Controlling of pasteurized milk production using SPC and TRIZ

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Abstract. Pasteurized milk has high nutrition, but it is perishable. Production controls are vital to secure nutrition, safety, and consumer satisfaction. This research supports the determination of protection during pasteurized milk production and provides appropriate repair approvals. The statistical process control (SPC) method determines the number of defects and their dominant causes and the Theory of Resheniya Izobretatelskikh Zadatch (TRIZ) approach to discuss appropriate solutions. The results showed that 92.5% of product defects consisted of inappropriate volumes of the cup. There are no sensors on the filling machine, incorrect tap and timer setting, inadequate lighting in the production room, and less conscientious labour. The TRIZ method can recognize the contradictions of proposed improvements in greater detail, namely an automatic level control system and improved lighting to control the production.

1. Introduction

Improving public health needs nutritious food intake. Milk is a highly nutritious food, but it is perishable. Company X produces pasteurized milk by heating 72-92°C for 15-20 seconds to remove pathogenic bacteria. Dairy is packed in plastic cups and plastic bottles with a variety of chocolate, durian, melon, mocha, and strawberry flavours. During production, defective products are controlled.

Production control can use the statistical process control (SPC) method. SPC can control production and damage [1]. SPC has seven tools, including check sheets, histograms, control diagrams, Pareto diagrams, cause, and effect diagrams, scatter diagrams, and process diagrams [2]. Application of SPC to improve food quality became more popular, such as SPC for FDA regulation [3], apple juice [4], wheat flour packaging [5], frozen fish vacuum packaging [6], and integrated SPC with hazard analysis and a critical control point (HACCP) [7]. To get innovative repair solutions could use Reshiya Izobretatelskichh Zadatch (TRIZ) theory to solve problems by eliminating contradictions on innovative solutions [8]. TRIZ is determining the specific issue from the technical response. Then, it defines the general problem of technical inconsistencies that can be solved by contradiction matrices and inventive principles 40. The last get a specific solution from alternative solutions [9]. TRIZ is superior to other methods for resolving the most challenging problems but cannot cause and search directions. TRIZ has proven effective and efficient in solving technical issues [10]. The purpose of this study was to determine
defective products in pasteurized milk production by the SPC, identify the causative factors, and provide improved support according to the TRIZ method's principles.

2. Materials and Methods
The research was conducted at X Company by observing the packaging process of pasteurized milk for 26 days. Observation data were analyzed using SPC and TRIZ, especially for a defective product each day to find out the causative factors and provide improvement in production.

2.1. Statistical process control (SPC) method
Determination of defective products was carried out using SPC methods as follows; firstly, defective product identification in the packaging process. Secondly, evaluating the primary cause of the defective product using the Pareto diagram. The result was then analyzed using a control chart, both qualitative and quantitative data. Lastly, analyzed the main problems using a cause-effect diagram. Before the cause-effect diagram, the production was calculated with process capability. The production capability was carried out using yield measures with equation (1).

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yield = 100\% - \left( \frac{\text{Total Defect}}{\text{Total Inspection}} \times 100\% \right)
\]  

(1)

2.2. The methodology of Teoriya Resheniya Izobretatelskikh Zadatch (TRIZ)
The main problem that has been identified using the cause-effect diagram was then modelled using TRIZ parameters. TRIZ analysis was carried out using the contradiction of the 39 x 39 matrix. The intersection of the matrix was analyzed to find out the specific solution using four separation principles (separation in space, time, the whole and its parts, and condition) in each type of problem are recorded in the TRIZ parameter matrix or generic solution. According to [11], inventive principles for developing the best solution appear at least twice.

3. Results and Discussions

3.1. Statistical process control (SPC) method
3.1.1. Identification of defectives products
In the pasteurized milk production in the company is three types of damage. The plastic cup is leaking because the plastic cup body is broken or the plastic cup's shape and the pressure are not appropriate. The seal failed because the seal was detached or perforated. If the temperature is too hot, then the lid is melted or hollow, and if the temperature is too low, the cover does not stick to the plastic cup. Volume is not appropriate (more or less) due to improper adjustment of milk flow taps and timer controls.

3.1.2. Pareto diagram analysis
Retrieval of attribute data, i.e., leaked plastic cup and seal, failed from the entire production per day for 26 days. Variable data, i.e., incompatible volumes, were taken five observations per day for 26 days. Based on the Pareto diagram in Figure 1. (a), there are three types of defects: broken plastic cup, failed seals, and incorrect volume. Volume is not appropriate is 13930 or 92.5% packs; the plastic cup leaked 947 cup packs or 6.3%; the seal failed 185 cup packs or 1.2%. The incorrect volume (variable) is very high compared to the leaking plastic cup and failed seals. Incorrect volume due to plastic cup closure is handled manually, which depends on the accuracy of the workers. Paper conducted by [12] also found overweight in Serbian food packaging. The incorrect volume continues to be sold, while the plastic cup is leaking, and the seal fails (attribute) is reworked. Seal strength is influenced by sealing temperature, time, and pressure. If the sealing temperature was inaccurate, then seal strength decreases [13].
3.1.3. Control chart calculation and analysis

The packaging volume specification is 220 ± 5 ml. Figure 1b shows the average (\(\bar{X}\)) volume was 222.57 ml, the highest was 226.00 ml on the fifth day, and the lowest was 216.80 ml on the 12th day. The volume filling was not yet stable. The R chart shows that the average range is 10 ml with Upper Control Limit (UCL) 21.4 ml, and Lower Control Limit (LCL) 0 ml. Retrieval of attribute data, i.e., leaked plastic cup and seal, failed from the entire amount of production per day for 26 days. Variable data, i.e., incompatible volumes, were taken five observations per day for 26 days.

From the P-Chart (Figure 2a) is known that UCL is 0.02455; \(\bar{P}\) 0.01696; and LCL 0.00936. There are 3 points outside the control limit, namely the second day with a damaged proportion of 0.00913, the fourth day of 0.02679, and the eighth day of 0.03704 outside the upper control limit. Furthermore, the control chart with data out of control was revised. The revised P control chart (Figure 2b) has removed data outside of UCL and LCL, then recalculated the UCL value is 0.02364; \(\bar{P}\) 0.01621; and LCL 0.00878. All points are within the control limits, but the trend is erratic, so it is necessary to look for the cause and correct it. Incorrect volume is because of packaging manually. Research conducted by [12] also found overweight in dairy packaging.
3.1.4. Process capability calculation and analysis
Cp is the comparison of product output with design specifications [14].

![Process Capability Chart](image)

Figure 3. Process capability.

Cp analysis (Figure 3) shows the average sample size is 222.5692 ml. In the short term (potential within capability), the C index is used, and the long time (overall capability) index P. A CPL value of 0.59 < 1 indicates the process is unable to meet the lower specification limit (LSL). The CPU of 0.19 < 1 shows the process cannot meet the upper specification limit (USL). Cp of 0.39 is less than 1, the process capability is low, so it needs to be improved performance. A Cpk value of 0.19 between 0 and 1 indicates the standard process within the specification limits, but some parts of the process variations are outside the specification limits. According to [15], the Cp index is used in conjunction with the Cpk performance index to explain the closeness of the current process average value to one of USL or LSL.

According to [16], the determination of process capability values for samples with attribute data is seen from the % final yield of the process. Yield measures indicate the effectiveness of a process producing defect-free products. Calculation of final yield by Equation 1, before improvement: is 98.30437% and after improvement is 98.37908%. According to [17], a process is said good if the final yield is > 69.1463% for accurate 6-sigma process in Indonesia, > 99.3790% for USA standards, and > 99.99966% for international standards. The packaging process at the company is suitable based on Indonesian standards.

3.1.5. Cause and effect analysis
Factors causing volume mismatch is followed:

a. Labor. Workers must be skilled and thorough in producing quality products. Workers need regular training and briefings related to production plans per day. Supervision of workers regulating milk flow taps and filling machine panels is required.

b. Methods. The filling and packaging method is considered not standard, so it needs SOP or work instructions. During the study, SOP in the company started from acceptance to cooling. The company needs to add SOP for packaging and storage. The method for estimating taps for milk flow needs to be replaced more precisely.

c. Machine. Inaccurate filling volume because of the main engine. The addition of load cell level sensors under the engine conveyor is expected to maintain volume accuracy—pressure filling machine based on the old filling time. For higher volume accuracy, we can use Programmable Logic Control (PLC).

d. Environment. The filling and packing room is less light. The 8x5 m2 filling and packaging room is installed with four neon lights @ 20 watts. Non-standard light causes tired eyes. According to [18],
the maximum light power of office space or industry is 20 watts/ m². The comfort of the work environment increases productivity.

3.2. The methodology of TRIZ

3.2.1. Problem identification and modelling

Factors that influence volume inaccuracy based on cause-effect diagrams identified specific problems using the TRIZ method: (a) The labour is less thorough and supervisory supervision. (b) The machine has no level sensor components, and the flow taps and timer settings are incompatible. (c) There is no completed SOP and work instructions in the filling section. (d) The lighting in the production room is dim. Paper written by [19] has identified several factors that cause worker packing defects.

Furthermore, the parameters determined are fixed but cause other problems (improve features) and parameters that become worse when the problem is solved (worsening feature) as a generic problem. The problem of volume mismatch in companies is modelled in Table 1.

### Table 1. Modelling problems.

| No | Specific Problem                                                                 | Generic Problem                  |
|----|----------------------------------------------------------------------------------|----------------------------------|
|    |                                                                                  | Improvement Feature              |
| 1. | Accuracy of labour                                                               | 21 (Power)                       |
| 2. | There is no SOP                                                                  | 32 (Ease of manufacturing)       |
| 3. | There is no sensor                                                               | 38 (Extent of automation)        |
| 4. | The faucet & timer settings are wrong                                            | 28 (Measurement accuracy)         |
| 5. | Dim lighting                                                                     | 18 (Illumination intensity)       |

Five factors are impacting the quality of the product. Firstly, the accuracy of labour. The less careful workers need supervisors to coordinate and supervise production related to parameter number 21 (power as improving features). The accuracy of the labour under pressure is related to parameter number 11 (pressure). Secondly, there is no SOP. Production has not been standardized, and the results will be out of specification. Therefore, according to parameter number 32 (ease of manufacturing as improving features), it is necessary to implement the production SOP. SOPs' impact is sometimes ignored by employees related to parameter number 27 (reliability as a worsening feature).

Thirdly, there is no sensor on the filling machine. Volume accuracy was difficult to maintain if the machine does not have a level sensor. The level sensor's addition can weigh the specifications according to parameter number 38 (the extent of automation as the improving feature). The weighing feature is the difficulty of monitoring related to parameter number 37, called the problem of detecting. Fourthly, incorrect tap, and timer setting. Manual adjustment by sliding the tap based on estimates causes the inappropriate volume. The automation of volume control machines related to parameter 28, called measurement accuracy an improving feature. The effect is an increase in the settings' complexity with parameter number 36, namely device complexity, as a worsening feature. Lastly, inadequate lighting in the production room shows that light needs to be brighter so that the work environment is comfortable as parameter number 18, Illumination intensity. The characteristic feature is the increase in costs related to parameter 26, which is the quantity of substance.

3.2.2. TRIZ contradiction analysis results

In TRIZ, simultaneous problems are called contradictions. The existence of contradictions helps solve issues with an innovative solution. A contradictions matrix of the inaccurate volume is shown in Table 2. Table 2 shows 16 general solutions to the crossing of 5 contradictions. The principle numbers of the contradiction matrix are 1, 10, 12, 18, 19, 22, 25, 27, 34, and 35. The minimum number out twice is principle number 1 segmentation, 10 preliminary actions, 27 cheap short-living objects, 34 discarding and recovering, and 35 parameter changes. These are discussed further.
Table 2. The contradiction of TRIZ technical parameters.

| No. | Parameter Contradiction                                      | Generic Solution |
|-----|-------------------------------------------------------------|------------------|
| 1.  | 21 (Power) x 11 (Pressure)                                 | 17, 14, 35       |
| 2.  | 32 (Ease of manufacture) X 27 (Reliability)                | 1, 35, 21, 12    |
| 3.  | 38 (Extent of automation) X 37 (Difficulty of detecting)  | 34, 27, 25       |
| 4.  | 28 (Measurement accuracy) X 36 (Device complexity)         | 27, 35, 14, 34   |
| 5.  | 18 (Illumination intensity) X 22 (Quantity of substance)   | 1, 11            |

3.2.3. Elimination and selection of the specific solution

According to [20], the inventive principle is obtained from improving features and worsening features to develop solutions. The principle is based on the sub-principles of each principle to the proposed solution.

1. Principle 1 Segmentation

The principle of segmentation has three sub principles. Sub-principle is to overcome SOP, which is "dividing objects into separate parts." Companies need to make and publish separate SOP and work instructions for filing and storing. Important work instructions to support worker performance. Work instructions can revitalize human-machine relationships [21]. SOP are documented, and work instructions are posted in the production room. The proposed improvement uses principle b, namely "Making objects or systems that easily dismantled (modular)." Sub principle b is to overcome the dim light in the production room. Add modular LED lights to areas that need a lot of light, such as for filling and packaging machines. The LED are used in the indoor industry to be extended to lighting and energy-saving [22].

2. Principle 10 Preliminary action

This principle can be implemented in the wrong setting of the tap and timer volume. This solution is under the sub-principle of principle 10, "take action before it is necessary to change an object or system (either full or partial)". Adjusting the volume of the filling machine by manually shifting the tap based on estimates. It is necessary to experiment with opening the milk flow tap and timer panel right before the production process. Sub principle b, namely "the initial arrangement of objects so that they can work in the most comfortable places and without losing a time of delivery," is the solution to the problem of labour rigour. Supervisors brief so that workers are more thorough before production. Briefing regarding daily targets and machine settings to produce products according to specifications. Briefing or training is urgent to workers. The training gives the worker the experience and skills to do something rather than just knowledge about their job [23].

3. Principle 27 Cheap short-living object

The development of solutions with this principle is applied to the problem of no censorship. The company should add a load cell type sensor. Because the largest volume is 220 mL, the company can use a load cell with 2 kg and affordable prices. The problem of setting the tap and timer is not right. The company can replace the timer system with an automatic control system type Programmable Logic Controller (PLC). PLCs are connected to load cell level sensors to convert and store weight readings from load cell sensors. According to [24], the price of a PLC is lower than the cost of several relays capable of wiring the same amount of a PLC.

4. Principle 34 Discarding and Recovering

This principle is the solution for setting the tap and timer. Under sub-principle, namely, "Eliminating the portion of an object that has fulfilled its function." The timer on the filling and packaging machine can be replaced by the PLC control system to achieve volume accuracy. PLCs include relays, timers, counters, sequencers, and various other functions [24].
5. Principle 35 Changes Parameters
This principle is a solution to the problem of labour precision. There are no sensors, taps and timers are not right. Sub principle b is "change concentration and consistency" into a solution to improve workforce accuracy. Enhanced environmental comfort so that labour concentration increases. Supervision needs to be done. The problem is there is no SOP, and the tap and timer settings are not adequate according to sub principle, which is "change characteristics or techniques." The company needs to add complete SOP and work instructions to filling. According to [25], to get higher accuracy using weight variations, the choice of a weight sensor, weight calculation mechanism, and valve work accuracy must be well designed. The tap needs to be replaced periodically. Complicated reading difficulties are overcome by connecting the load cell level sensor with the PLC control system instead of the mechanical timer panel control system.

4. Conclusions
The defects in pasteurized milk packaging at the company were 92.5% inappropriate volume; the plastic cup leaked 6.3%, and the seal failed 1.2%. Process capability is 0.39000 for a control chart $\bar{X}$ And R for filling and 98.38% Yield or equivalent 3.7 level Sigma for P-control chart. Inaccurate packaging volume of the plastic cup is caused by labour less thorough, there is no SOP in the filling, there is no level sensor in the filling and packaging machine, the faucet and timer settings are not right, and the light is dim. Based on the TRIZ method, fixing the problem of volume mismatch is principle 1 (segmentation), 10 (preliminary action), 27 (Cheap short-living object), 34 (discarding and recovering), and 35 (parameter changes). The company needs to update the SOP documents and work instructions, including the standard values of each machine-setting panel. The company can add sensors to the filling and packaging machines connected by a PLC control system, thereby increasing the accuracy of the filling volume.

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