A Simulation Approach for Performance Measures of Food Manufacturing Process

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Abstract— In Malaysia, Small and Medium-sized Enterprise (SME) of food manufacturing industry is the second highest contributor in manufacturing sector and plays an important role to the economic development and growth. Hence, monitoring process of the industry should be occupied comprehensively and appropriately even though it is categorized under small- scale organization. Shrimp paste production is one of the small-scale food production that is popular in Malaysia. In this study, a performance of shrimp paste production is measured by using simulation approach. A discrete event simulation model is developed to illustrate the processes in the production line which involved four major processes. From the model, it is estimated that the average process time taken to produce 2000 pieces of shrimp paste is 235.13 minutes while the average waiting time taken in the operation system is 89.21 minutes. The findings also show that the bottleneck of the production process is found to be at packaging process and some of the resources are not fully utilized.

Keywords-*Performance measures, Simulation, Food manufacturing, Shrimp paste, SME*

1. Introduction

Food manufacturing is defined as industries that change livestock and agricultural products into instantaneous product or final consumption according to the U.S. Bureau of Labor Statistics. The food manufacturing and processing cover everything from simple processes to complex and classy systems that use expensive equipment which aim to create good products. In order to follow the government's focus on the agriculture sector, the Malaysian food processing industry has become an important part of the agro-based industry. In the Industrial Malaysian Plan 2006-2020 (IMP3) period, the food processing industries investment target have been set at RM24.6 billion according to Malaysian Investment Development Authority 2012. SMEs are one of the country's economic development agents. In most countries, the SMEs lead the industrial and commercial infrastructure [1]. Generally for any sectors, Small and Medium-sized Enterprise (SME) is defined as firms with sales turnover not exceeding RM50 million or number of full-time employees not exceeding 200. The SME increases the national production by providing more job opening, create export and assist the production of large and medium industries. The rate of economic growth was positively affected by the assistances and support from SME industries. Thus, in order to be more competitive in the business world, SMEs need to recognize, prioritize and minimize their business challenges for them to sustain in this industry. Comprehensive review of SME performance must be taken seriously due to effect it might have on the economy. In the food manufacturing sector, SME manufacturer need to constantly monitor the process of manufacturing of food products to optimize production as well as to observe any floppy or failure process. The average time taken for production need to be established as well as processing time at each section of the process. By having these measurements, the production planning and resource allocation can be well managed so that the current production can be enhanced.

Simulation is the imitation of the operation of a real-world process or system over time. It involves the process of developing a model of the real system and conducting experiment by using the model for the purpose in understanding the behavior of the system. In addition, simulation provides the users to develop experiments which can answer various questions without messing with the real world system. Even though classical methods such as hierarchical linear models, meditation analysis, and structural equation models are being used to establish measurement of the variables, the statistical power of those models cannot be estimated directly, however, the simulation capable to do it.

The simulation model is used to simulate the layout and the output in order to evaluate the productivity's performance and efficiency. The layout will be relocated by reducing the travel time between the workstations. Productivity and efficiency are calculated for both layouts to being compared [2]. According to [3], before the real application was developed; it is required the further design of the complex simulation model. A study

International Journal of Supply Chain Management
IJSCM, ISSN: 2050-7399 (Online), 2051-3771 (Print)

on simulation study has been applied successfully in many different areas such as manufacturing, system services, bank, transportation, health care management, and restaurant [4][5][6]. Simulation is a well-established planning aide for planning purposes in production environments [7], both for production control and planning [8][9] and for optimizing factory processes [10][11][12][13].

Moreover, simulation modeling and analysis is conducted in order to gain understanding into this kind of complex systems, to attain the testing of new operating and development of resource policies and new systems or concept where it can live up to the expectancy of modern manufacturing before implementing it. By using simulation, one can measure their current level of performance and also identify specifically the stage or step of the process that should be further improved. Other than that, the virtual improvement can be demonstrated before implementing the real one without affecting the system of real operation [14].

The purpose of this study is to measure the performance of shrimp paste production at one of the food manufacturing company in the north of Malaysia by developing a discrete event simulation (DES) model of the manufacturing process.

2. Simulation Model Development

The production of shrimp paste involves for major phases; drying, grinding, forming and packaging as illustrated in Figure 1. While the whole operating system and layout are shown in Figure 2. The numbers shown for each process in the figure represent the number of workers needed to accomplish the tasks. Currently the manufacturing process is run by eight workers with the help of processing machines for each process. The process starts with drying process which takes around 2 hours for 140kg dough.

Next is grinding process where the dough is smoothly grinded by batch of 28kg dough (400 pieces) per batch. It takes about ten minutes for each batch. It follows by forming process where the dough is formed into round shape by three workers. Finally for the packaging process, two phases of packaging are involved, white plastic packaging and red logo wrapping. The DES model development involves ten stages as shown in Figure 3

Figure 1. Operation system flow

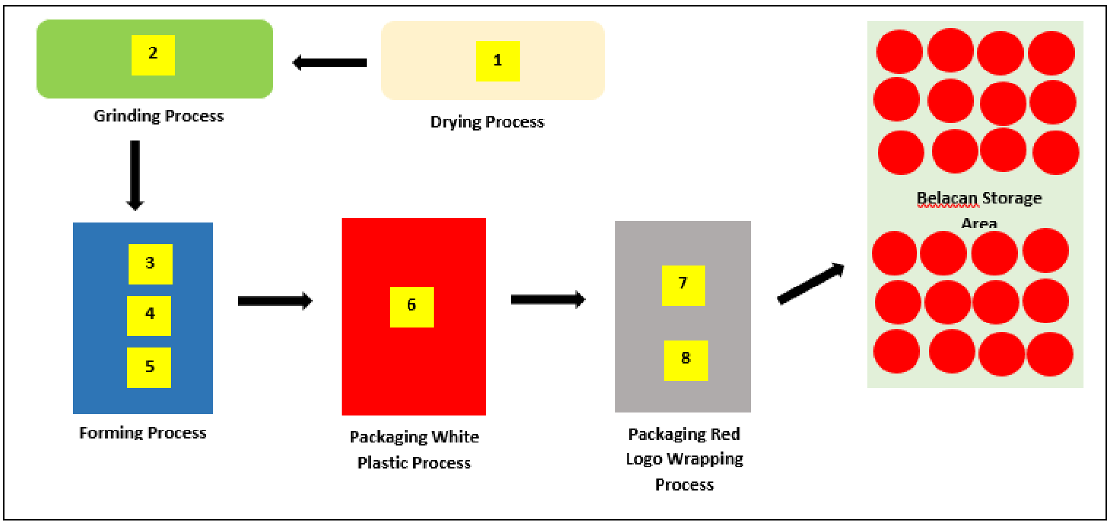


Figure 2. Operating system and layout

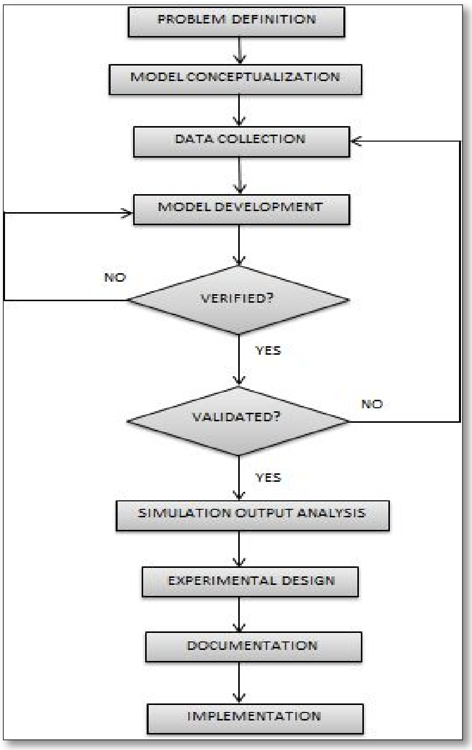


Figure 3. Simulation steps for model development

2.1 The Proposed DES Model and Its Elements

For the simulation model development, ARENA software is chosen due to its capability and suitability [15][16]. The entity types that enter the simulation model is shrimp paste, which in bulk of 140kg dough where it can produce up to 2000 pieces of shrimp paste at the end. While total number of workers involved is eight, thus eight modules are being considered in this DES model which are creation, process, batch, separate, decide and dispose, while for transfer panel, two modules are considered namely station and route. After all the input data and the expression value are recorded, the modules in arena are being connected to form the DES model where it is exactly similar to the real operating system. Figure 4 shows the DES model of the operation system. The model can be animated as shown in Figure 5 to make it more realistic and interesting

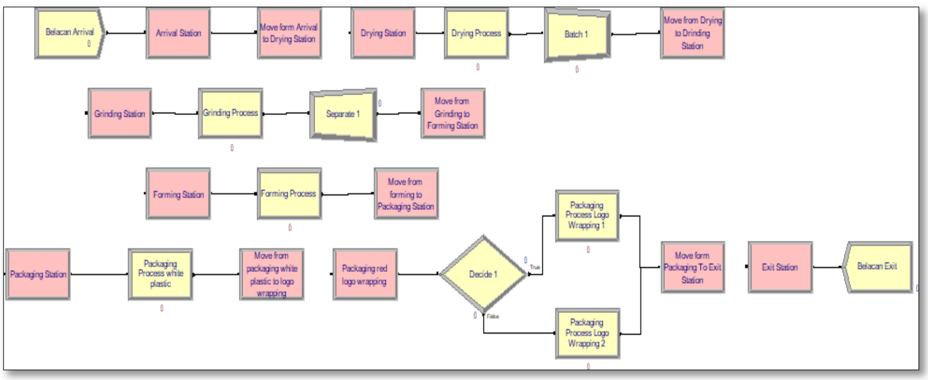


Figure 4. DES model of manufacturing process

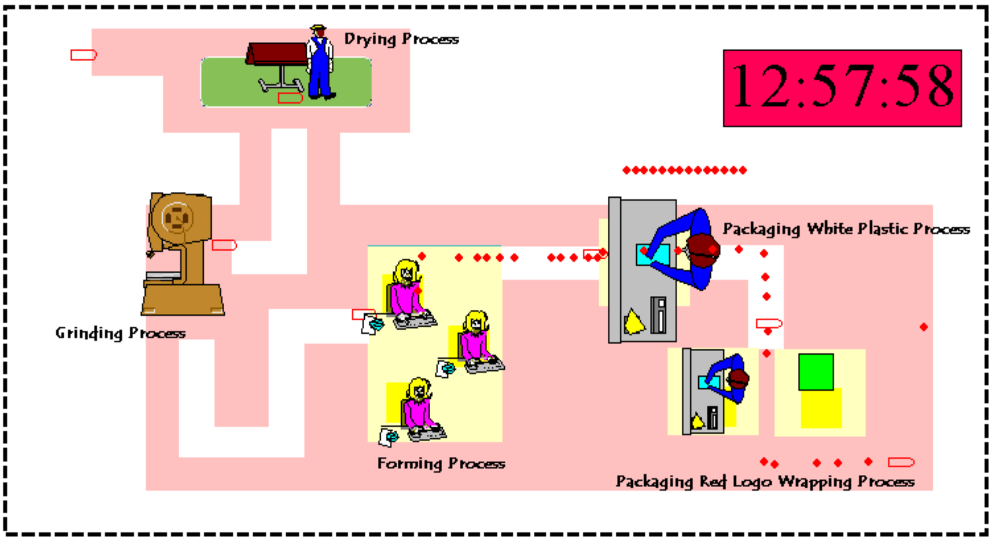


Figure 5. Animation model

2.2 Data Collection and Distribution Fitting

All the data and information about the real operation of the manufacturing process are obtained from the interviews sessions with a manager and workers. In order to record the processing time for each process, the observation was done for 3 operating days starting from 9am to 2pm as that period is their main daily production hours. In Arena Software, Input Analyzer has been used to fit the distribution of the data as shown in Figure 6. Expression distribution value is shown in the Table 1 below.

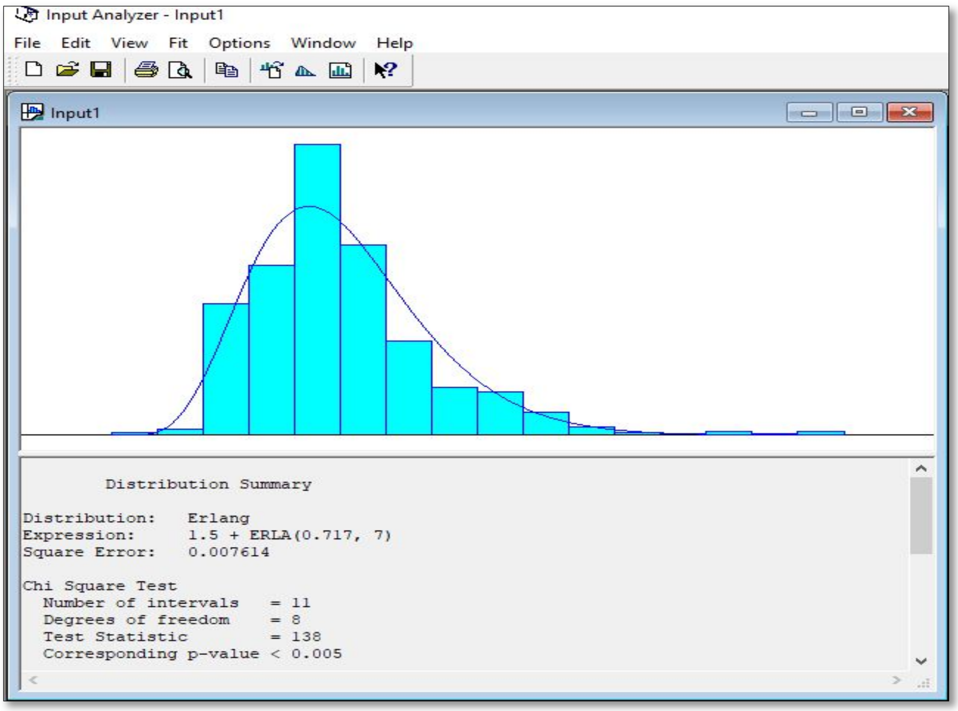


Figure 6: Distribution in input analyzer

Table 1. Expression probability distribution of data

Process	Expression	Expression Value
Time between arrival of 140kg dough	Expo	RANDEXPO(1)
Drying	Uniform	UNI(2,2.5)
Grinding	Uniform	UNI(10,11)
Forming	Gamma	3 + GAMM (2.83, 2.05)
Packaging white plastic	Gamma	3 + GAMM (2.83, 2.05)
Packaging red logo wrapping 1	Weibull	3 + WEIB (5.84, 2.08)
Packaging red logo wrapping 2	Weibull	3 + GAMM (2.74, 2.08)

2.3 Run Length and Number of Replication

The DES model was run for five replications to ensure that the results obtained from the model are accurate as suggested by [17] and the average run for each process is recorded as shown in Figure 7. The replication length for processing shrimp paste is five hours or 18000 seconds. The maximum input value for this model is limited to 2000 pieces of shrimp paste as it represents the actual data for one-day operation process. There are several outputs that been measured in the model for analysis such as average waiting time for each process, average total waiting time for each process, average total processing time to produce shrimp paste and resources utilization rates.

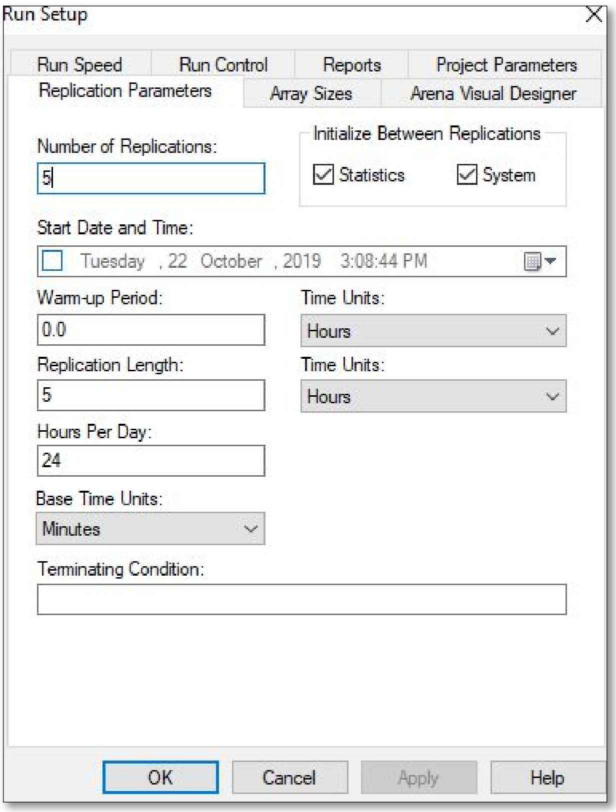


Figure 7. Run setup setting

2.4 Verification and Validation of the Model

For model verification and validation, the justification is obtained by calculating the differences between the simulation output and the actual data. For verification, animation method is used to shows the entities movement inside the model and to ensure the movement is similar and followed with the real operation system. For validation of the model, the results of the simulation model are compared to the actual results of the current operation by using the following formula:

Different (%) = [(Simulation Output – Actual Data) / Actual Data] x 100

= [(2005 – 2000) / 2000] x 100
= 0.25%

The actual number of shrimp paste that have been produced during the operation hours (5 hours) is 2000 pieces. Meanwhile, the output from the DES model shows 2005 pieces of shrimp pastes are produced. The difference is 0.25% and according to [18], to make sure the DES model achieves the sufficient accuracy, the difference must be less than 10%. Thus, the proposed DES model is verified and validated.

3. Results and Analysis

The results of the DES model are shown in Table 2. From the table, it shows that in average 235.12 minutes is taken to produce 2000 pieces of shrimp paste. Meanwhile it takes 89.26 minutes for waiting in the system. The bottlenecks of the system is identified at the packaging white plastic process with the average of 52.57 minutes and 52.66 minutes of average total waiting time and average total processing time, accordingly.

Table 2. Result of the simulation model

Process	Average total waiting time (minutes)	Average total processing time (minutes)
Drying	0.00	134.85
Grinding	27.92	19.20
Forming	8.71	28.07
Packaging:		
Packaging white plastic	52.57	52.66
Packaging red logo wrapping 1	0.03	0.16
Packaging red logo wrapping 2	0.04	0.19

Table 3 shows the results of the total production, the number of shrimp paste pieces that are still in the process and the number of workers involved. It shows 1084 pieces of shrimp pastes have been produced and there are 921 pieces still remained in the process when the run time completed.

Table 3. Total production, number of pieces are in the process and the number of worker.

Total production	Number of pieces are in the process	Number of worker
1084	921	8

From the output of DES model, the resource utilization for each worker is measured. Overall the resources are not fully utilized as the rate is at the minimum level of 27.52%. Most of the resources are utilized at the packaging process in which the total is half of the total utilization rate.

Table 4. Average percentage of resource utilization for each worker

Process	Worker	Average Resource utilization (%)
Drying	Drying worker 1	0.00 (Delay)
Grinding	Grinding worker 1	17.48
Forming	Forming worker 1 Forming worker 2 Forming worker 3	32.64 32.66 32.64
Packaging	Packing worker 1 Packing worker 2 Packing worker 3	53.20 25.12 26.43
Overall average		27.52

Based on the output, two what-if scenarios can be developed to improve the performance of manufacturing process of shrimp paste production.

3.1 Scenario 1: Add one worker at forming process

The forming process involves some skills in rounding the shape and consumes more times compare to the other processes. Hence if one worker is added at this station, it is believed the process will become faster.

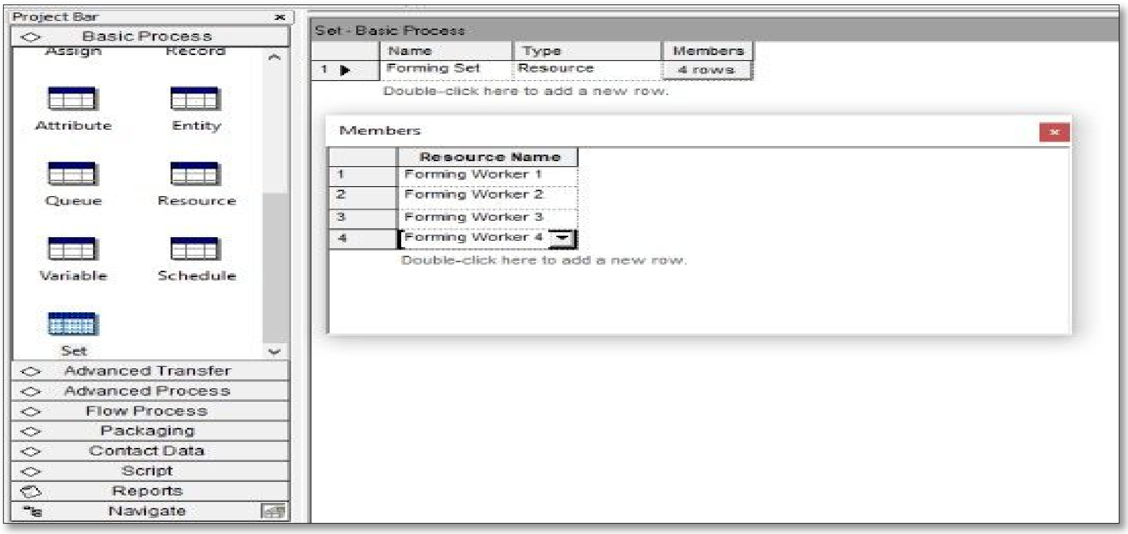
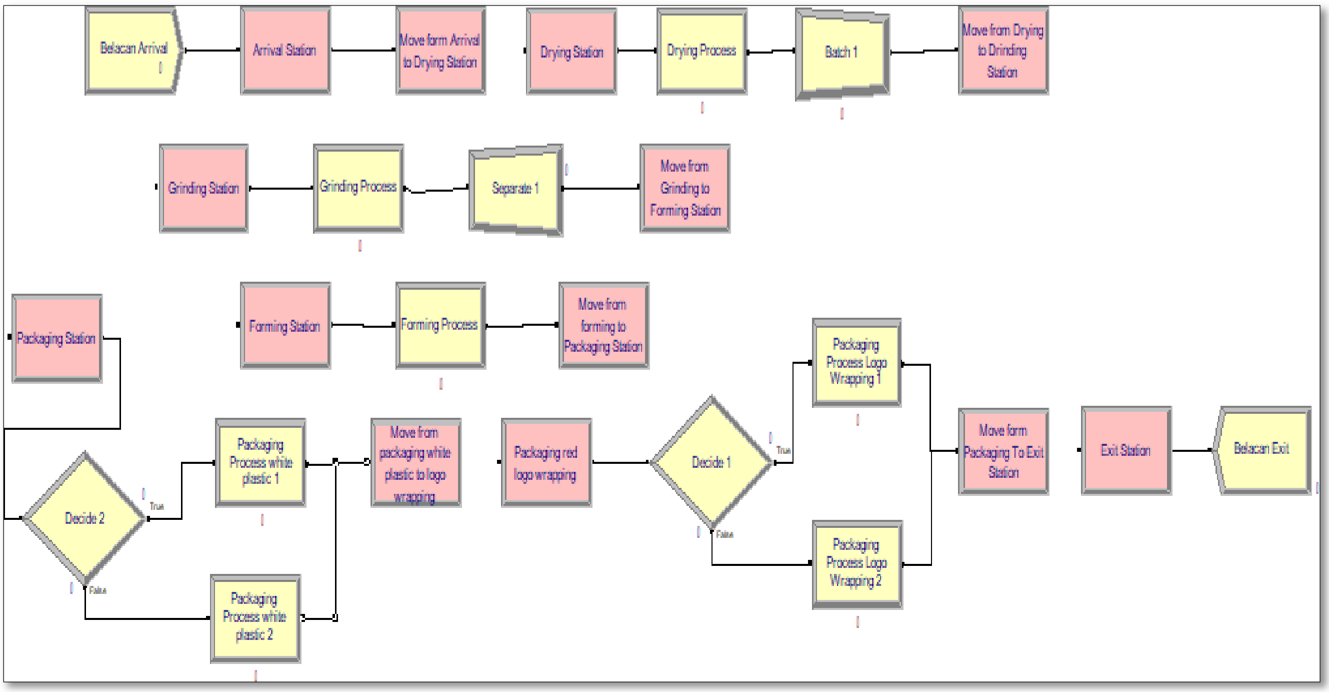


Figure 8. Add resource into forming set

3.2 Scenario 2: Add another station at packaging process

Since the utilization rate for the packaging process is the highest, one station is proposed to be added to the operating system as shown in Figure 9.



. **Figure 9.** Add another station in packaging white plastic process

Both scenarios are implemented to the DES model and the results are shown in Table 5.

Table 5. Results comparison between actual DES model and what-if models

	Actual Scenario	Scenario 1	Scenario 2
Drying	0.00	0.00	0.00
Grinding	8,71	8.85	8.74
Forming	27.92	15.76	27.42
Packaging:			
Packaging white plastic 1	52.57	59.23	23.90
Packaging white plastic 2	-	-	26.00
Packaging red logo wrapping 1	0.03	0.02	0.59
Packaging red logo wrapping 2	0.04	0.03	1.71
Total waiting time	89.21	89.90	88.37

It can be seen from Table 5 that scenario 2 has successfully reduced the total waiting to 88.37 minutes which is 0.84 minutes earlier from the actual time. However scenario 1 did not yield any better results from the actual results even though the forming process has been reduced from 27.9181 minutes to 15.7601 minutes. This scenario happened because the packaging process has bottleneck. Hence, scenario 2 can be recommended to the manager for improvement of the shrimp paste production. In addition the manager also is suggested to implement machine-based packaging type in order to reduce total waiting time.

4. Conclusion and Recommendation

This study has employed the discrete event simulation approach in measuring the performance of shrimp paste production. The DES model is one of the best alternative to study the performance based on the real situation. In addition, further improvement also can be analyzed by developing what-if scenarios to the developed DES model. This kind of study is much needed to the manufacturing or services based industry in order to level up their performance. Shrimp paste production is a small-scale manufacturing industry, however this industry can be benefitted most by having research and development (R&D) elements in its operation management.

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