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(Research Article)

An implementation of lean technology to improve the lead time of syrup batching process and reduce hot fill line downtime

Duy Ly-Anh [1], An Phan-Hoang [1], Dung Le-Phuong [1], Quynh-Lam Ngoc-Le [1, 2] and Do Ngoc Hien [1, *]

[1] *Department of Industrial Systems Engineering, Ho Chi Minh City University of Technology, Vietnam.*

[2] *Center for Education Accreditation, Vietnam National University Ho Chi Minh City, Ho Chi Minh City, Vietnam.*

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Abstract

The research would present an effective performance of lean tools implementing in an Lemon Tea processing line of a Drink Industry as a case study. An improved strategy to reduce the lead time of syrup batching process and then reduce downtime on hot fill line would be considered as well as used. The DMAIC (Define - Measure - Analyze - Improve - Control) methodology would be followed. As the results, the lead time of syrup batching process was reduced from around 140 minutes to (after implementation of lean technology) 98 minutes, and downtime on hot fill line was also dropped significantly by approximately 50 percent. Besides, the production flow was optimized by minimizing several non value added activities and time such as waiting time at the bottleneck points, machine breakdown, queuing time, and other unnecessary waiting time. Eventually, this case study would be useful in developing a generic approach to design lean environment in management system of the studied drink industry organization.

Keywords: Lean technology; Lead time; Downtime; Syrup batching process; DMAIC

1. Introduction

Improving product/process quality and reducing operational costs are very important aspects for manufacturers. Nowadays, the basic concern of any manufacturing company is to increase customers satisfaction by constantly improving delivery service on time by keeping the quality and quantity at the best level. At the same time, companies need to keep their costs and prices as low as possible to be able to compete with others while they still keep their profitability. Therefore, they should have a very good control on production systems and a relish for improvement wherever it could be possible.

It is important to find and eliminate causes of mistakes or defects in business processes by focusing on outputs which are of critical importance to customers [2]. One key to the success of the initiative research is the step-by-step approach as DMAIC methodology. It is an acronym of Define, Measure, Analyze, Improve, and Control phases. DMAIC organizes the use of a large range of tools during improvement projects [3].

In this research, DMAIC methodology would be used to figure out the problems on production line, suggest alternatives and show a desired future state. The data was first collected to determine the current overall equipment effectiveness (OEE), which is known as percentage of the loading time during which the equipment produces value [4]. The goal of this research project is to focus on decreasing processing lead time and downtime to achieve the optimum rate of product quantity in production process in dairy products of manufacturing company. In addition, after completion of each DMAIC cycle, it could help managers recognize new required project objectives, improve system performances and enhance quality [5]. DMAIC is known as a data driven consistency approach to enhance processes, in which various tools have been used in different phases [6, 7].

2. Implementation of lean technology following DMAIC process

2.1. Define phase

Lemon Tea was known as a new product of the studied manufacturing company, so the product formular and process, especially syrup batching process, were different from the existing ones. Syrup batching process is started by blending a tank of high fructose corn sugar (HFCS) with tea extract solution, then quality check is done and finally high temperature is processed in short time.

The manufacturing process of lemon tea is shown as on *Figure 1*.

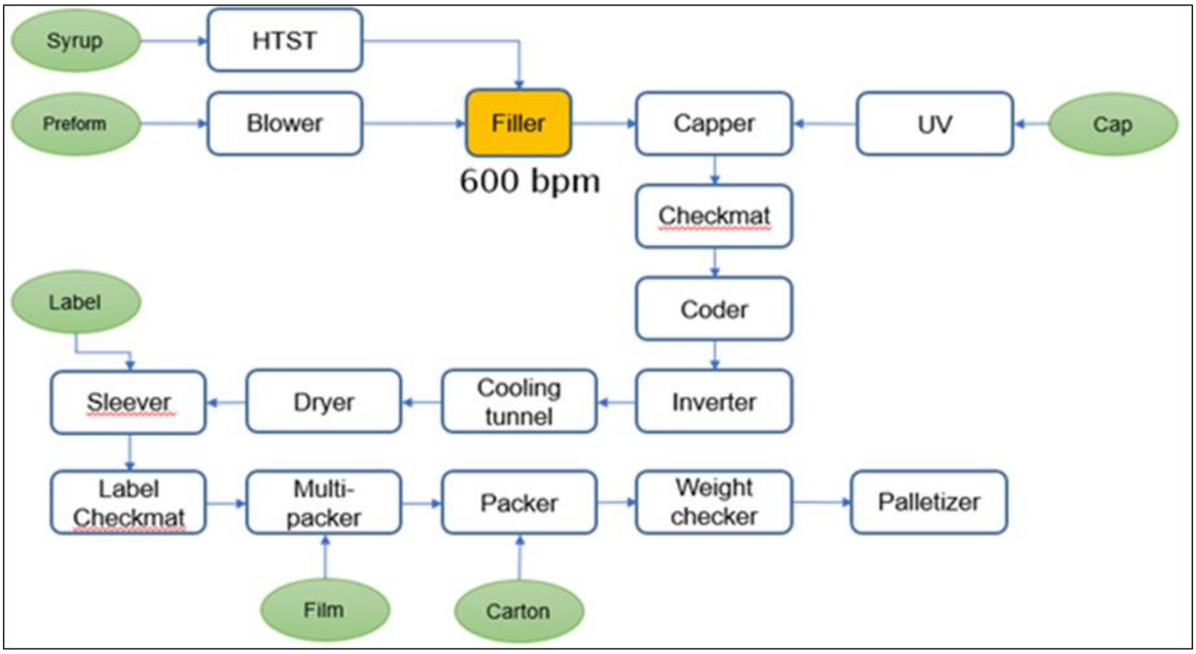


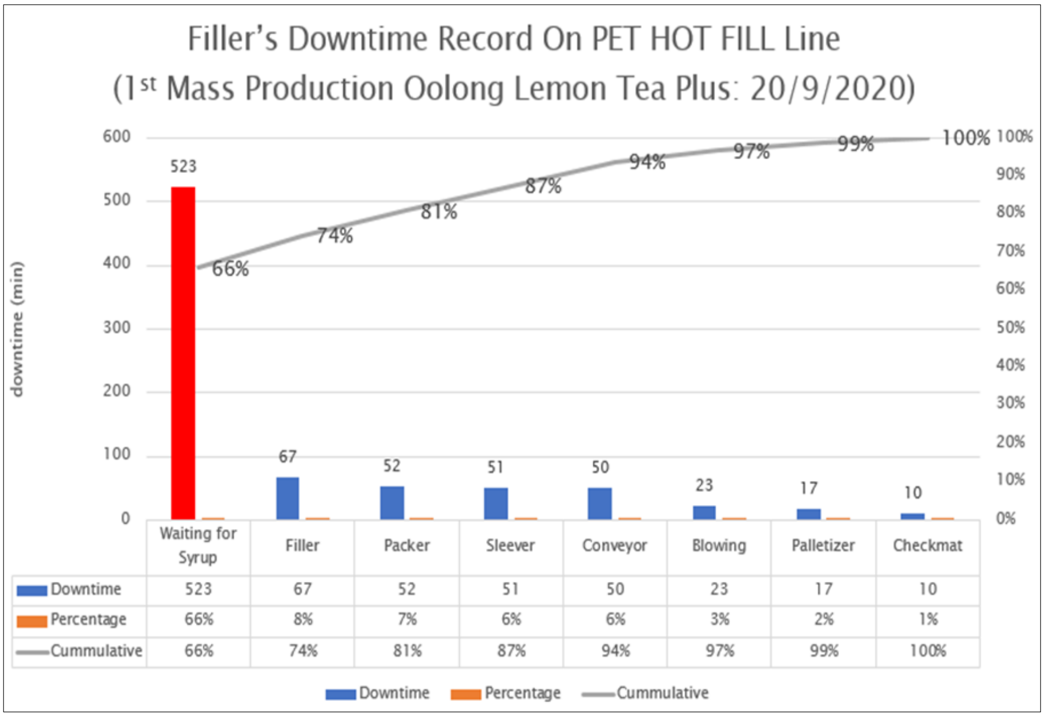
Figure 1 Manufacturing process: pet hot fill line

Syrup batching process would be done before the filling stage is begun. The machine downtime is recognized as a critical problem of the waiting time for syrup, filler, packer, sleever, conveyor, which accounts for 66 percent of the total time (as shown on *Figure 2)*.

The bottlenecks in the process was identified at the syrup batching stage, which is the reason for wastes. The goal of the project is to identify the root causes of this problem as well as find out the ways to increase the line performance. In order to reduce wastes, the process balancing method was applied.

First, the current OEE was calculated (as shown on *Figure 3*) with some assumptions:

- The filling speed is not set up depending on types of product and always kept at 600 bmp;
- There is not substandard product in process;
- Downtime is only counted when filler is stopped.



	Waiting for Syrup	Filler	Packer	Sleever	Conveyor	Blowing	Palletizer	Checkmat
Downtime	523	67	52	51	50	23	17	10
Percentage	66%	8%	7%	6%	6%	3%	2%	1%
Cummulative	66%	74%	81%	87%	94%	97%	99%	100%

Figure 2 Pareto chart of types of downtime Recorded on PET hot fill line

Based on the OEE ratio, the ultimate effective, efficiency of production assets was grasped. It would be used to assess how much room is expected for improvement and measure the effectiveness of improvement activities. Actually, the present OEE is unsteady, so the target is made it stable at least more than 75 percent.

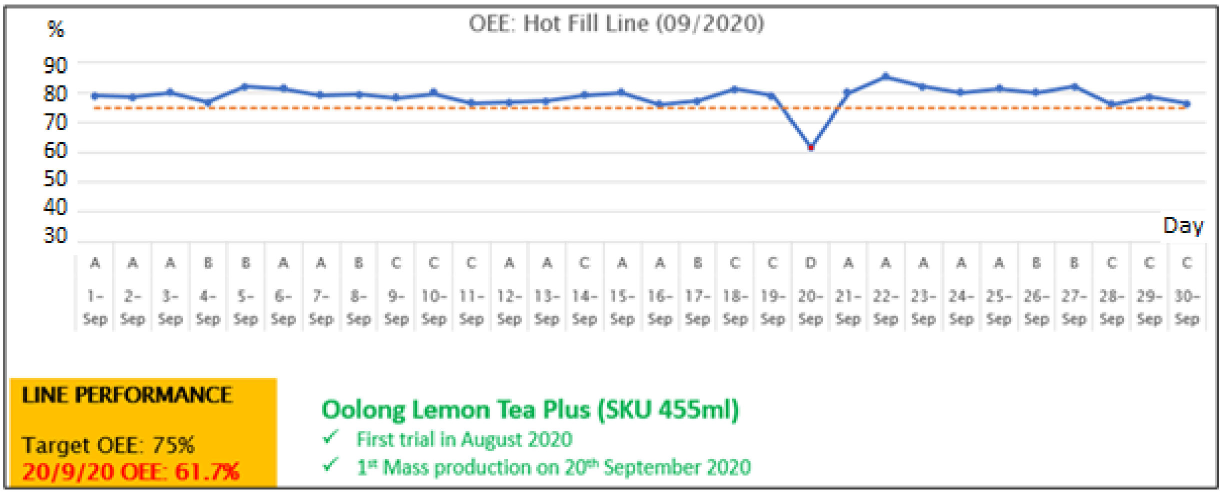


Figure 3 OEE ratio Hot Fill Line

In addition, the batching and filling cycle could not be finished at the same time as shown on Figure 4. Batching process was always take more time than filling process which is the main problem caused downtime. The problems were found in batching process that high fructose corn sugar transfer period (35 minutes) and the time waiting for finished syrup (30 – 35 minutes) were too long. It is better to find out the ways to reduce to get the optimum process as shown on Figure 5.

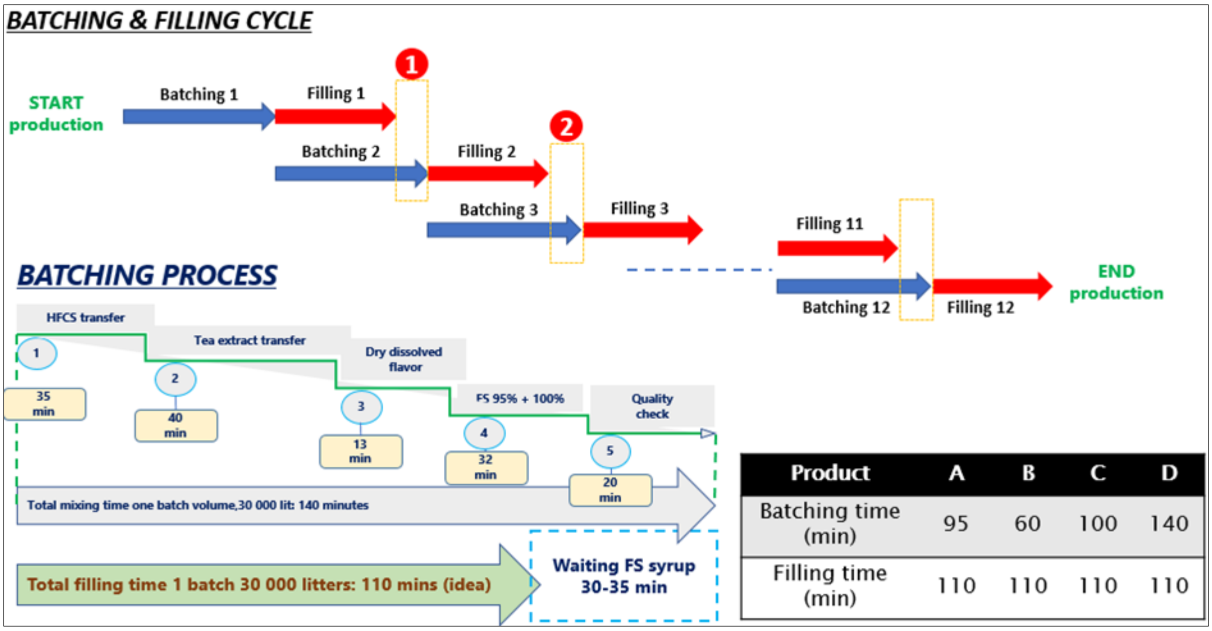


Figure 4 Batching and Filling cycle

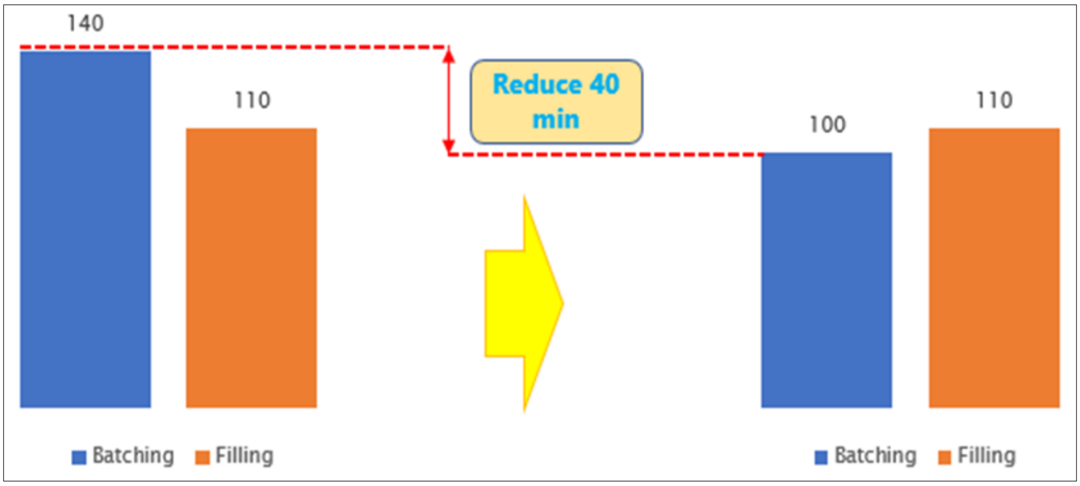


Figure 5 Batching and filling interactions

2.2. Measure and Analyze phase

In this part, detail measurement and root causes would be described to find bottlenecks in batching syrup process. The improvement alternatives would be implemented to forces on cutting downtime.

2.2.1. Syrup batching process.

High fructose corn syrup (HFCS) would be pumped from the HFCS tank through a filter bag system (Diameter of filter pores = 25μm) into the mixing tank NCB-7 and NCB-8. The treated water is pumped into two Gum dissolved tanks with including some necessary additives (emulsifiers, viscosity regulators, stabilizers, …); Then it would be flited again by a 20 mesh sieve system before pumping into NCB-7 and NCB-8. At the same time, tea extract is also pumped into NCB-7 and NCB-8.

The flow is pumped into NCB-7 and NCB-8, which is controlled by damper. Actually, the sample is collected after mixing all of solutions to check quality. If all parameters meet the quality requirements, syrup would be cut line and transfer to hot fill process. In the steps of mixing additives and tea extracts, it is strictly proposed according to the required technology, so required time can not be changed because it would affect the product quality strongly. The syrup batching process is shown as on Figure 6. The leading time of each process step is measured and summarized as on Figure 7.

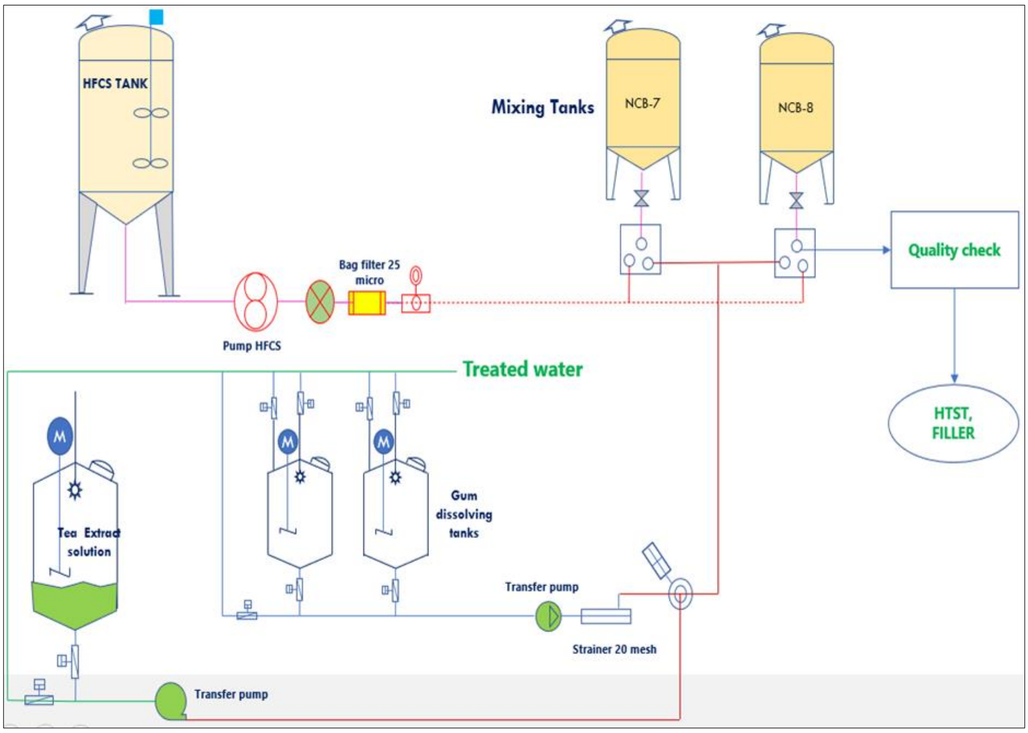


Figure 6 Syrup batching process

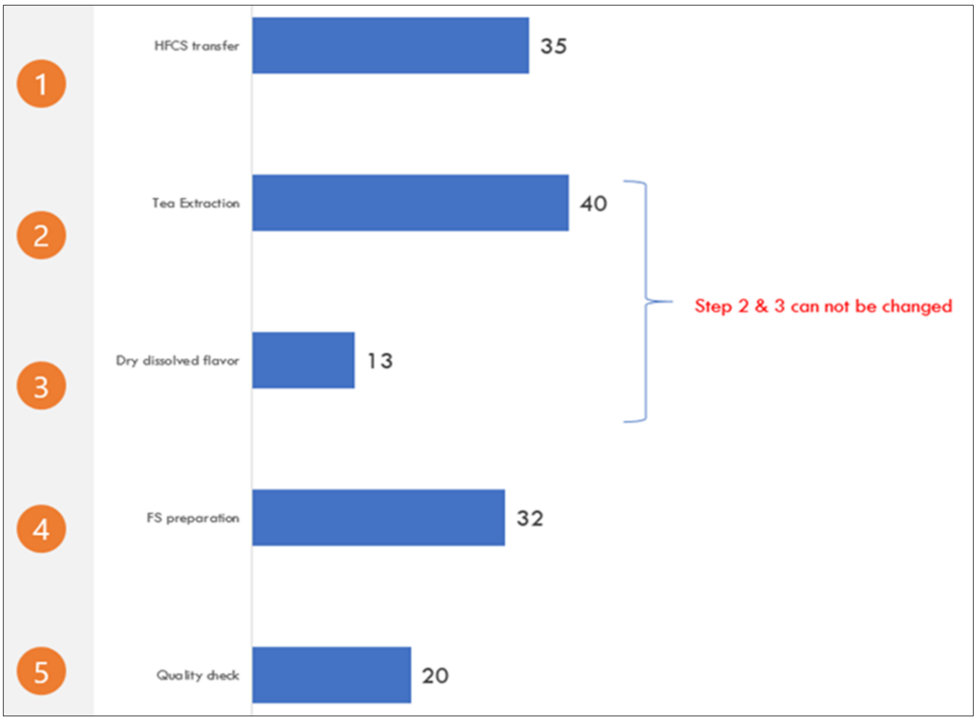


Figure 7 Total leading time of Syrup batching process

2.2.2. Root Cause Analysis

Ishikawa diagram was used to depict root causes, which was referred from quality, engineer and operation staff by conducting survey, getting experiences and ideas from experts. Some main root causes were found out: (1) Parameters of pump setting are not utilized, (2) HFCS pipeline system needs to optimize, (3) Moving time between QC (Quality Control) lab and Syrup Station was longer than expectation, (4) Quality check step cost a lot of time but unnecessary.

Total leading time of recently batching syrup process for new product is 140 minutes. Moreover, extract tea solution and dissolve gum cost a time 40 minutes and 13 minutes, respectively. Both of them are toughly fixed because of the issued technology, so the improvement just might deploy in step 1, 3, 4 as illustration on Figure 8.

2.3. Improve phase

2.3.1. Renovation of pump setting and pipeline system

In step 1, transfer of the sugar solution from the HFCS tank to the mixing tank is determined as the bottleneck due to the nonoptimal pump capacity. The current capacity is 4.5 bar. If this level is exceeded, the pump would automatically shut off. However, the maximum design capacity of the pump is up to 10 bar. In fact, the setting pressure is set at 4.5 bar. The actual pump capacity just reach to 3.5-3.8 bar and the corresponding flow is 10.8 m^3/h.

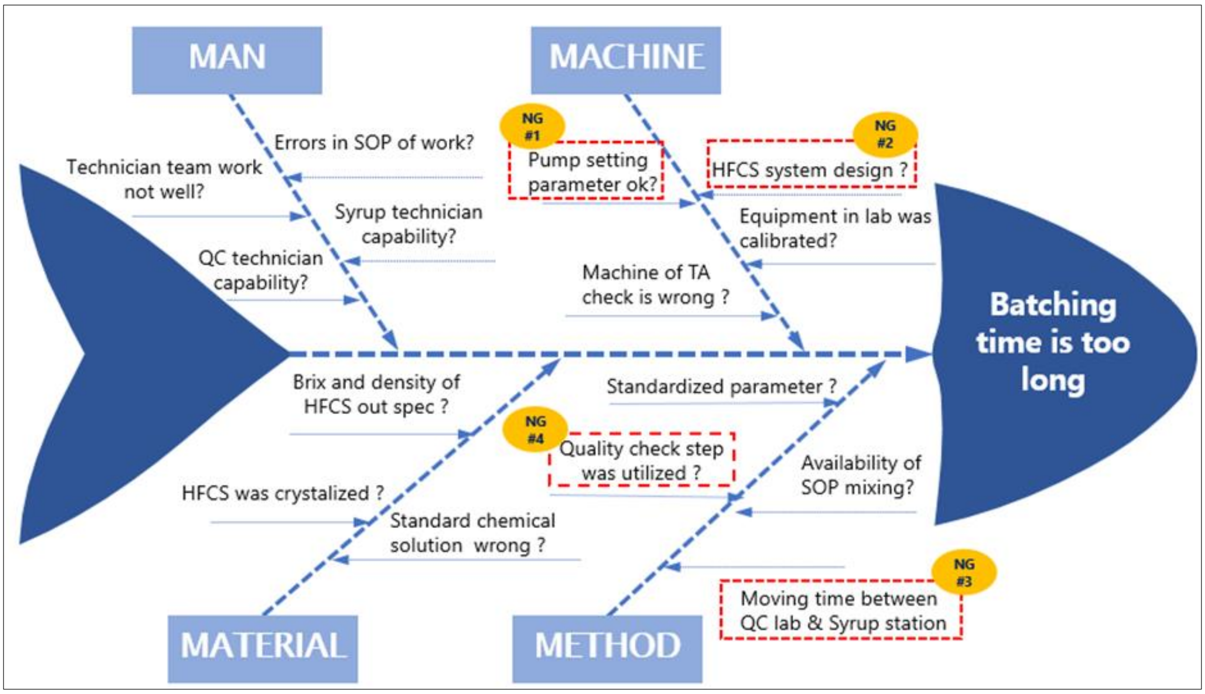


Figure 8 Ishikawa diagram was used to find out root causes

The total time to complete pumping sugar solution is 35 minutes with a pump diameter of 50mm, length 30m (flexible hose pipeline). The gap between actual and design capacity is still large, so it was not been fully utilized. Engineers perform pump adjustment to the optimal point by increasing the inlet pressure on the pump to the maximum threshold when the sugar shows signs of clumping because the flow pressure is too high. Besides, to utilize pump capacity, diameter of pipeline need to be recalculated to fit the new pressure. It could help the system operate more efficiency while it still keeps retaining certain flexibility to easily move the pipeline and avoid clumping sugar by high pressure and temperature.

As results, the inlet pressure of the pump reaches to 6.2 bar and the actual pressure is 5.7 bar with the new diameter of 80mm while the length still remains 30 meters. The new flow rate is measured at 18.9 m^3/h; The total time to pump all the necessary sugar solution is down to 20 minutes; The usefulness of the pump reaches 58% increasing 24% in comparison with previous system.

2.3.2. Redesign layout of Brix check station.

In the fourth step, according to the current procedure, the machine operator has to take samples when the syrup dilution concentration reaches 95% to check the Brix level. It ensures that the syrup is still stable because if it is just checked when syrup dilution concentration is 100%, the syrup would have to be completely destroyed with any problem.

The operator has to move from the syrup mixing station to the QC department where the brix meter is located to do the inspection. It takes a lot of time about 10-12 minutes for moving both the back and forth because all inspecting activities should be done in a clean room environment (as shown on Figure 9). Actually, measuring the Brix on the meter is completely simple, so the operator just needs to insert the sample into the machine and take the measurement. After the results are obtained, the syrup batch is further diluted to 100%. At this time, it would be checked by QC before it is moved to the finished product hot filling step into plastic bottles. To eliminate the moving time waste due to excessive movement in the Brix test step with 95% dilution of syrup concentration, the Brix meter was reassigned to the syrup mixing station for the operator to check directly after taking a sample at 95% dilution concentration. The operator would be trained to make sure that the measurements are accurate even the job is simple. It could help reduce downtime by moving too far about 10-12 minutes.

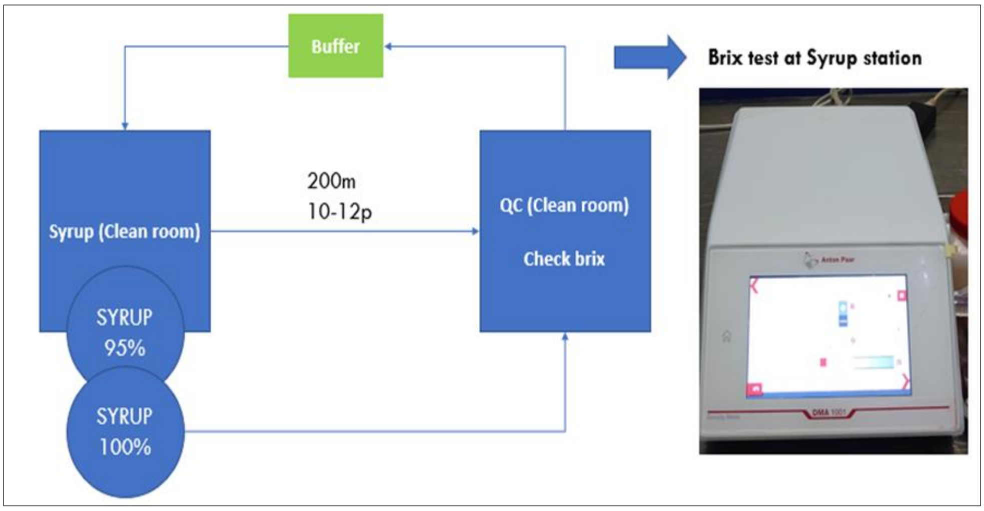


Figure 9 Brix check process and Brix test machine

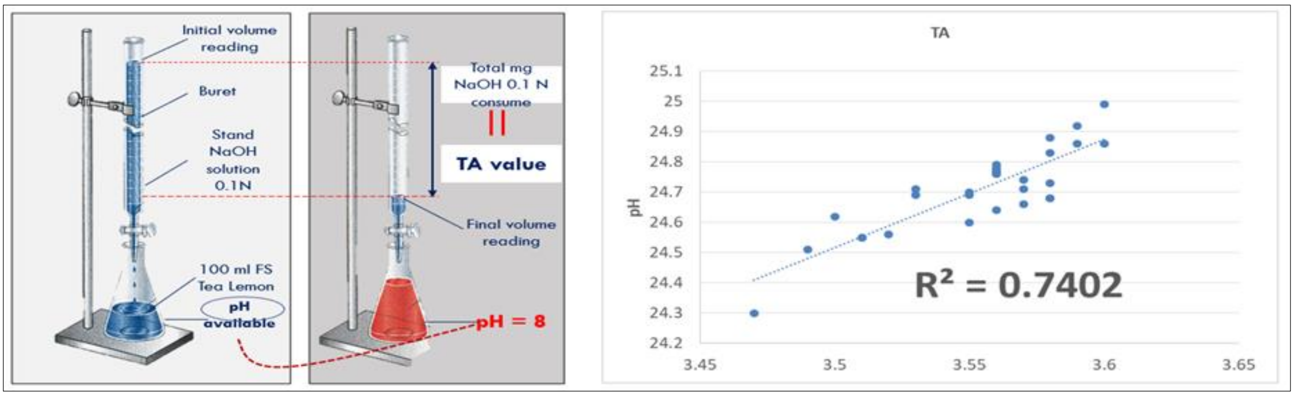


Figure 10 Neutralizing acidity of syrup by NaOH to find pH and relative equation between pH and TA

2.3.3. Rearrangement of quality check process

In the last step before moving to the hot fill stage, the syrup output parameters are carefully checked by QC such as: Brix, acidity (TA), pH, appearance (Color). The total time for QC to complete the job is around 20 minutes. However, the machine running time to measure TA is around 15 minutes. It shows that the measurement of TA takes long time, which leads to downtime, while TA is the acidity relating to the pH of the syrup. The experiments was done to find out a linear regression equation representing the relation between pH and TA. As a result, it is necessary to measure the pH value by neutralizing the syrup sample with 0.1N NaOH and then the equation with the correlation coefficient $R^2 = 0.74$ is used to infer the TA value as shown on Figure 10. If the pH value is in the range of 3.4-3.6, the TA would correspond at 24.1 - 25.2 ml ever since the batch would be move to hot filling stage. In addition, during the bottling time, the sample is still being tested by the mechanical TA again to ensure the quality. It could help cut the downtime around 15 minutes.

3. Results

The project results obtained that the total time in the syrup batching process was reduced from 140 minutes to 98 minutes - a dramatic decrease of 42 minutes (equivalent to a 30% reduction) as shown on Figure 11.

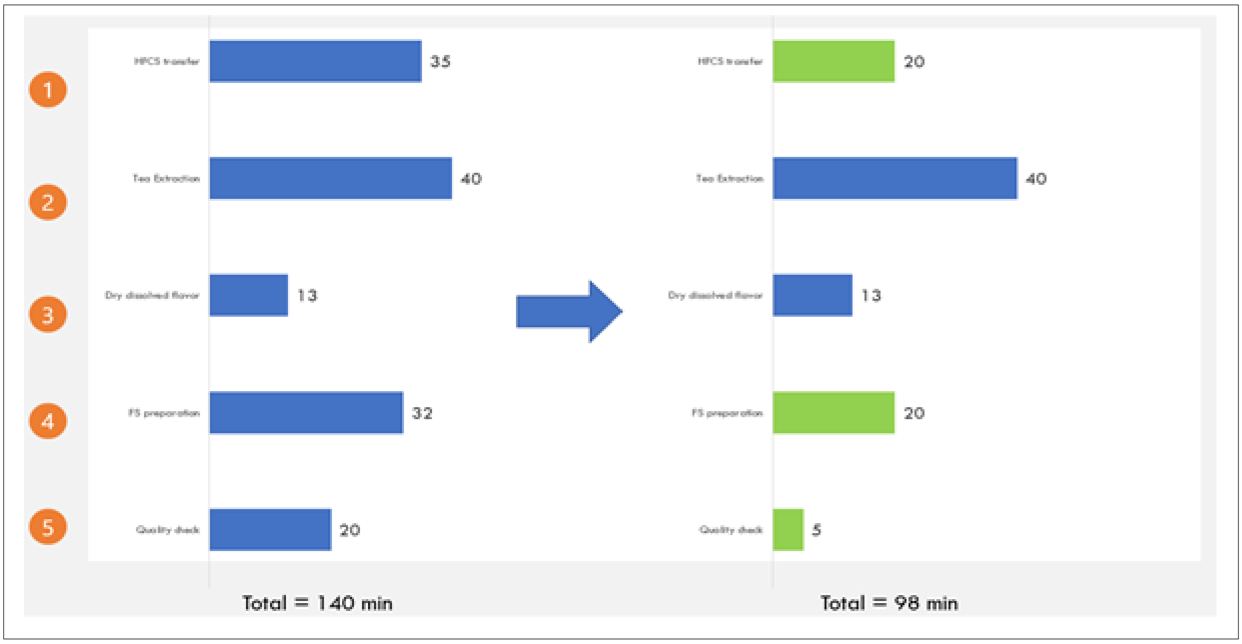


Figure 11 Total leading time of Syrup batching process after improvement

After increasing the inlet installation pressure of the pump to 6.2 bar and raising the pump pipe diameter to 80mm (as shown on Figure 12), the HFCS flow rate reaches 18.9 m^3/h and the time to fulfill the mixing tank is reduced from 35 minutes to 20 minutes (10.72%).

As a suggestion, a Brix meter (newly purchased one) in the syrup mixing station is installed and the syrup mixer staff is trained to do the correct job as shown on Figure 13. The process is cut down 10-12 minutes of downtime (8.57%).

After rearranging the quality test for syrup output parameters, the time to complete batching and move to filling step is shortened to only 5 minutes. In addition, it ensures that the product quality meet the standards when the TA measurement step is taken place at the same time with the filling stage. The TA interval (24.1 - 25.2 ml) based on into the equation to correlate the pH (3.4-3.6) is figured out.

Figure 12 New setting parameter of pump system and new pipeline with diameter of 80mm

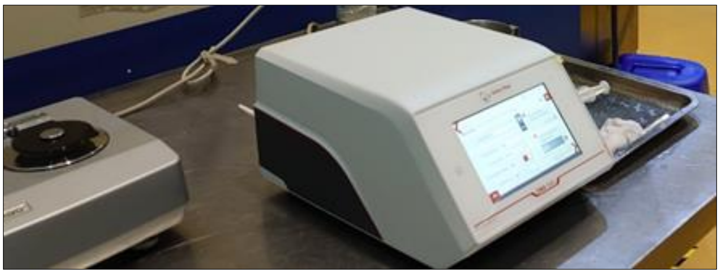


Figure 13 New brix meter at mixing syrup station and do OPL to ensure job of operator

4. Discussions

The project research results in reducing downtime of the syrup batching process of the new tea product line could help reduce production time, eliminate some wastes of resources while product quality still meet requirements. In particularly, it ensures that the syrup preparation process must be less than 110 minutes to avoid waiting for transport the batch to filling stage as critical requirement. The old process to complete the syrup brewing process took around 140 minutes. As results, there are 30 minutes to wait for filling, so the factory consumes a lot of energy to continuously heat and cool to ensure the syrup batch remains keep quality requirements. The risks would be increases when a downtime is over last longer than permission, so the batch of syrup may be damaged. As results, total cost of destruction during demolish process is enormous due to energy and labor source.

In addition, the improvement of the syrup mixing process in the new product line is the foundation to improve the syrup mixing time for all current products in the company. It could help save potential energy and resources, increase buffer time to prevent malfunction.

5. Conclusion

This paper presents a way to use the DMAIC cycle to solve the practical problems with a case study. The lean tools were applied in suitable stages as systematic improvement in order to achieve multiple benefits. Some specific problems of drink industry were figured out and the root causes were deeply identified. Consequently, the appropriate lean alternatives were proposed to eliminate the wastes. The successful implementation of lean tools following DMAIC cycle in this study would provide the positive change in improving culture of the company. In addition, it also shows the effective solutions for drink industrial companies to enhance their operations, so they could follow to improve their similar systems. This research would extend as well as enhance the contribution to the application of lean technology in industry.

Compliance with ethical standards

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Disclosure of conflict of interest

No potential conflict of interest was reported by authors.

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