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TEMPERATURE AND MACHINE SPEED SETTINGS TO REDUCE DEFECTS PRODUCTS IN THE GLASS BOTTLE WASHING PROCESS

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ABSTRACT

Surabraja food trading company produces chili sauce and soy sauce. In July 2019, this company suffered a loss due to the number of broken bottles in the bottle washing process amounting to IDR 29,597,400. This study will identify the causes of defects using the six sigma method. Based on the define, measure, and analyze stages, it was found that the main causes of broken bottle defects were the temperature setting that was too hot and the engine speed that was not optimal. The repair process uses the taguchi experiment by determining the temperature and speed settings. The results of the Taguchi experiment showed that the best selected setting dosage formulations and their levels were A_1 and AB_2 where A_1 (temperature 140°C), and AB_2 (speed 10,000 bph). Based on a confirmation experiment with a temperature setting of 140°C, and a speed setting of 10,000 bpd, it was carried out using 48,000 bottles with 5 experiments, and a defect of 505 bottles was obtained. The results of the study concluded that the best results, namely at a temperature of 140°C and a speed of 10,000 bpd, can reduce the defect rate from 780 bottles to 505 bottles per day, and the value of the company's losses from IDR 466,429, - to IDR 301,900, -.

INTRODUCTION

Surabraja food trading company is a private company engaged in the food industry in Cirebon. Its superior products are chili sauce and soy sauce. One of the important components in chili sauce and soy sauce products is a glass bottle. This glass bottle serves as a container or packaging for sauce, soy sauce and syrup products. Glass bottles used by Surabraja food trading company is a 625 ml glass bottle. The bottles used so far are new bottles and used bottles from consumers. The new bottles are clean and flawless, while used consumer bottles have dirt, brand labels, soy sauce or sauce residue and other impurities so it is necessary to wash the used bottles.

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The CTQ (Critical to Quality) quality character on the sauce and soy sauce packaging bottles is cleanliness and no defects. Based on an interview with the head of the bottle washing division, the company suffered losses due to broken bottles in the used bottle washing process. The company suffers monthly losses due to the bottle washing process. This is evidenced from the data obtained in July 2019 which resulted in a loss of IDR 6,182,124.00 (number of defects multiplied by the price of the bottle). The following in table 1 is the data of the defect.

Table 1. Data on the number of bottle defects in July 2019 (total wash=1,431,168)

No.	Type Defect	Amount (Unit)	Percentage
1	Broken Bottle	10,206	0,713 %
2	Cracked Bottle	119	0,008 %
3	Gompal Bottle	13	0,001 %
	Total	10,338	

Therefore, this study identifies the causes of broken defects in the washing process of used bottles and how to overcome them using the six sigma method. The use of the Six sigma method is because the statistical-based quality improvement method is carried out comprehensively by eliminating the main source of the problem with the Define-Measure-Analyze-Improve approach (Lertwattanapongchai & Swierczek, 2014).

RESEARCH METHOD

A. Six Sigma

According to Hanum et al. (2020), six sigma is a comprehensive approach in solving problems and improving the process through DMAIC (Define, Measure, Analyze, Improve, Control). This research will not discuss about Control. Define is a step to identify problems in an ongoing process (Cherrafi et al, 2017). This stage is the first step in the Six Sigma quality improvement program by identifying the number of reject products and the types of rejects that occur. Once known, then determine the quality character or called CTQ (Critical to Quality) which is used to describe customer needs. According Khari (2016), measure is looking at how well you are meeting customer requirement. Measurement of the sigma performance with the aim of knowing the current level of employment. Baseline performance as a unit of measurement in defects per million opportunities (DPMO) or sigma capability level. The calculation phase starts from the DPO, DPMO and Sigma Value. Defect Per Opportunities (DPO) is a failure measure that is calculated in the Six Sigma quality improvement program which shows the number of defects or failures one opportunity.

$$DPMO = \frac{\text{number of defects x 1.000.000}}{\text{Number of Defect Opportunity} \times \text{ number of unit}} \tag{1}$$

Analyze based on the root of the problem which causes sigma performance in the process to decrease. In addition, listing all the factors that have an effect (significant few opportunities) on the quality to be improved, then select a few factors that are considered the most influential. (Tenera & Pinto, 2014). One of the analysis tools is Failure Mode and Effect Analysis (FMEA is a set of guidelines, processes and formats for identifying and prioritizing critical problems (failures). According Pardiyono (2020) FMEA consists of the severity, occurrence and detection value of each cause of defect starting from 1 to 10. Next calculates the RPN (Risk Priority Number) to determine the causes of critical defects that have the greatest priority for corrective action. The ranking stages of severity, occurrence and detection assessment are carried out by brainstorming and giving questionnaires to the head of the bottle washing division and the operator of the bottle washing machine.

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B. The Taguchi Experiment

According to Sivasakthivel (2014) Taguchi experiment is to find the best level for each operating parameter so as to maximize. Off-line quality control is carried out at the beginning of the product life cycle, namely improvements to the beginning to produce the product (to get right first time). The steps in the taguchi experiment are:

1. Variable Identification
   According to Pyzdek & Keller (2014) dependent variables are variables whose changes depend on other variables. The dependent variable of this study is the successful group and the disabled group. Independent variables are variables whose changes are not dependent on other variables. The independent variables in this study are the temperature and engine speed settings.

2. Identification of Control Factors and Noise
   Control factors are factors whose values can be set or controlled, or factors whose values we want to set or control. Meanwhile, noise factors are factors whose values we cannot control or control, or factors that we do not wish to regulate or control. The factors that can be controlled are temperature and speed settings (Pyzdek & Keller, 2014)

3. Determination of Total Levels and Factor
   Values The determination of the number of factor levels is very important to the results of the study. The more factor levels are used, the more accurate the experimental results will be, but this method will incur large costs and a long time. The input of determining the factor level value is the predetermined control factor.

4. Determination of Degrees of Freedom
   According to Iswanto et al. (2013) The calculation of degrees of freedom is carried out to calculate the minimum number of experiments that must be carried out to investigate the observed factors. If nA and nB are the number of treatments for factors A and B, then
   dk factor A = nA -1 (2)
   dk factor B = nB – 1 (3)
   dk interaction factor A and B = (nA-1)(nB-1) (4)
   Total dk = (nA-1)+(nB-1)+(nA-1)(nB-1) (5)

5. Determination of the Orthogonal Array
   An orthogonal matrix is a matrix in which the elements are arranged according to the minute and column. The column contains the factors that can be changed in the experiment, while the dripping contains the level combination of the factors in the experiment. To determine an appropriate orthogonal matrix, one must pay attention to the number of factors, the number of levels and the number of observations made (Iswanto, et al. 2013).

6. Implementation of Experiments
   Experiments were carried out by setting the factor at a predetermined level with the selected orthogonal array (Khan, 2014). From this experiment, the best factor setting will be produced. Before conducting an experiment, it is necessary to determine the number of replications (repeated trials for 1 trial) and randomization. Replication is related to the accuracy of the results of the experiments and the randomization of the trial sequences. According to Yakub et al. (2016) the ANOVA (Analysis of variance) method is a statistical analysis method that is included in the inference statistics branch which is to determine the magnitude of the contribution of each factor to the response in

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the experiment. According Raphael et al. (2014) The steps for calculating ANOVA for attribute data can be seen in the sequence as follows:

a. Calculate the total cumulative frequency for each class
b. Calculate the weight of each class
c. Calculate the total sum of squares
d. Calculate the total degrees of freedom
e. Calculate the sum of square based on the average
f. Calculate the sum of square for each factor
g. Calculate the degrees of freedom for each factor
   - Calculate the degrees of freedom for a factor
   - Count the number of degrees of freedom of error
h. Count the mean square of each factor
i. Calculate the F-ratio of each factor
j. Calculate the percentage contribution of each factor
k. Pooling Up Strategy
   Pooling Up aims to avoid over-estimation and also avoid mistakes in the experiment. Pooling up is done on the factors that have the smallest variance of Sq factor compared to Mq error. The first of pooling up is to combine the value of Sq_{factor} an insignificant (Sq_{factor} < Sq_{error}). F-Ratio Test The results of the analysis of variance did not prove any differences in treatment and the influence of factors in the experiment. The F hypothesis test is done by comparing the variance caused by each factor with the variance of the error. The factor selection is made based on the value of the comparison between the F-ratio and the F-table. If the F-count value ≥ F-table, then the factor is declared to have an effect on the response, and it is the chosen factor.

1. Calculation of the signal to noise ratio (SNR) value
   The calculation of the signal to noise ratio (SNR) value aims to determine which factors affect the variance value in this experiment (Wang, 2018). The SNR used in this study is the francion defective SNR or the so-called omega transformation because the observed quality characteristics are the percentage of defects. The following is the SNR value calculation.
   - Calculate the SNR value
   - The mean percentage of defects in the Taguchi experiment results

   The interpretation was carried out by calculating the percentage contribution and the calculation of the factor confidence interval for the treatment conditions at the time of the experiment. According to Davis & John (2018), the steps for calculating the best estimate of conditions and the confidence interval for attribute data can be seen in the sequence as follows:
   - Calculate a confident interval
   - Confidence interval
   - Compute the confidence interval for the confirmation experiment

   Then the confidence interval for the confirmation process is:

$$\mu \text{ confirmation } - CI \leq \mu \text{ confirmation } \leq \mu \text{ confirmation } + CI \quad (2)$$

RESULTS AND DISCUSSION

A. Define

Define stages, namely Surabraja food trading company has several departments, one of which is the bottle washing department. Bottle washing is done using an automatic glass bottle washer (AGBW) machine with a capacity of 8,000-10,000 bottles / hour. The steps to pay for bottles use an automatic glass bottle washer (AGBW) machine, namely, the process of lowering dirty bottles from the truck to the bottle opening, then opening the improvised bottle caps by initial spraying. After that, the initial visual sorting is done to see the defective bottles after going through the previous process. The defective bottles will be discarded and the ones suitable

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for the second sorting process. This second sorting process aims to make sure the bottles fit into the machine or not. Bottles that are too dirty will be taken by the labor force for manual washing.

The process of washing bottles on an automatic glass bottle washer (AGBW) machine by setting the temperature, speed, and immersion air temperature. For temperature regulation, the operator only uses intuition, which is around 130° -150°C, this machine temperature setting serves to optimize engine performance, in addition to the hot temperature which serves to maintain the quality of the bottle material. The maximum speed setting is 10,000 bpd. The last rinse process is carried out manually, then the third-final sorting process to ensure the bottles are not defective and the packaging of the bottles are ready for shipment to the factory.

In July 2019, the number of bottles washed was 1,431,168 bottles, from the washing results there were 10,338 defects, with details of 10,206 broken bottles, 119 cracked bottles, and 13 bottles of chipped bottles. Based on these data, the most types of defects were broken bottles, totaling 10,206 units or 98.70% of the total defective products during July 2019. Defective products from broken bottles resulted in the product not being able to function according to specifications and included in defects, namely permanent defects that cause bottle cannot be used. In addition, a broken bottle defect caused a loss in July 2019 for the company of IDR 6,103,188. (IDR 598 x 10,206 bottles).

B. Measure

According to Pardiyono & Indrayani (2020), the measure stage is the measurement stage to test the defect standard by performing the six sigma stage by calculating the DPO, DPMO and Sigma values. The number of defective bottles was 10,338 bottles from 1,431,168 bottles with one chance of defect in the bottle washing machine process. Based on the results of the DPMO calculation according to equation (1) with a number of defect opportunity worth 3, then the DPMO number shows a value of 2407.82 with a sigma value of 3.95. The sigma value is included in the fairly good category value, but the company still expects minimal defects or the sigma achievement target of 4.00 so that the resulting losses will also decrease.

C. Analysis

The analytical tool that can be used in accordance with the six sigma method is FMEA (Failure Mode And Effect Analysis). FMEA data obtained from the results of distributing questionnaires to the head of the bottle washing division and bottle washing machine operators. The biggest RPN value in the type of broken bottle failure is the error in setting the temperature and speed in the bottle washer so that the temperature and speed of the machine are less precise. This is because the best temperature and speed have not been determined during the bottle washing process. So far, operators in determining engine temperature and speed are based on intuition only. The results of FMEA processing are presented in table 2 below.

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Table 2. Result of Failure Mode and Effect Analysis

Type of Failure	Source of Failure	Cause	RPN	Recommendation
Broken Bottle	The temperature setting when tuning the machine causes the bottle not to be able to withstand a temperature that is too hot..	Temperature setting	512	Determine the right temperature for the bottle washer
Broken Bottle	Too much quantity of bottles causes friction between bottles, this results in cracks in the bottles during the washing process	Speed setting	512	Determine the best speed in the bottle washing process
Broken Bottle	Operators are less skilled in operating the machine and less careful in positioning the bottles when they enter the bottle washer	The operator lacks training	192	Conduct periodic training by providing materials and hands-on practice
Broken Bottle	Old bottle material expands easily, bottles cannot withstand temperatures that are too hot so they break	Old bottles	224	Check the service life of the bottle
Broken Bottle	Not heating the engine first results in the engine not working optimally	Machine set-up	384	Adjusting the bottle washing machine according to the applicable SOP, namely heating the machine first

D. Improve

The identification of variables that affect the bottle washing process is temperature and speed settings. Based on the engine manual book, the allowable temperature setting is between 120°C to 150°C with speeds between 8,000 to 10,000 bpd. The selected factors obtained based on interviews with the head of the bottle washing division obtained for level I are a temperature of 1400°C and a speed of 9000 bpd, for level II are a temperature of 1450°C and a speed of 10000 bpd. Determination of the degrees of freedom for factor A (temperature) and factor B (speed) is presented in table 3 below.

Table 3. Degrees of freedom

Number Dof Factor (A, B, (AxB),)			
1. Factor A	= n_{A-1}	= 2-1	= 1
2. Factor B	= n_{B-1}	= 2-1	= 1
3. Factor AxB	= $n_{(A-1)X(B-1)}$	= (2-1)x(2-1)	= 1
Number Degrees of Freedom		= 3	

Experiments in actual conditions are the temperature and speed settings used by machine operators so far. Experiment with actual conditions with a temperature setting factor of 150°C, speed of 10000 bpd and carried out one hour per one experiment for 5 (five) days. The actual experimental results data is presented in table 4 below. The calculation of the company's loss value is by multiplying the purchase price of a new bottle multiplied by the number of defects.

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Table 4. Actual conditions and losses experiment

Trial	Clean Bottle	Defective Bottle	Number of Bottle Washes	New Bottle Price	Loss
1	9,432	168	9,600	IDR 598,-	IDR 100,462,-
2	9,648	192	9,840	IDR 598,-	IDR 114,813,-
3	9,192	168	9,360	IDR 598,-	IDR 100,462,-
4	9,420	132	9,552	IDR 598,-	IDR 78,934,-
5	9,576	120	9,696	IDR 598,-	IDR 71,758,-
Total	47,268	780	48,048		IDR 466,429,-

From the calculation of table 4, the total loss incurred by the company is IDR 466,429, - under observation for 5 (five) days. In the Taguchi experiment, experiments were carried out 4 times with replicas 3 times in each experiment. This is done using the orthogonal matrix table $L_4(2^3)$. The experimental results using the taguchi setting on the orthogonal array level I are 140°C temperature and 9000 bpd speed, while in level II the temperature is 145°C and the speed is 10000 bpd. The results of the taguchi experiment are presented in table 5.

Table 5. Result Taguchi experiment

Trial	Setting Factor	Replication	Result	
			Good	Defects
1	Temperature 140° (1) Speed 9000 (1)	1	9,608	112
		2	9,457	143
		3	9,352	128
		Total	**28,417**	**383**
2	Temperature 140° (1) Speed 10.000 (2)	1	9,486	114
		2	9,480	120
		3	9,466	134
		Total	**28,432**	**368**
3	Temperature 145° (2) Speed 9000 (1)	1	9,566	154
		2	9,298	134
		3	9,479	169
		Total	**28,343**	**457**
4	Temperature 145° (2) Speed 10.000 (2)	1	9,441	159
		2	9,428	172
		3	9,404	196
		Total	**28,273**	**527**

The ANOVA stage aims to determine the size of the contribution of each factor to the response in this experiment. Based on the results of the calculation of the ANOVA stage, it can be concluded in table 6 below.

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Table 6. Recapitulation of calculations ANOVA

Factor	Sq	V	Mq	F-Ratio	Rho (%)
A	4524.10	1	4524.10	18	1.75
B	252.10	1	252.10	1	0.10
AB	602.10	1	602.10	24	0.23
error	2012.67	8	251.58		0.78

The factor selection is made based on the comparison value of the F-ratio calculated with the F-table. If the F-count value ≥ F-table, then the factor is declared to have an effect on the response, and it is the chosen factor. The F-table value is obtained from the F table with a 95% confidence level. The value of F(0.05; 1; 8) is 5.32.

In table 6, it can be seen that there is no Mq factor value that is smaller than the Mq error value, meaning that the factor is significant so there is no need to calculate the pooling up strategy. After knowing the results of ANOVA calculations and the factors that affect bottle breakage defects in the bottle washing process, a confirmation experiment is then carried out to ensure that the experiment has been successful or not. The selected factor hypothesis is presented in table 7 below

Table 7. Selected factor hypothesis

No	Hypothesis	Value F	F(0,05;1;8)	Result Hypothesis	Conclusion
1	H_0 : There is no factor influence A H_1 : there is a factor influence A	18	5.32	H_0 Reject	there is a factor influence A
2	H_0 : There is no factor influence B H_1 : there is a factor influence B	1	5.32	H_0 Received	There is no factor influence B
3	H_0 : There is no factor influence AB H_1 : there is a factor influence AB	24	5.32	H_0 Reject	there is a factor influence AxB

From the results of the hypothesis in table 6, the factors that influence the glass bottle washing experiment are factors A and AB or the factors of temperature and speed. To find out the response of each factor, the average response factor is calculated to determine which level is the best. Based on the smallest average response, the selected factors are A and AB. Based on the calculation of parameter settings, the selected factor for the taguchi parameter setting in this experiment is A_1, namely the temperature setting factor with a temperature of 140° C and AxB_2, which is a speed setting factor of 10000 bph.

E. Calculation of Signal to Noise Ratio (SNR)

Value The calculation of signal to noise ratio (SNR) using smaller the better aims to determine which factors affect the variance value in this experiment. Table 8 below is the calculation of the SNR value.

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Table 8. Orthogonal matrix with SNR value

Orthogonal Matrix L_4 (2^3)										
Experiment	1	2	3	Replication			Frequency		ŷ	S/N
	A	B	AxB	1	2	3	Good (I)	Reject (II)		
1	1	1	1	112	143	128	28.417	383	127,67	-42,16
2	1	2	2	114	120	134	28.432	368	122,67	-41,79
3	2	1	2	154	134	169	28.343	457	152,33	-43,69
4	2	2	1	159	172	196	28.273	527	175,67	-44,93
Total							113.465	1735	578,33	-172,58

F. Best Condition Prediction and Confidence

Interval Based on the ANOVA for attribute data, the factors that influence and have the greatest contribution to reducing the disability group are factors A_1 and AxB_2. A recapitulation of SNR responses is presented in table 9 below.

Table 9. SNR response

	A	B	AxB
Level 1	-41,98	-42,93	-43,55
Level 2	-44,31	-43,36	-42,74
Difference	2,33	0,43	0,80
Ranking	1	3	2

G. Best Condition Prediction and Confidence

Interval Based on the ANOVA for attribute data, the factors that influence and have the greatest contribution to reducing the disability group are factors A_1 and AxB_2. The following is a calculation of the approximate best conditions and the confidence interval.

- Best conditions forecast

Transformation of defect percentage

$\mu = A_1 + AxB_2 - 2 \text{ X } \hat{y}$

$\mu = 125.2 + 137.5 - 2 \text{ X } 144.58$

$\mu =$ -26.46

$$n_{eff} = \frac{Total\ number\ replica\ of\ the\ experiment}{1+vA+vB+vAB} = \frac{4\ x\ 3}{4} = 3$$

$$CI = \sqrt{\frac{(F_{0,05;1;8})\ x\ Mq}{ne}} = \sqrt{\frac{5.32(251.58)}{3}} = \pm 21{,}12 =$$

Then the confidence interval for the best process is:

$$\mu\ predictions - CI \leq \mu\ predictions \leq \mu\ predictions + CI$$

$$-26.46 - 21.12 \leq \mu\ predictions \leq -26.46 + 21.12$$

$$-47.58 \leq \mu\ predictions \leq -5.34$$

- Estimated response and confidence interval for SNR

$\mu = A_1 + AxB_2 - 2 \text{ X } \eta$

$\mu = -41.98 - 42.74 - (2 \text{ X} - 43.15)$

$= -41.98 - 42.74 + 86.29$

$= 1.57$

$$n_{eff} = \frac{Total\ number\ of\ the\ experiment}{1+vA+vB+vAB} = \frac{4}{4} = 1$$

$$CI = \sqrt{\frac{(F_{0,05;1;8})\ x\ Mq}{neff}} = \sqrt{\frac{5.32(251.58)}{1}} = \pm 36.58$$

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Then the confidence interval for SNR is:

$$\mu\ predictions - CI \leq \mu\ predictions \leq \mu\ predictions + CI$$
$$1.57 - 36.58 \leq \mu\ predictions \leq 1.57 + 36.58$$
$$-35.01 \leq \mu\ predictions \leq 38.15$$

H. Confirmation Experiments

The confirmation experiment is the third experiment conducted to test the predicted value of the factor level setting at the best conditions. If the results of the confirmation experiment can test the predicted results, then the level setting for the best conditions can be concluded that it meets the requirements in the experiment. The level setting applied is A_1 temperature setting of 140°C and B_2 setting the speed of 10000bph. The following are the results of the confirmation experiment can be seen in table 9 below:

Table 9. Confirmation experiment results

Confirmation Experiment	Result	
	Reject	Good
1	103	9,497
2	114	9,486
3	96	9,504
4	92	9,508
5	100	9,500
Total	505	47,495

The calculation of the average value is as follows:

$$\mu = \frac{1}{n}\sum_{i-1}^{N} Y_i$$
$$\mu = \frac{1}{5}(103+114+96+92+100) = 101$$

The calculation of the variance value is as follows:

$$\sigma^2 = \frac{1}{n-1}\sum_{i-1}^{N}(y_i - \mu)^2$$
$$= \frac{1}{5-1}((103-101)^2+(114-101)^2 + (96-101)^2 + (92-101)^2 + (100-101)^2)$$
$$= 70$$

The SNR calculation for the results of the confirmatory experiment is as follows;

$$\text{SNR} = -10\ log_{10}\ [\ 47495]$$
$$= -46.77$$

With an average value of 101, the variance value of 70 and the SNR value of -46.77. The accepted assessment or the results of the confirmation experiment is carried out by comparing the confidence interval between the predicted response results at the best conditions and the confirmation experiment. With a confidence interval for the mean of the confirmatory experiment is 101-26.63≤ μ predictions ≤ 101 + 26.63, or 74.37≤ μ predictions ≤ 127.63.

The values of this confidence interval will be compared with the confidence interval for the best conditions, so the confidence interval for the confirmation experiment is 46.77-40.07≤ μ predicted ≤ 46.77 + 40.07, or 6.70≤ μ predicted ≤ 86.84.

I. Calculate the loss value of the confirmation experiment

The calculation of the company's loss value in the best setting conditions is by multiplying the purchase price of a new bottle multiplied by the number of defects as shown in table 10 below.

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Table 10. Company losses

Confirmation Experiment	Result		New bottle price	Loss
	Reject	Good		
1	103	9,497	IDR 598,-	IDR 61,594,-
2	114	9,486	IDR 598,-	IDR 68,172,-
3	96	9,504	IDR 598,-	IDR 57,408,-
4	92	9,508	IDR 598,-	IDR 55,016,-
5	100	9,500	IDR 598,-	IDR 59,800,-
Total	505	47,495	IDR 598,-	IDR 301,990,-

Comparison of experimental results in actual conditions with confirmation or proposed experiments can be seen in table 11 below.

Table 11. Comparison of initial and proposed conditions

	Actual Conditions	Proposed Conditions
Temperature setting	120°C - 150°C	140°C
Speed settings	8000 – 10000 bph	10000 bph
Loss	IDR 466,429,-	IDR 301,990,-

CONCLUSIONS

Based on the results of the research, it can be concluded that the best results are setting the temperature factor of 140 ° C and setting the speed of 10000 bpd which can reduce the defect rate from 780 bottles to 505 bottles per day, and the value of the company's losses from IDR 466,429 to IDR 301,900. -. In the future, further research is needed to overcome bottle defects that are caused by factors other than the bottle washing machine.

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