PRODUCTION TIME LOSS REDUCTION IN SAUCE PRODUCTION LINE BY LEAN SIX SIGMA APPROACH

Thitima Ritprasertsri¹ and Parames Chutima¹,²

¹Department of Industrial Engineering, Faculty of Engineering Chulalongkorn University, Bangkok, Thailand 10330

²Regional Centre for Manufacturing Systems Engineering, Faculty of Engineering Chulalongkorn University, Bangkok, Thailand 10330

E-Mail: cparames@chula.ac.th

Abstract In all industries, time losses, which are incurred in processing are very important. As a result, losses are incurred in productivity and cost. This research aimed to reduce lost time that occurs in sauce production line by using the lean six sigma approach. The main objective was to reduce the time for heating sauce which causes a lot of time lost in the production line which affects productivity. The methodology was comprised of the five-phase improvement model of Six Sigma. This approach begins with defining phase, measuring phase, analysing phase, improving phase and controlling phase. Cause-and-effect matrix and failure mode and effect analysis (FMEA) were adopted to screen the factors which affect production time loss. The results showed that the percentage of lost time from heating sauce reduced by 47.76%. This increased productivity to meet the plan.

1. INTRODUCTION

Commercial food world has been modified from its original focus on the export of agricultural products which are the basic food for humans and animals primarily through privatization as a processed or dried product by applying unusually high technologies. There is no value added to the product lot. Nowadays more processed foods are exported. Industrial sauce manufacturing is one of the most popular processing industries because sauce helps to improve the taste and flavor of food to taste delicious. Manufacturing sauce has been growing steadily resulting in high competition. Therefore, manufacturers must produce products of high quality to get more market share. Strategy relies on the production of high quality. To lower production costs, losses which occur in the production process need to be reduced. Productivity needs to be increased and products supplied timely which are sufficient for customers' needs.

Lean Manufacturing (LM) is a systematic approach to eliminate waste and change processes. This is done by identifying and reducing waste with continuous improvement [1]. There are seven wastes identified by Shigeo Shingo, namely over production, defect, unnecessary inventory, inappropriate processing, excessive transportation, waiting/idle time and unnecessary motion [2]. LM aims to develop...
solutions by using the minimum amount of resources (human, material and capital) and to ensure the products reach customers on time [3]. Six Sigma, provides quality philosophy and is a statistical tool to monitor process performance. It aims to reduce the variability in the process and to eliminate errors [4]. Also it gives more value to customers and stakeholders with focus on improving product quality and company productivity. There are five stages called DMAIC method (define, measure, analyse, improve, control) [5]. Lean and Six Sigma each have their own strengths in different applications and the two methodologies can be combined or applied in different situations to achieve the best results.

In this case study, the important problem in the production process and impact on the factory at this time is productivity which is insufficient to meet the demand due to time lost in boiling sauce. As a result, most shipments are unable to meet the delivery dates. This research aimed to reduce lost time which occurs in the process of heating sauce by using LM Six Sigma method to identify significant factors which affected losses in productivity. It is expected that by implementing LM Six Sigma the company could reduce production cost, increase utilization of resources, reduce loss time, and reduce variability in the production system.

2. DEFINE PHASE
This research focuses on lost time in the process of manufacturing sweet chili sauce (name SCS-TRI21) which is the main product of the factory and a huge demand from customers. The production process of the SCS-TRI21 consists of mixing, pre-heating, heating, cooling down and pasteurisation. From the data report, it was found that the volume of production per hour during the months of February to August 2016 less than planned as shown in Figure 1, resulting in the volume of sauce production during the months of February to August 2016 was below the target in every month as shown in Figure 2. As a result, some products could not be shipped on time.

![Figure 1](image1.png)

**Figure 1.** Actual production volumes per hour compared to the target during February to August 2016

![Figure 2](image2.png)

**Figure 2.** Actual production of sauce compared to the target during February to August 2016
3. MEASUREMENT PHASE

This phase was concerned with two main steps, which were waste measurement and problem identification analysis, which can be described as follows [6].

3.1. Waste Measurement

Concept 7 was applied in which waste can occur due to over production, defect, unnecessary inventory, inappropriate processing, excessive transportation, waiting/idle time and unnecessary motion [2]. The result of the waste in the production process of SCS-TRI21 is shown in Table 1. Obviously, the lost time, which is the most influence in the production, is waiting/idle time (42.27%) and inappropriate processing (20.32%).

| No. | Types of waste           | Frequency (%) |
|-----|--------------------------|---------------|
| 1   | Over production          | 1.01          |
| 2   | Defect                   | 15.2          |
| 3   | Unnecessary Inventory    | 5.58          |
| 4   | Inappropriate Processing | 20.32         |
| 5   | Excessive Transportation | 11.93         |
| 6   | Waiting/Idle Time        | 42.27         |
| 7   | Unnecessary Motion       | 3.69          |

3.2. Problem identification analysis

Brainstorming sessions were conducted with a team of experts from different departments involved in the production of the sauce. A system was implemented to identify factors which could affect the time lost in process. The cause and effect analysis concerned Man, Machine, Material, Method and Environment (4M1E) which were applied in this process [7]. It was revealed that the number of tentative causes was 12 factors as shown in Table 2. These factors were used for further analyzing the relationship between cause and related effect using the cause and effect matrix. By scoring these relationships 0, 1, 3 and 9 respectively, and analyzing data from the Pareto chart analysis the factors which significant impacted to the production time lost were identified as shown in Figure 3. Room temperature was found to have no effect.
Table 2. Cause and Effect Diagram with 4M1E
(Source: Brainstorming by the experts in the production of sauce)

| No. | Area cause | Cause of problem                                      | Total |
|-----|------------|-------------------------------------------------------|-------|
| 1   | Man        | Employees lack attention to process control           | 3     |
| 2   | Machine    | Size of mixing tank                                   | 3     |
| 3   | Machine    | Long lifetime of mixing tank                          | 1     |
| 4   | Machine    | Lack of preventive maintenance plan for mixing tank   | 1     |
| 5   | Machine    | Speed of agitator of mixing tank                      | 9     |
| 6   | Material   | Type of raw material                                  | 3     |
| 7   | Material   | Steam for heating                                     | 9     |
| 8   | Method     | Heating time                                          | 9     |
| 9   | Method     | Heating temperature                                   | 9     |
| 10  | Method     | Syrup temperature                                     | 9     |
| 11  | Environment| Equipment not enough                                  | 3     |
| 12  | Environment| Room temperature                                      | 0     |

Figure 3. Pareto chart of Cause and Effect matrix

The results from cause and effect matrix analysis showed that 5 factors (speed of agitator of mixing tank, steam for heating, heating time, heating temperature and syrup temperature) have the highest scores. These factors were further screened by using Failure Mode and Effects Analysis (FMEA) as shown in Table 3.
Table 3. The Risk Priority Number of Each Root Cause

| No. | Potential Failure                  | Risk Priority Number (RPN) |
|-----|------------------------------------|---------------------------|
| 1   | Speed of agitator of mixing tank   | 648                       |
| 2   | Steam for heating                  | 175                       |
| 3   | Heating time                        | 125                       |
| 4   | Heating temperature                 | 900                       |
| 5   | Syrup temperature                   | 900                       |

Figure 4. Pareto chart of Failure Mode and Effect Analysis

Figure 4 showed three factors with high rating in each category which were selected for the design of experiment (DOE) in the analysis phase. These three factors contribute 89.1% of the total score. Three factors which could affect the time lost in process are heating temperature (the temperature was in the boiling sauce), syrup temperature (the temperature was dissolved syrup before bringing to boil the sauce) and speed of agitator of mixing tank (agitator helps to mixed ingredient very well and heat transfer).

4. ANALYSIS PHASE
At this phase, the analysis was carried out to determine the causes of the problem. The $2^k$ factorial design is particularly useful in the early stages of experimental work when many factors are likely to be investigated. It provides the smallest number of runs with which $k$ factors can be studied in a complete factorial design. Consequently, these designs are widely used in factor screening experiments [8]. Three factors were selected to study in this analysis phase including heating temperature, syrup temperature and speed of agitator of mixing tank. The level of each factor has been selected by the minimum and maximum adjustable values of the instruments used in the process as shown in Table 4. The eight trials were conducted within a completely randomized experiment. The response variable in this study was the time involved in the process.

Table 4. Factors and Level of Factors in $2^3$ Factorial Design

| No. | Factors                        | Units         | Symbols | Levels of factor |
|-----|--------------------------------|---------------|---------|------------------|
|     |                                |               |         | Low (-) | High (+) |
| 1   | Speed of agitator of mixing tank| RPM           | A       | 30      | 45      |
| 2   | Syrup temperature              | Degrees Celsius| B       | 70      | 80      |
| 3   | Heating temperature            | Degrees Celsius| C       | 85      | 90      |
Figure 5 has shown the experimental data which were analyzed by using the Minitab software (version 17) and the results showed that the main effects were caused by syrup temperature (B) and heating temperature (C) and in three-factor interactions these were significant factors at 95% confidence interval, whereas factor A (speed of agitator of mixing tank) and interactions (AB, AC and BC) were not significant. One approach to the analysis of a single replicated factorial is to assume that certain high-order interactions are negligible [8]. Therefore, it could be concluded that the main effects B and C were significant at 95% confidence interval. As a result, all significant factors need further investigation to find their appropriate level settings.

Figure 5. Pareto chart of effects

5. IMPROVEMENT PHASE
In this phase, two levels of the significant factors derived from the $2^k$ fractional factorial experiments were tested to find their appropriate levels which could reduce the lost time in process. Central Composite Design (CCD) was used in this experiment [8], to test the interaction of these factors and whether their impact was significant or not in lost time in process. The level of each factor was randomly selected, three levels of syrup temperature (B) and three levels of heating temperature (C) as shown in Table 5.

| No. | Factors               | Units          | Symbols | Levels of factor |
|-----|-----------------------|----------------|---------|------------------|
|     |                       |                |         | Low (-1)         | Medium (0) | High (1) |
| 1   | Syrup temperature     | Degrees Celsius| B       | 70               | 75         | 80       |
| 2   | Heating temperature   | Degrees Celsius| C       | 85               | 87.5       | 90       |

The experimental data were analysed by using the Minitab software, which produced the statistics [9] shown in Figure 6 which revealed that the main effect of syrup temperature and heating temperature have the P-value less than 0.05. Therefore, it can be concluded that the main effect of syrup temperature and heating temperature affected the lost time in process at 95% confident interval.
Figure 6. Results of Analysis of Variance.

The significant factors in the previous step were analysed to find the optimal condition by using Response Optimiser of the Minitab software. Figure 7 shows the optimized value of the syrup temperature and the heating temperature are 77.6°C and 91.0°C, respectively, to consume the minimum lost time in the process.

Figure 7. Response Optimiser of syrup temperature and heating temperature

6. CONTROL PHASE

In this phase, all settings of the significant factors derived from the previous phase were implemented in the process and the data relating to the time taken in the process were collected for 30 days. It was found that the volume of production per hour in the month of September 2016 was above target (3,300 bottles per hour) as shown in Figure 8 and the volume of sauce production in the month of September 2016 was above target (521 tons), comparing between the production volume before and after the improvement process as shown in Figure 9.
Figure 8. Production volumes per hour compared to the target during February to September 2016

Figure 9. Production of sauce compared to the target during February to September 2016

The process improvements, which could reduce the time taken in each step, showed that syrup preparation was reduced by 3 minutes, heating was reduced by 8 minutes, cooling down was reduced by 51 minutes and pasteurization was reduced by 2 minutes. To sum up, the total time in production process was reduced by 47.76% as shown in Table 6.

Table 6. Production time compared between before and after improvement

| No. | Process          | Time (mins) |    |    |
|-----|-----------------|-------------|----|----|
|     |                 |  before improvement | after improvement |
| 1   | Syrup preparation | 25          | 22 |
| 2   | Heating         | 41          | 33 |
| 3   | Cooling down    | 51          | 0  |
| 4   | Pasteurisation  | 17          | 15 |
|     | Total           | 134         | 70 |

To maintain the production time of the process after improvement, the work instructions for operational control in the process were written and shared among all the production personnel that were involved in these activities. This helped the operators to manage and monitor the process systematically.

7. CONCLUSIONS
The Lean Six Sigma method was applied to reduce lost time which occurred in the sauce production line. Five steps of the Six Sigma were utilised in order to find the proper parameter settings of the significant factors and to indicate how to set the relevant process control parameters. It was found that the syrup
temperature and heating temperature had significant effects on the problem of interest. After applying all new settings to the process, the result showed that the time in production process was reduced by 47.76% which could cut the cooling down process which caused the lost time. Consequently, productivity was increased to meet the plan. Thus LM Six Sigma can be applied to reduce the time in another part of the production process.

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