the company's income in the income sub-model: the level of price and the number of products sold. In comparison, the profit is obtained from the difference between production costs and income. In the sub-model of costs, there are several variables related to the cost burden, including production costs, raw material costs, wage costs, and electricity. In the sub-model, costs are strongly influenced by the amount of production. Finally, there are variables related to supply, delay, order rate, and sales in the sub-model of raw inventory. The daily supply of fish for *pindang* is 7 tons. In addition, the fish stock sub-model indicates a fixed value.

Processing of Waste Processing Results

Waste results from boiling *pindang* that are disposed of in rivers generate environmental pollution. Waste results from boiling *pindang* are reused with not much despite generating profits and, of course, environmentally friendly. One processing way is make *petis*. In the sub-model of increasing the added value of *pindang*, there are several related variables, such as income and profit. The added value of *pindang* is closely related to waste treatment, which is the profit from the sale of *petis*. The value-added results are seen from the difference between the income and production costs and the profit of *pindang* production. In the sub-model of sewage treatment, several variables are related to fish processing: waste and utilization of waste products. The amount of waste amounts to 20% of the total production of *pindang*. Moreover, each 10L of wastewater can be produced into 0.5 kg of *petis* . However, the waste from the production of *pindang* is not appropriately treated, further dumped into the river, thereby polluting the water. The production of *petis* depends on the liquid waste produced from boiling *pindang*.

Liquid Smoking

Liquid smoking is a form of improvement from ordinary smoking, which is simpler processed by dipping the fish in the liquid smoke. Other advantages include more efficiency in the use of firewood, minimal environmental pollution, and flexibility to control the taste and color of the desired fish. In the production of liquid smoke, the amount of production is assumed to be 30% of the demand for *pindang*. The raw material for fresh fish weighing 1 kg requires 0.05 liters of liquid smoke.

1. Model Formulation

The formulation of the model indicates how the model is based on the mathematics formula and other quantitative approaches. Table 1 illustrates the formulation based on a mathematical formula constructed from the model.

TABLE 1. Mathematic Formulation

Variable	Formulation	Variable	Formulation
Production	Demand	Wage Cost	(wage*number of employees)
Demand	Random (2000;6000)	Delay	1 day
Sales	Production	Order rate	Sales
Inventory	0	Supply	Order rate*delay
Profit of *Pindang*	(Sales**Pindang* price)-Production Cost	Fish Inventory	7000 kg
Production Cost	(Production*Raw material cost)+wage cost+electricity cost	Added Value of Petis	Profit from *Pindang* and *Petis*-
Liquid smoked fish production	30%*demand	Waste	Production*20%
Liquid smoked fish production cost	Liquid smoked fish production*Liquid smoked fish production raw material cost	Waste Production	Waste*0,05
Total Profit	Liquid smoked fish production profit + Profit of *Pindang* and *Petis*	Added Value-	Total Profit of *Pindang*

2. Model Verification and Validation

Upon the formation of the desired model, the next step is conducted to check whether the model achieved the desired steps and whether there are no errors or not. In addition, to navigate whether the logic of a system object constructs the function of the model. The purpose of model validation is to navigate whether the simulation results are conducted according to the constructed process. The importance of the model's validity is to meet the requirements as a scientific model, requiring the accuracy of the simulation with actual conditions. Moreover, to ensure that the simulation model can represent the actual conditions, the calculation is conducted with Mean Absolute Percentage Error or abbreviated MAPE. The variable to be tested for validity is the request variable, resulting in the validation: The MAPE result of 0.335% is excellent because the MAPE value is below 5%, indicating a smaller the simulation result error.

3. Preparation of Improvement Scenarios

Change scenarios are prepared based on conditions in the existing system that will affect the future system. Further, analysis is conducted by changing the values of the variables in the changing scenario to navigate the impact. Two scenarios include fluctuations to anticipate the fish consumption rate improvement. If there is an increase in demand, production capacity would maximize labor productivity and existing facilities. Changes in demand will change production and orders for inventory. Because the supply of raw materials is only 7 tons, it is imperative to increase into 10 tons to meet the maximum range of 10 tons. Reducing production costs is conducted by the following scenario. To get the maximum profit, costs reduction could be through finding a lower raw material supplier.

RESULTS AND DISCUSSION

Comparison of Fish Processing Waste

The generated waste must be minimized to achieve environmentally friendly processing. Table 2 presents the comparison of Fish Processing Waste. Liquid waste from liquid smoking (*pemindangan*) is deemed detrimental to the environment due to containing much organic matter. Fish processing wastewater contains fat and protein, potentially increasing BOD 5, TSS, and COD, thereby generating pollution when improperly treated. The fatty oil content on the water's surface will inhibit biological processes in the water, creating smelly gas. The production of *petis* generates the s smoke during the cooking process, having a slight odor. While in liquid smoking, the waste produced contains the remnants of liquid smoke. This liquid is utilized several times, leaving a modest waste and not containing hazardous materials.

TABLE 2. Comparison of Fish Processing Waste

Fish Processing Type	Waste
Pindang	Liquid waste 20% of total production
	Solid waste
Petis	Smoke
Liquid Smoking	Liquid waste leftover from soaking

Fish Value Added Comparison

The added value of fish is obtained from the additional advantages of the initial conditions in leaching after processing waste and liquid smoking. The following diagrams compare *Pindang* and *Petis* and all of the fish processing. Comparison of Fish Processing profits is illustrated in Figure 2. From the comparison results, the best value is liquid smoking production by 30% of the demand, in which the total profit is the sum of the profit from *pindang* with a demand of 70% and the profit of liquid smoked fish with a demand of 30%, in which higher production of liquid smoked fish leads to higher profit.

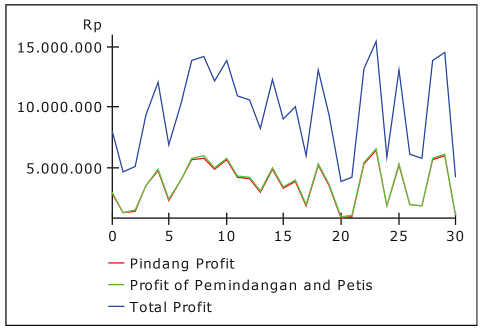

FIGURE 2. Comparison of Fish Processing Profits

Figure 3 describes the comparison of Value Added Fish Processing, indicating that the best value is liquid smoked fish production with a production of 30%. This total is obtained from the difference between the profit from the removal and the profit after waste treatment and the addition of liquid smoking.

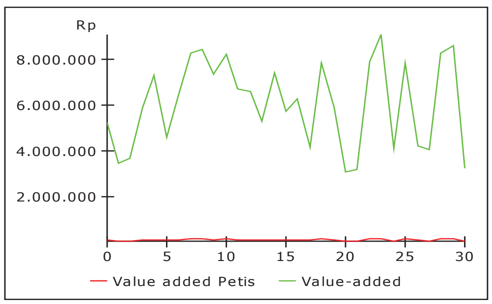

FIGURE 3. Comparison of Added Value in Fish Processing

Comparison of Scenario Implementation Results

Scenarios of Fish Processing in Normal and New Conditions are illustrated in Table 3. The following presents a comparison of the results from the implementation of the scenario, as conducted in the Bengkorok fish processing center. The best fish processing alternatives are selected based on the maximum added value of profits. The three alternatives' most significant advantages are *pemindangan*, waste treatment, and liquid smoking. Liquid smoking has a high selling price because the quality is also high, while the utilized costs are, on average, are similar to *pindang*.

TABLE 3. Scenarios of Fish Processing in Normal and New Conditions

Alternative Processing	Variable	Normal Condition (Demand = 5 tons)	New Condition (Demand = 7 tons)
Pindang	Production	3500 Kg	4900 Kg
	Raw material inventory	7000 Kg	10000 Kg
	Raw material cost	Rp. 17500	Rp. 17000
	Sales	3500 Kg	2100 Kg
	Order rate	5000 Kg	7000 Kg
	Delay	1 day	1 day
	Selling price	Rp. 1500	Rp. 1500
	Advantage	Rp. 5,033,000	Rp. 10,283,000
Waste treatment	Production	35 Kg	49 Kg
	Waste	700 Kg	980 Kg
	Raw material cost	Rp. 15000	Rp. 14500
	Sales	35 Kg	49 Kg
	Selling price	Rp. 20000	Rp. 20000
	Advantage	Rp. 175,000	Rp. 269,500
	Total income	Rp. 5,208,000	Rp. 10,552,500
Liquid smoking	Production	1500 Kg	2100 Kg
	Raw material inventory	7000 Kg	10000 Kg
	Raw material cost	Rp. 20000	Rp. 1500

Alternative Processing	Variable	Normal Condition (Demand = 5 tons)	New Condition (Demand = 7 tons)
	Sales	1500 Kg	2100 Kg
	Order rate	5000 Kg	7000 Kg
	Delay	1 day	1 day
	Selling price	Rp. 25000	Rp. 25000
	Advantage	Rp. 7,500,000	Rp. 11,550,500
	Total Profit	Rp. 12,708,000	Rp. 22,102,500

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Proposed Fish Processing

The proposal given to the fishing industry is to add processing of *pindang* waste, by producing *petis*. Another alternative treatment is liquid smoking which has the maximum benefit. Of the three methods, a total added value of IDR. 11,819,500 is generated from 70% removal, 30% liquid smoking, and waste treatment. The total profit indicates IDR. 22,102,500 by using environmentally friendly fish processing that utilizes waste processing and liquid smoked fish production after implementing the scenario, conducted maximizing the production capacity of 10 tons. The scenario is also utilized by minimizing production costs through a selection of the cheapest raw material supplier.

CONCLUSIONS

The modeling of fish processing is divided into three parts: processing of pindang fish, processing waste from *pemindangan*, and liquid smoked fish processing. The result of the scenario of the three parts by increasing demand and lowering production costs is regarded as a twofold increase in profits. An increase in demand to 10 tons has thus affected fish stocks, which are only 7 tons, requiring a further increase to 10 tons. Reducing raw material costs is also conducted by choosing the cheapest supplier. Based on research that is simulated for 30 days, each alternative presents different benefits. The most significant advantage and added value are in the alternative of liquid smoking fish processing with a profit of IDR. 11,819,500 after the scenario. To obtain an environmentally friendly production, the waste is processed into *petis*. In addition, other fish processing alternatives are in the form of liquid smoke to get maximum profit and avoid the environmental pollution. It is recommended that further research expands the scope of the variables.

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