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Reducing waste in frozen crab stick product inspection process by applying ECRS technique

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***Abstract*---**The objective of this research is to reduce waste in the process of inspection of frozen crab stick products by applying ECRS (Eliminate, Combine, Rearrange and Simplify) technique to an analysis to find the ways to reduce time, defects and effects of waste in the process of inspection of frozen crab stick products. Research findings indicate that it takes a long time to complete the process to inspect frozen crab stick products. The severity, probability of occurrence, and ability to detect the defects are assessed. Then, the Risk Priority Number (RPN) is calculated to choose the primary cause of the problem to be solved. This research study has also employed ECRS, a lean technique, to help analyze the causes of problem, make required improvements, and control the quality of production process. After making improvements, the Risk Priority Number is analyzed and used to identify possible causes affecting the defects before making the improvements. The percentage of the amount of time spent before the improvements is 65.93% whereas that after the improvements is 14.56%. The percentage of the reduced amount of time is 77.92%.

***Keywords*---**Waste Reduction, Lean Technique, ECRS.

Introduction

Thailand's seafood processing industry has a direct impact on the country's economic system. Global seafood stocks are concentrated in the Asia-Pacific region due to its strategic location, which enables the region to have sufficient raw materials. Both captured and farmed marine animals of Asia account for 78% of the world's production. Apart from raw material abundance, Asia also has certain advantages in terms of sufficient labor and lower wages compared to other regions. As a result of the abovementioned factors, Asia is the world's largest exporter of processed seafood with the value of almost 40% of the global

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processed seafood market whose size is approximately $150 billion in 2018. Most of the products are in the forms of frozen food, canned food, and finished food. Thailand is the world's fifth largest producer of processed seafood. One advantage is that the country borders oceans on both sides and has long stretches of shoreline so it has an abundance of marine animals and its geography also supports aquaculture. Thailand's seafood processing industry can be classified into two major categories, namely canned seafood industry and frozen seafood industry. In terms of frozen seafood industry, freezing is the primary process to preserve the quality and extend the storage life of marine animals. Currently, consumers' behavior has changed, especially younger generations who live a fast life and enjoy convenience. As a result, there is a constant need for frozen seafood. One of the most popular seafood products is crab stick, which is made of surimi, a paste made from fish with bones removed and thoroughly washed to eliminate fats. Color and flavor are added to make surimi taste like crab. Mostly, it is made to be in a shape of stick.

Although many countries around the world are encountering Covid-19 crisis, Thailand still has the potential as food producer and possesses modern technology that meets international standards to develop the products that meet the various needs of markets." This research concerns a case study of a company producing processed and frozen seafood products in Samut Sakhon Province of Thailand. The product of concern in this study is vacuum packed crab sticks (undergoing the freezing process). The problem found is that after completion of the production process, the product has to be inspected, but it takes a long time for the product to thaw and be inspected so there are many samples awaiting inspection. Based on such information, the researcher has an idea to find out the cause of delay in thawing of the product during the inspection process so the production process and the thawing methods would be investigated. The expected outcomes are that inspection of the product will be faster, the product obtained will meet customers' requirements, and the customers' confidence will be gained.

Related Research and Theories

Quality control is a process intended to ensure that raw materials and production adhere to a defined set of quality criteria in order to prevent the production of defective or damaged products, which may result in loss of reputation. To ensure that the products manufactured will be of required quality, it is necessary to plan and determine a goal and clear procedures by adopting the principle of ECRS as follows (Kerdpitak et al, 2022); Stoelb, 2016):

E = Eliminate - Identify the steps in a process that can be eliminated without decreasing production value;

C = Combine - If nothing can be eliminated, see if any steps can be combined to save time or force required to carry out such steps;

R = Rearrange – Properly rearrange the process steps; and

S = Simplify – Improve the work methods or develop equipment to make the process work easier to complete.

ECRS is a lean technique that is primarily used to reduce waiting times or remove wasteful steps in order to improve the work process and increase effectiveness. Eliminate is to take out unnecessary steps in the process. Combine is to combine certain steps in order to save time or labor required to complete such steps. Rearrange is to rearrange work in a different order or sequence that is more suitable. Simplify is to improve work methods or develop certain equipment to make the work easier to complete. At each step of the research, the following quality tools will be used to help with analysis and problem-solving procedures (Kasemset et al. 2016): (1) inspection form to help with collection of data required to prepare Pareto diagram; (2) Pareto diagram to help prioritize problems with an emphasis on types of defects; (3) Fishbone diagram to help with reasonable analysis of the causes of defects, including the root cause; (4) graph to help with presentation of data and to make it easier to understand and interpret data; and (5) Control chart to help control the production process and determine the process consistency. When carrying out every step, employees must keep ECRS in mind all the time. That is to say that they need to think if the tasks they are working on can be eliminated or combined or not, whether or not it will be better to rearrange such tasks, and if there is any method to make the tasks easier to complete. This concept can be applied to every matter at every organization (Suhardi, Sari & Laksono, 2016).

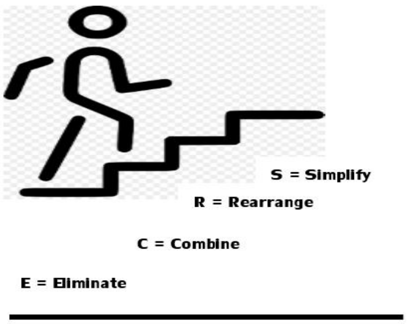

Figure 1: Application of ECRS for reduction of waste to improve work process

Research Methodology

Case Study

General Information: A processed and frozen seafood company in Samut Prakan Province produces processed and frozen seafood products, such as crab stick, prawn, meatball, tofu, and others. Information on the company is shown below.

Overview

- Company: Processed and Frozen Seafood Company
- Location: Samut Prakan Province, Thailand

A primary product of the Processed and Frozen Seafood Company in Samut Prakan Province is made of surimi (fish paste). It is processed and frozen crab sticks of various sizes and shapes.

Studying the Work Process
Primary Production Process

The production process of crab stick products is examined from the start to the step of bringing the products into the warehouse as shown in Figure 2, which describes crab stick production at each station from the first step up to storage of the products in the warehouse. Details of the production steps are as follows: (1) preparation of surimi and ingredients: prepare surimi from fish paste with bones removed and thoroughly washed with water and other ingredients including flour and sugar; 2) mixing: surimi is mixed with other ingredients; (3) cooking: the mixture is streamed at the temperature of 96 - 98 °C until it is cooked; (4) packing of product: the crab stick is packaged; (6) weighing: weighing machine is used to measure the product's weight; (7) metal detection: metal detection equipment is used to find and remove metals from the crab stick; (8) pasteurization: the product is treated with heat to eliminate pathogens; (9) freezing: the product undergoes the freezing process; (10) metal detection: metal detection equipment is used to find and remove metals from the crab stick; (11) finished lab: samples of the product selected from the code manufactured during a certain period of time are tested; (12) packing in carton: the crab stick product is packed in carton; and (13) cold storage: the packaged crab sticks are kept in cold storage.

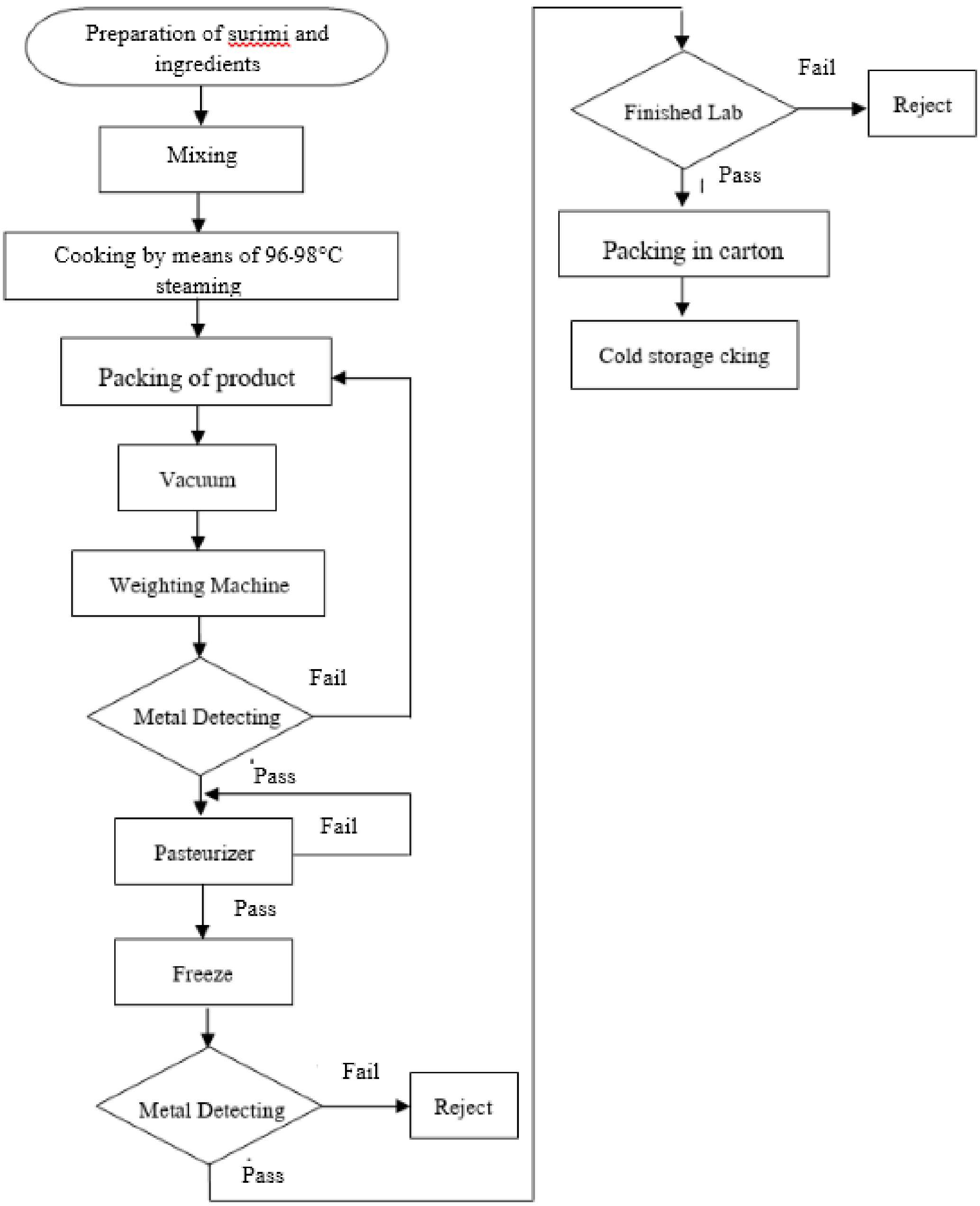

Figure 2: Crab Stick Production Steps

Collection of data on the problem before solving

With regard to data on damage caused to crab stick products by the inspection process, an investigation of the major work processes in a processed and frozen seafood company reveals that there is delay in the inspection process. In the finished lab step, product samples will be received from QC line for inspection. If the product samples from the code manufactured at a certain period of time fail the inspection, all of the products of the same code as the samples inspected will be rejected and become waste as shown in Figure 3: Quantities of Waste from July to December 2018.

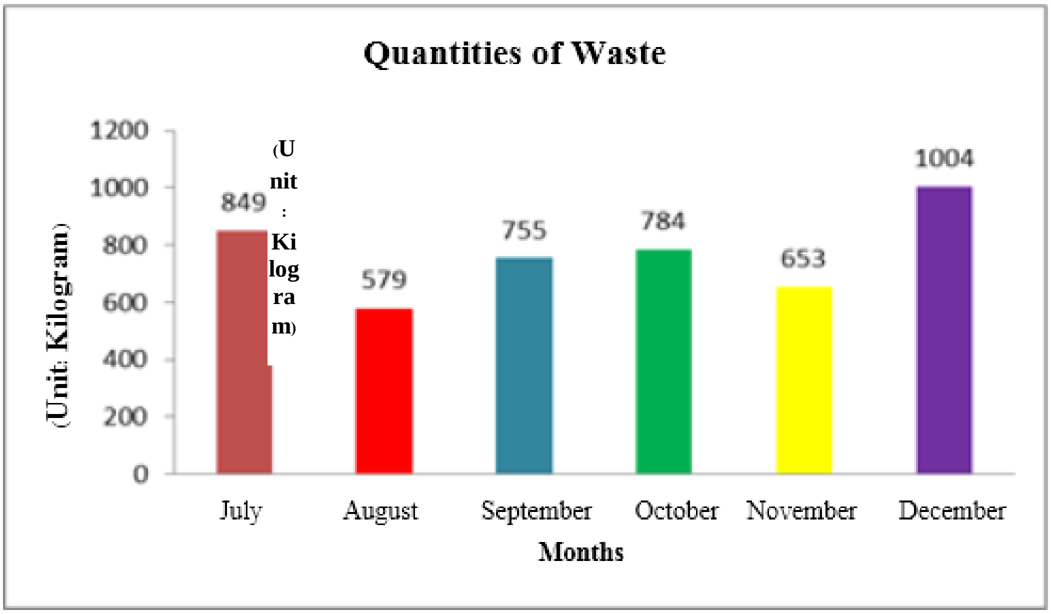

Figure 3: Quantities of Waste from July to December

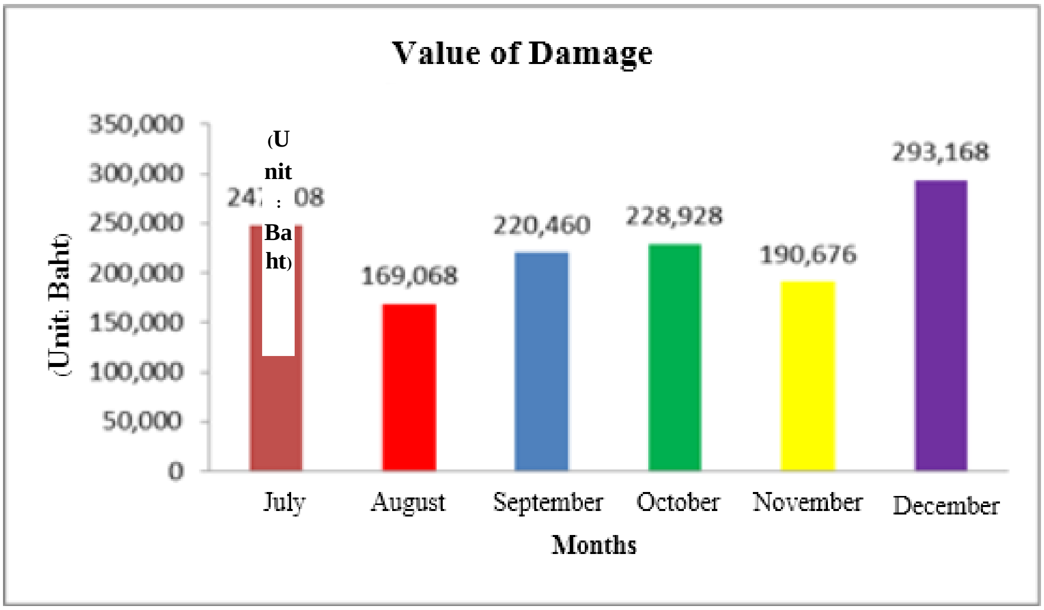

Figure 4: Value of Damage

Inspection Process: according to an investigation of the value of damage caused to the quantities of waste shown in Figure 3, which indicates the quantities of waste for a total of six months from July to December, it is found that the amount of accumulative damage increases as shown in Figure 4. The total value of damage is 1,350,208 Baht. According to such data, those in charge of the finished lab task resolved at the meeting that the causes of damage had to be determined and corrective actions had to be carried out to reduce the value of damage in such case as soon as possible.

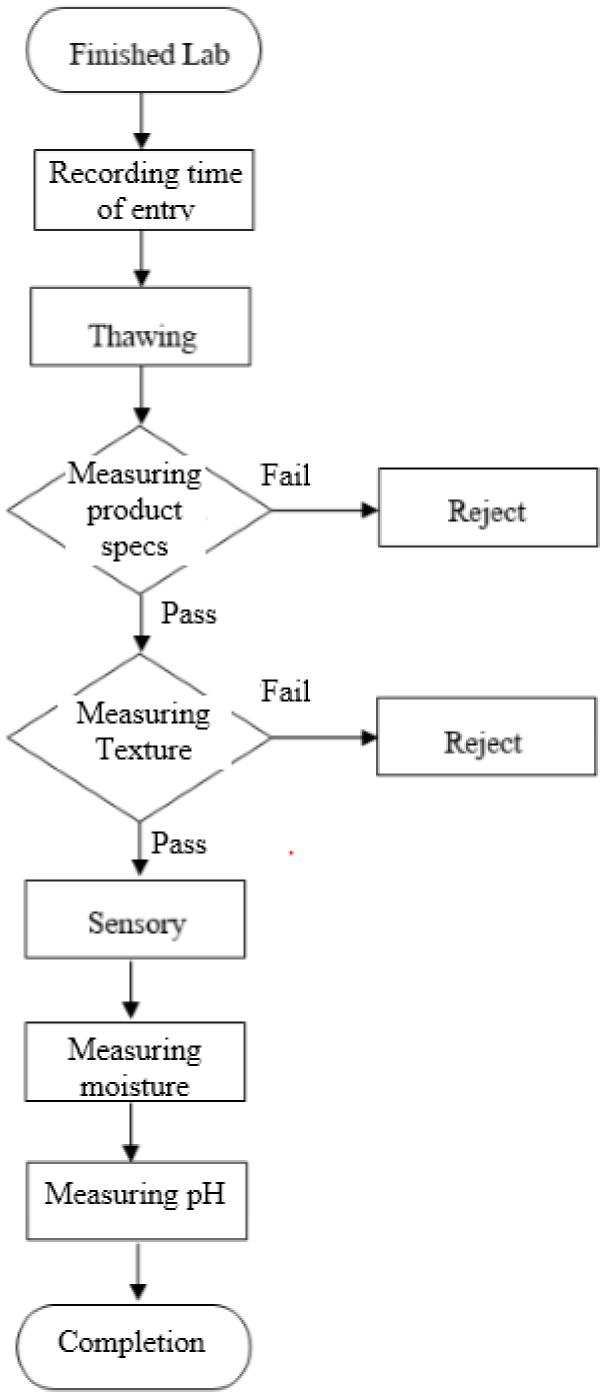

Figure 5: Inspection Steps

Figure 5: Inspection Steps shows how the inspection is conducted at each station from the first to the last steps as follows: (1) finished lab: this is a process where

the product samples are inspected; (2) recording time of entry: this is the process when random products from QC line are received for inspection; (3) thawing: the samples are thawed in a water bath; (4) measuring product specifications, including weight, width, length and thickness of the products; (5) measuring texture: this process is to measure gumminess of crab sticks; (6) sensory: this is the process where the samples are tasted; (7) measuring moisture: this is the process where moisture of the products is measured; (8) measuring pH of the product; and (9) completion of finished lab process.

Steps for Analyzing the Causes of Problems

Cause and effect diagram is a quality tool used to conduct an analysis. In the case where causes of the problem are unknown, it is necessary to make assumptions, discover the causes of problem, collect and record ideas from the study and collection of data on members attending the meeting by applying the concept of brainstorming and gathering every person's ideas to identify the causes of problem. Then, when the causes of problem are identified, the amount of time spent on each cause will be determined to discover the root cause of the problem (Kharismawati, A., & Herliansyah, M. K. 2016).

Use of Fishbone Diagram for Cause Analysis: fishbone or cause and effect diagram shows the assumptions of systematic relationship between possible causes of the problem.

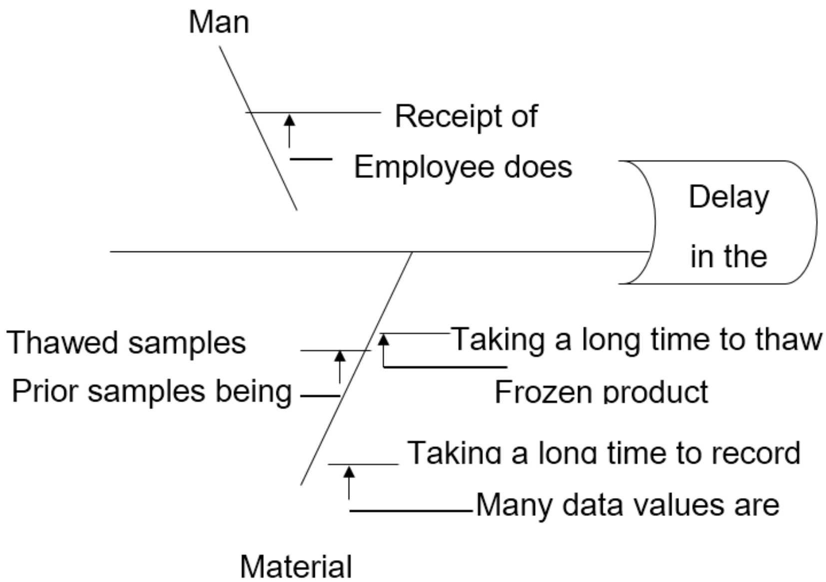

Figure 6: Use of Fishbone Diagram for Cause Analysis

According to Figure 6: Use of Fishbone Diagram for Cause Analysis, after conducting cause analysis, four possible causes of the inspection delay problem are identified as follows: (1) receipt of samples; (2) taking a long time for thawing of samples; (3) taking a long time to record the time of entry; and (4) thawed samples awaiting inspection. The cause that takes the longest time is thawing of samples as shown in Table 1: List of Causes of Problem and Time Spent between July and December 2018.

Table 1
List of Causes of Problem and Time Spent between July and December 2018

Data collected for six months between July and December 2018	
Causes of Inspection Delay	Time Spent
Receipt of samples	4 minutes
Thawing of samples	1 hour and 22 minutes
Recording of entry time	5 minutes
Thawed samples awaiting inspection	4 minutes

According to Table 1 above, it is found that the cause that takes the longest time is thawing of samples. Therefore, such cause is chosen for conducting the "Why-Why" analysis to identify the root cause in order to make improvements and eliminate the problem (Buranasing, Y. and Choomlucksana, J. 2018).

Table 2
"Why-Why" Analysis

What	Why	Why	Why	Why	Why
The problem of delay in inspection	Taking a long time to thaw the samples	Frozen product samples	Low water temperature	Water temperature changes in response to temperature of thawed samples	-

According to Table 2, it is found that it takes a long time to thaw the samples to be inspected (Pujiati, R. 2017) since the crab stick products have been frozen and have to be thawed in the water bath whose temperature is approximately 26 - 30 °C. The samples thawed in a water bath are of various sizes. While the samples are thawed, water temperature continuously deceases in response to the temperature of the samples being thawed.

Figure 7: Crab Stick Samples in Water Bath

According to Figure 7, the crab stick sample of 60 grams in size is thawed in a water bath. Temperature of the sample before thawing is -13.4 °C whereas the temperature after thawing is 5.2 °C. Water temperature before thawing is 28.66 °C and after thawing is 28.10 °C. The time spent on thawing is 11 minutes.

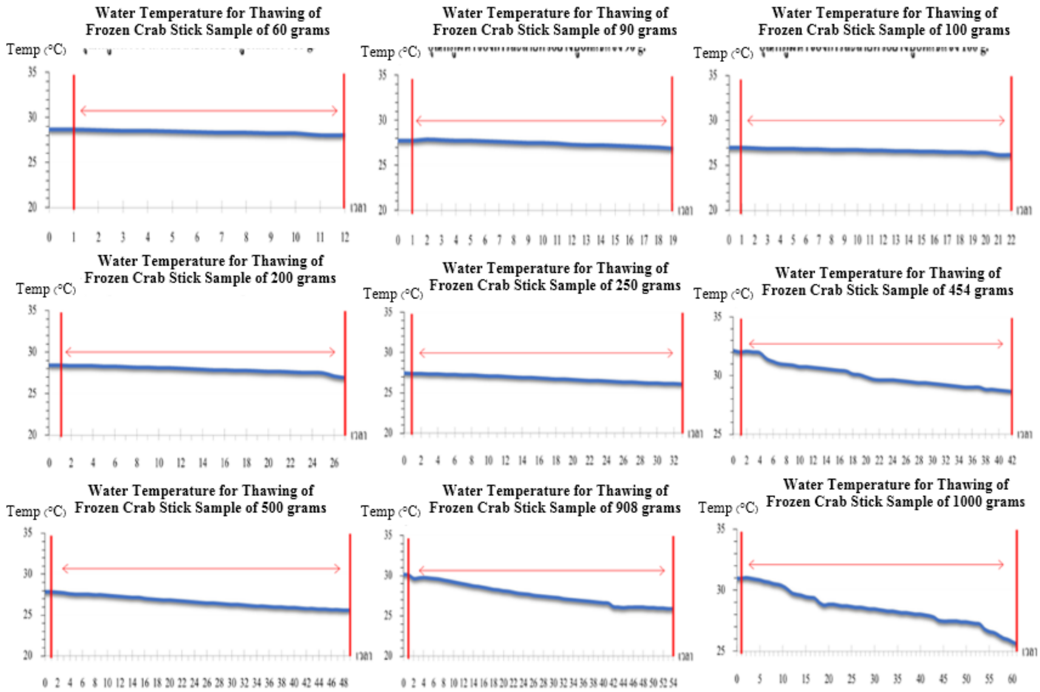

Figure 8: Graphs Showing the Thawing of Frozen Crab Sticks of Nine Sizes

According to Figure 8, when samples are thawed in a water bath, temperatures of the water change in accordance with the temperature of samples simultaneously thawed in a water bath at 26.97 °C. When the frozen samples are thawed in the water bath, temperature of the water gradually decreases. With regard to the sizes of samples, the heavier the samples, the longer it takes for thawing as shown in Table 3: A Comparison of Weights, Water Temperatures, Sample Temperatures from Start to End and Amount of Time Spent on Thawing the Nine Sizes of Samples One by One in a Water Bath (Munadi, E. 2017).

Table 3
A Comparison of Weights, Water Temperatures, Sample Temperatures from Start to End and Amount of Time Spent on Thawing the Nine Sizes of Samples One by One in a Water Bath

Weight of Crab Stick Product	Water Temperature before Thawing	Water Temperature after Thawing	Sample Temperature before Thawing	Sample Temperature after Thawing	Time Taken for Thawing
60 g	28.66 °C	28.10 °C	-13.4 °C	5.2 °C	11 min
90 g	27.79 °C	26.91 °C	-14.7 °C	4.7 °C	18 min
100 g	26.97 °C	26.16 °C	-12.1 °C	3.8 °C	21 min
200 g	28.41 °C	26.91 °C	-14.8 °C	4.5 °C	26 min
250 g	27.47 °C	26.10 °C	-15.1 °C	5.4 °C	32 min
454 g	32.17 °C	28.66 °C	-13.0 °C	2.9 °C	41 min
500 g	27.85 °C	25.60 °C	-14.3 °C	3.8 °C	48 min
908 g	30.16 °C	25.85 °C	-13.4 °C	2.7 °C	53 min
1000 g	30.97 °C	25.61 °C	-14.9 °C	3.1 °C	60 min

According to Figure 9, when samples are simultaneously thawed in a water bath, it is found that slighter samples are thawed faster than the heavier ones and the amount of time spent on thawing all samples altogether is longer than that spent on thawing the samples one by one as shown in Table 4: A Comparison of Weights, Water Temperatures, Sample Temperatures, and Amount of Time Spent on Simultaneously Thawing the Nine Sizes of Samples in a Water Bath.

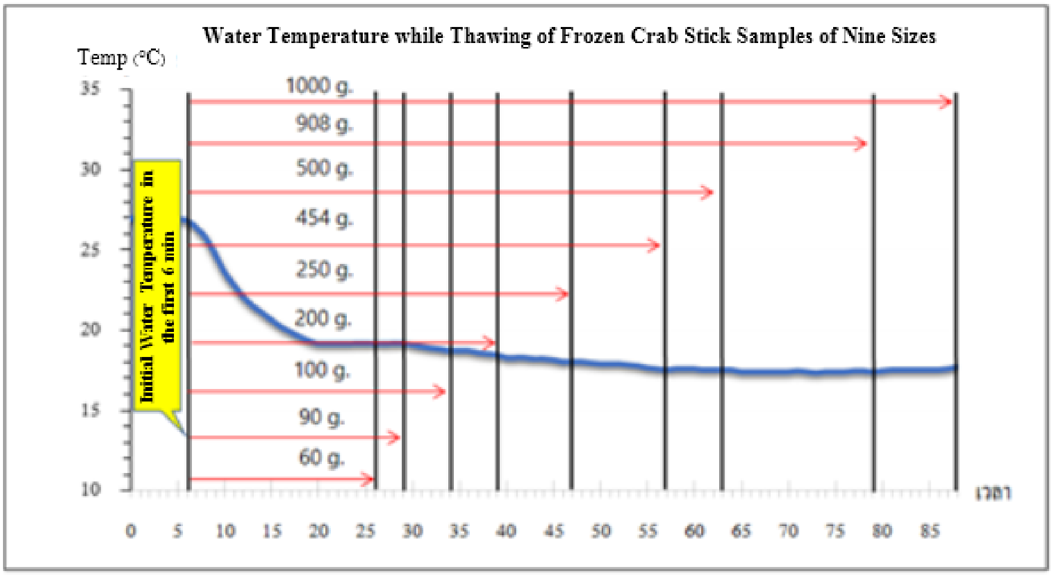

Figure 9: Water Temperature while Thawing Frozen Crab Stick Samples of Nine Sizes

Table 4
A Comparison of Weights, Water Temperatures, Sample Temperatures, and Amount of Time Spent on Simultaneously Thawing the Nine Sizes of Samples in a Water Bath

Weight of Crab Stick Product	Water Temperature before Thawing	Water Temperature after Thawing	Sample Temperature before Thawing	Sample Temperature after Thawing	Time Taken for Thawing	Taking Longer Time than One-by-One Thawing
60 g	26.976 °C	19.169 °C	-14.8 °C	3.7 °C	20 min	9 min
90 g	26.976 °C	19.185 °C	-13.2 °C	4.4 °C	23 min	5 min
100 g	26.976 °C	18.722 °C	-14.0 °C	4.5 °C	28 min	7 min
200 g	26.976 °C	18.472 °C	-15.3 °C	3.9 °C	33 min	7 min
250 g	26.976 °C	18.033 °C	-14.9 °C	4.1 °C	41 min	9 min
454 g	26.976 °C	17.533 °C	-13.8 °C	3.6 °C	51 min	10 min
500 g	26.976 °C	17.533 °C	-15.3 °C	3.9 °C	57 min	9 min
908 g	26.976 °C	17.408 °C	-15.7 °C	3.1 °C	73 min	20 min
1000 g	26.976 °C	17.721 °C	-15.2 °C	3.6 °C	82 min	22 min

When the samples are thawed simultaneously or consecutively, water temperature will gradually decrease in accordance with temperatures of the samples being thawed so it takes a long time before the samples can be inspected. Therefore, two water baths are used and various sizes of the samples are thawed in both water baths.

Discussions

Based on the research methodology, the researcher has investigated the current condition of frozen crab stick inspection and found that delay in the inspection process is caused by the excessive amount of time spent on thawing the samples. Therefore, the researcher has made improvements to the water bath and replaced defective parts in order to solve the problem of inspection delay. The improved water bath is capable of temperature control.

Cause analysis: fishbone diagram is used to analyze possible causes of inspection delay and it is found that there are four causes as follows: (1) receipt of the samples; (2) lengthy thawing of the samples; (3) recording of entry time; and (4) thawed samples awaiting the inspection.

Regarding the amount of time spent on the causes of problem, it is found that thawing of the samples is the cause that takes the longest time so this cause is used for “Why-Why” analysis.

Results of the “Why-Why” analysis indicate that it takes a long time to thaw the samples because the crab stick products are frozen and have to be thawed in a water bath and temperature of the water keeps decreasing in accordance with the thawing temperature.

The samples thawed in the water bath are of nine sizes. When the samples are thawed one by one, it is found that the sample that takes the longest time to thaw is one of 1000 grams in size, taking 60 minutes for thawing. Then, all nine sizes of the samples are thawed simultaneously and it is found that the size taking the longest time to thaw is that of 1000 grams, taking 1 hour and 22 minutes. After that, two water baths are used to thaw the samples and it is found that the sample taking the longest time to thaw is the 1000-gram one, which takes 11 minutes less to thaw compared with that spent on thawing the samples of all sizes at once. Thawing the crab stick samples in a water bath employs the second law of thermodynamics, which is thermal conduction where heat passes from a warmer material (water in the water bath) to a colder material (frozen crab sticks).

The time spent on inspection process, including the steps from receipt of the samples from QC line to sensory step, is 1 hour and 31 minutes, which results in a delay in the inspection process. If the product samples from the code manufactured at a certain period of time fail the inspection, all of the products of the same code as the samples inspected will be rejected and become waste.

Problem-solving method and improvements of the water bath: the problem is caused by change in water temperature so to solve the problem, a way to control the water temperature to prevent it from changing must be discovered.

As shown in Figure 10, improvements are made to the original water bath and 95% alcohol is used to disinfect the water bath. This water bath is capable of temperature control. Function of the temperature controller begins with SV (Setting Value), which is a variable used to determine the temperature needed for the process. In Figure 10, the temperature is set at 45°C. Then, the temperature controller will compare or find the different values between PV and SV whereas PV Process Value) is a variable derived from reading the temperature being controlled on the Sensor Input. If PV is less than SV, a command will be sent to Control Signal Output to send out signals to activate the heater to increase the temperature. When PV is more than SV, the value of Control Signal Output will be reduced to make the heater work less to solve the problem of inspection delay caused by lengthy thawing of the samples and control the temperature of water in the water bath used to thaw frozen crab stick products. Increase the temperature to reduce the time spent on thawing the frozen crab stick products.

Figure 10: Water Bath after Improvements

Examine the times spent to thaw frozen crab stick products before and after improvements are made. Before making the improvements, the total time spent on thawing the samples in the water bath from receipt of the samples to the sensory process is 1 hour and 31 minutes. After the improvements, the total time spent is 44 minutes and 15 seconds. It is faster to inspect the samples and to know whether products of the specific code of production pass or fail the inspection before keeping the products of such code in storage. The improvements show a decrease in the times spent on thawing the samples.

Time before the Improvements:

- % of the time before improvements $= \frac{\text{Amount of time before improvements} \times 100}{\text{Time spent on inspection before improvements}}$
- % of the time before improvements $= \frac{60 \times 100}{91} = 65.93\ \%$

Time after the Improvements:

- % of the time after improvements $= \frac{\text{Amount of time after improvements} \times 100}{\text{Time spent on inspection before improvements}}$
- % of the time after improvements $= \frac{13.25 \times 100}{91} = 14.56\ \%$

Percentage (%) of the Reduced Amount of Time:

- % of the reduced amount of time $= \frac{(\text{Before improvements} - \text{After improvements}) \times 100}{\text{Before improvements}}$
- % of the reduced amount of time $= \frac{(65.93 - 14.56) \times 100}{65.93}$

$= 77.92\ \%$

Value of Damage before the Improvements
The value of damage from July 2018 to December 2018 is 1,350,208 Baht.

Value of Damage after the Improvements
The value of damage from January 2019 to June 2019 is 313,900 Baht.

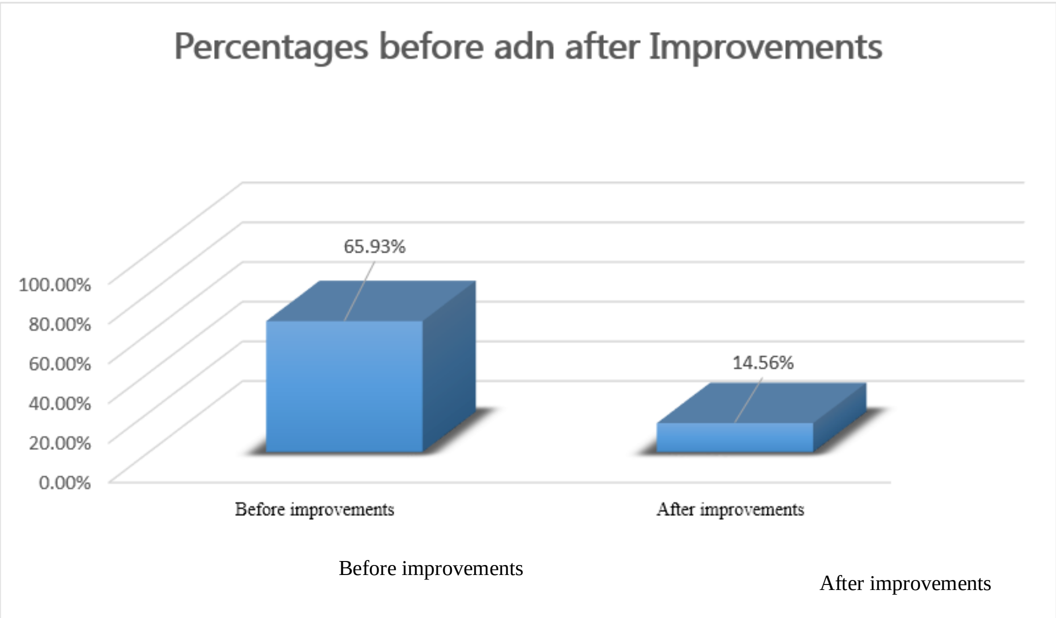

Figure 11: A Comparison of Percentages of Decreased Times

Conclusions

This research study is conducted to reduce waste in frozen crab stick product inspection process by comparing the percentage of the reduced amount of time spent by replacing the original water bath with an improved one to reduce the delay in the inspection steps, accelerate the delivery of products to the customers, and obtain the products meeting the customers' quality requirements. Improvements are made to the inspection steps by reducing the time required for thawing the products. As a result, it takes less time to determine quality of the products without damaging the products of the same code of production and helps reduce the time required for inspection of the products. Addition of a temperature controller improves the effectiveness of the whole inspection process. Conclusions of this research study are as shown below.

Based on an analysis of the problem of lengthy thawing of product samples, the researchers have solved such problem by making improvements to the original water bath by employing the technique of ECRS, especially the component of E (Eliminate), as well as eliminating seven types of wastes, including waiting time for thawing of the product samples (Suhardi,B., Anisa, N., & Laksono,P. W. 2019).

Results of the experiment indicate that when using the improved water bath, the temperature of the water can be controlled to be at 45°C with a deviation of ±2°C. It takes the longest time of 13 minutes and 15 seconds to thaw the sample of the size of 1000 grams. The time spent from receipt of the sample to the sensory step is 44 minutes and 15 seconds. With the original water bath, the time spent on thawing the sample of the size of 1000 grams is 60 minutes, which is the longest among all sizes of the samples being thawed whereas the time spent from receipt of the sample to the sensory step is 1 hour and 31 minutes. The percentage of the amount of time spent before the improvements is 65.93% whereas the percentage of the amount of time spent after the improvements is 14.56%. Thus, the percentage of the reduced amount of time is 77.92%.

After conducting a study of approaches to reduction of waste caused by a delay in the inspection process, it is realized that there is a lot of waste generated in the production process of crab stick products. To reduce waste in other production lines, the tool used in this research study can be applied to find the approach for reducing the waste.

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