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Study on optimization of ready-to-drink (RTD) guava juice production process at PT. XYZ using lean six sigma application

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Abstract. Continuous improvement efforts have been carried out in various ways by the food industry, especially in the production process so that it can work optimally, effectively, efficiently, and without defects so that the quality of the products produced is appropriate to the standards that have been set. one method that can be used to achieve this is to use the concept of lean six sigma analysis. PT. XYZ is a food company engaged in the processing of soft drinks such as fruit juice drinks. One of the main types of products is RTD guava juice. The production process carried out by this company is still semi-automatic. This causes the duration of the process to be not optimal, as a result, there is an impact on fast-moving products, such as RTD guava juice. To overcome these problems, it is done using an improved method with the concept of lean six sigma. The purpose of this study is to examine the factors that influence the optimization of the production process of RTD guava juice at PT. XYZ uses the lean six-sigma method. The results of this study show that the value added is 64.89% and the sigma value is 3.973 with the location of the highest waste in the production process being a defect, waiting, inappropriate process, and unnecessary motion. The problems from the causes of non-optimal products are spilled, product leaks, and engine disturbances. It was found that the main factors of non-optimality are man, method, and machine.

1. Introduction

Fruits are a source of vitamins, especially vitamin C, which has health benefits. One type of fruit that is widely consumed and rich in vitamin C is guava (*Psidium guajava* L.). In addition, guava also contains B vitamins (riboflavin), several types of minerals, as well as flavonoid compounds, quercetin, guajavarin, gallic acid, leucocyanidin, and ellagic acid which have good health benefits, such as antioxidants [1]. Guava contains 74-87% water, 0.5-1.0% ash, 0.4-0.7% fat, 0.8-1.5% protein, and 5.6% dietary fiber [2]. Besides being consumed in whole and fresh form, many fruits have been processed into fruit juice drinks that are ready to be consumed or ready-to-drink (RTD) fruit juice products.

According to SNI 01-3719-1955, fruit juice is defined as a beverage made of puree and water with or without the addition of sugar and permitted food additives [3]. Currently, RTD fruit juice is one of the most widely consumed processed food products and has become a practical and healthy alternative drink. Consumption of RTD fruit juice always increases every year. Based on data reported by [4], fruit juice consumption has always increased from 2015 until 2020. In addition, based on internal data of PT. XYZ, fruit juice production in 2015 was 199890 L and 2020 was 209746 L.

The increasing demand for fruit juice beverages has caused many food industries to be interested in

producing RTD fruit juice, one of which is PT. XYZ. In addition to producing jams, syrups, and concentrates, the company's main product is RTD fruit juice with various flavors, one of which is RTD guava juice. RTD fruit juice production process at PT. XYZ is still using a semi-automatic system. Based on the preliminary research conducted, this causes the company to often experiences obstacles when carrying out the production process. In the end, this causes the productivity and efficiency of the production process to be not optimal. One of the problems that often occurs is the duration of the process that exceeds the upper limit of the overall duration [5]. Therefore, it is necessary to optimize the production process.

One way that can be done to optimize the production process is to analyze using a combination of lean thinking and six-sigma methods. Both of these methods will be very useful because they can map the location of the non-optimization as well as assess process performance and provide continuous improvement [6]. Six-sigma is a statistical concept that measures a process related to defects at the six-sigma level, which is only 3.4 defects out of a million opportunities. In practice, the use of six-sigma can determine unproductive processes, eliminate defects, and develop new technologies for quality improvement. The process of six-sigma has five cycles, namely DMAIC (Define, Measure, Analyze, Improve, Control) [7]. While lean thinking is a systematic concept used to eliminate or reduce waste in a production flow. The main purpose of lean is to increase activities that provide added value to consumers through an assessment of the value-added and waste ratio [6]. Based on the description above, the purpose of this study is to examine the factors that influence the optimization of the production process of RTD guava juice at PT. XYZ using the lean six-sigma method.

2. Methodology
To determine the performance of the production process and the factors that can optimize the production process, this research was carried out using a lean six-sigma approach with five stages, namely DMAIC (Define, Measure, Analyze, Improve, Control). However, the control will not include because of a limited duration of the study.

2.1. Define
The first stage will collect field data in the form of process duration, production total, repetition total, slack duration, and operator performance based on the Westinghouse method from 25 batch production. Through the data, it will process into time measure data for cycle time, standard time, and normal time. After identification value each stage of time, seven-waste questionnaires will be spread to employees and mapping of VALSAT (Value Stream Analysis Tool). Waste major and minor will be identified after all processes are done [6].

2.1.1. Westinghouse method
Cycle time will be obtained from field data. Normal time will obtain from multiplication between cycle time and performance assessment. Performance assessment has criteria from Westinghouse into skill, effort, condition, and consistency. The value of the assessment will know after the one-plus-criteria total [8].

2.1.2. Seven waste questionnaires
Waste will have seven categories, over production, defect, unnecessary inventory, inappropriate process, waiting, and unnecessary motion. All of the categories have assessments and criteria based on relevancy and journal [9].

Table 1. Standard of performance assessment / rating factor (Fr) [8]

SKILL			EFFORT			CONDITION			CONSISTENCY		
0.15	A1	Super Skill	0.13	A1	Super Skill	0.06	A1 / A2	Super Skill	0.04	A1 / A2	Super Skill
0.13	A2		0.12	A2							
0.11	B1	Excellent	0.10	B1	Excellent	0.04	B1 / B2	Excellent	0.03	B1 / B2	Excellent
0.08	B2		0.08	B2							
0.06	C1	Good	0.05	C1	Good	0.02	C1 / C2	Good	0.01	C1 / C2	Good
0.03	C2		0.02	C2							
0	D	Average	0	D	Average	0	D	Average	0	D	Average
-0.05	E1	Fair	-0.04	E1	Fair	-0.03	E1 / E2	Fair	-0.03	E1 / E2	Fair
-0.1	E2		-0.08	E2							
-0.16	F1	Poor	-0.12	F1	Poor	-0.07	F1 / F2	Poor	-0.07	F1 / F2	Poor
-0.22	F2		-0.17	F2							

Standard time will be obtained after normal time multiply with one-plus-allowance time. The allowance time will obtain from field data. Allowance will determine by personal needs, physically exhausting, and delay.

Table 2. Seven waste assessment questionnaires criteria [9]

Waste Type	Score	Description
Over Production	0	Not Happen
	1	Happened but not distract production flow
	2	Start to distract production flow
	3	Distract production flow, and increase production cost
	4	Distract next flow of process
	5	Cause defect of product because product keep in warehouse for too long
Defect	0	Not happened
	1	Happened and cause minor rework
	2	Cause delay minor
	3	Potential to re-production
	4	Cause late for shipment and need extra inspection
	5	Defect discovered by consument and cause increase cost
Unnecessary Inventory	0	Not happened
	1	Happened but not distract production flow
	2	Need extra man to control the machine/ingredients
	3	Start to distract production flow
	4	Potential damage the machine/ingredients
	5	Need extra room and causing too much damage

Waste Type	Score	Description
Inappropriate Process	0	Not happened
	1	Happened but the effect not significant
	2	Happened and the effect significant
	3	Cause more ingredient consumption
	4	Cause duration more time
	5	Cause defect and endanger operator
Excessive Transport	0	Not happened
	1	Happened and not distract production flow
	2	Cause bad communication between division
	3	Cause more consumption of area
	4	Cause duration more time
	5	Cause damage of product
Waiting	0	Not happened
	1	Happened and not distract production flow
	2	Cause duration more time
	3	Cause bad production process
	4	Potential late for shipment
	5	Cause late for shipment
Unnecessary Motion	0	Not happened
	1	Happened and not distract production flow
	2	Added more process
	3	Potential to more duration
	4	Decrease operator productivity
	5	Potential to cause injury

2.1.3. VALSAT Mapping
Mapping of VALSAT has 2 stages, they are general mapping based on the value of each process and second based on VALSAT variety. The use of the second VALSAT table is carried out based on the level of suitability of the VALSAT variety with the problem and waste. The assessment is carried out based on the level of strength of the relationship between the function of the variety and the problem at hand [6].

2.2. Measure
Analyze the reason for waste in production will collect from the VALSAT table. The waste mayor will calculate by DPMO (Defect Per Million Opportunity) and sigma. The result will test significance to know the difference in the waste can give significant difference for production at XYZ company [7].

2.3. Analyze
The five whys form will arrange based on define and measure, problem each major waste which identified. Then a form will fill by the operator. Then FMEA (Failure Mode Effect Analysis) questionnaires will be spread to the employee. The Fishbone diagram will be mapped after all the questionnaires are done [9].

2.4. Improve
Fishbone diagram will be key to give the best solution based on relevancy. This stage-based on field observation and brainstorming to find the solution [7].

3.   Result and Discussion

3.1 Define

In table 3 can be seen that not all stage which has lower normal time has standard time lower than cycle time. While performance assessment (Fr) is more than 1, the operator works slower than normal time, which can cause the condition and consistency value low. Based on the field, when another operator breaks, other operators can back up. Then the standard time looks slower than cycle time [10].

Table 3. Time proses measure for each element work

Process	Element Work	Code	Fr	Cycle Time	Normal Time	Allowance	Standard Time	Identification
Mixing	Puree Preparation	P1	0.99	5.96	5.900	0.0729	6.331	NVA
	Puree Mixing	P2	0.99	7.64	7.564	0.0063	7.611	VA
	Additive Preparation	P3	1.02	4.28	4.366	0	4.366	NVA
	Additive Mixing	P4	1.05	11.7	12.26	0.0042	12.316	VA
	Mixing	P5	1.07	9.48	10.14	0.0063	10.208	VA
	Lab 1	P6	1.18	3.00	3.540	0.0104	3.577	VA
Revision	Revision	P7	0.97	12.68	12.30	0	12.300	VA
	Lab 2	P8	1.16	2.92	3.387	0.0042	3.401	VA
	Revision	P9	0.97	3.00	2.910	0.0042	2.922	NNVA
	Lab3	P10	1.16	1.16	1.346	0.0021	1.348	NNVA
	Revision	P11	0.97	0.32	0.310	0	0.310	NNVA
	Lab 4	P12	1.16	0.40	0.464	0	0.464	NNVA
	Revision	P13	0.97	0.12	0.116	0	0.116	NNVA
	Lab 5	P14	1.16	0.08	0.093	0.0042	0.093	NNVA
Pasteurization	Pasteurization	P15	1	45.4	45.40	0.0521	47.765	VA
Filling	Filling	P16	0.78	64.9	50.64	0.0542	53.382	VA

*Fr: Performance assessment/Factor Rating | VA: Value Added | NVA: Non-Value Added | NNVA: Non-Necessary Value Added
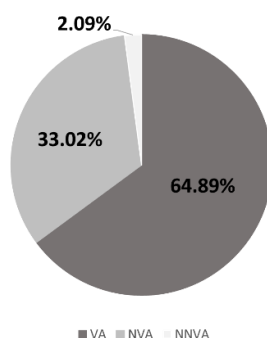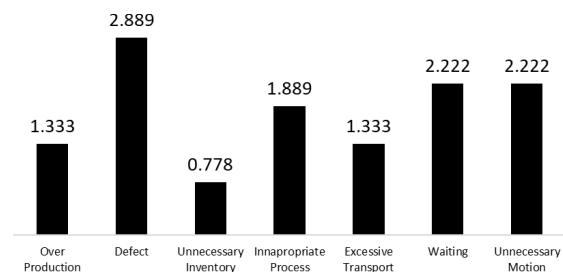

Figure 1. Ratio of value diagram

Figure 2. Seven waste diagram

From VSM (Value Stream Mapping) analysis in figure 1, it can be said that the production process of

RTD guava juice at PT. XYZ is quite optimal because the VA is more than 50% (64.89%). But this VA value can still be increased to be more optimal by eliminating waste to the maximum.
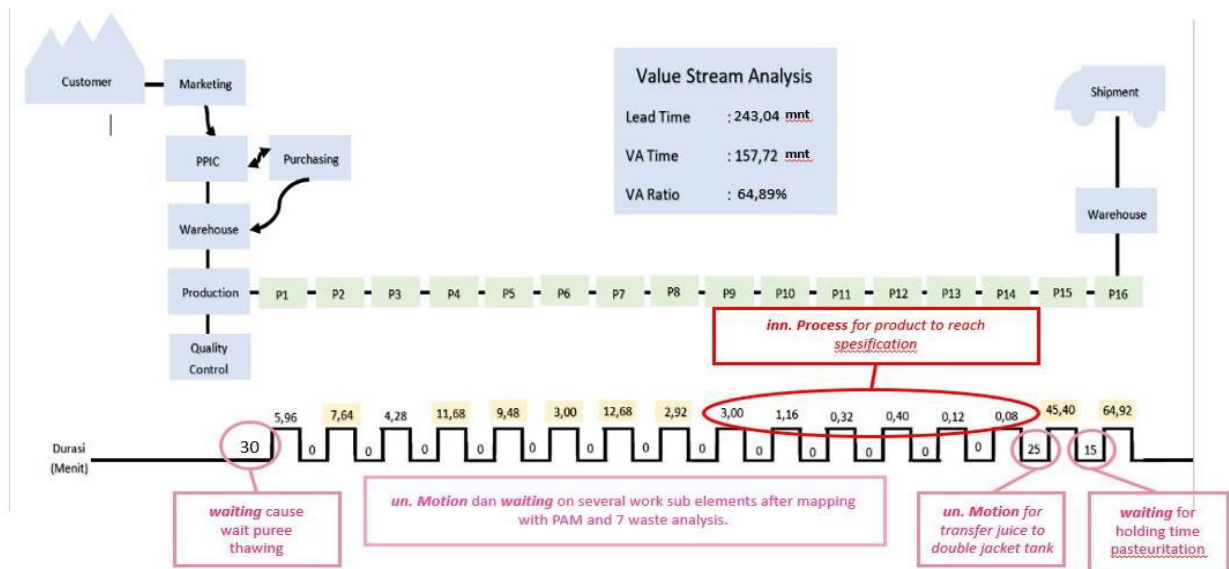

Figure 3. VALSAT mapping

The seven wastes diagram showing the highest rank of waste is defecting. These results will be used for further problem mapping using VALSAT. Based on the results of the VALSAT mapping, it was found that the most suitable method used for determining waste is the PAM method because this method can explain the waste that is a problem in the process flow, namely changes in duration during the production process. But PAM cannot be used to map defects. Defect mapping to be the one which analyzes by the Pareto diagram. The defect has five defects in guava juice RTD production: spills, underfills, leaks, barcode, and re-cap.

Table 4. VALSAT matrix table

	PAM	SCRM	PVF	QFM	DAM	DPA	PS
Over Production	1.333	0	11.997	0	0	0	0
Defect	2.889	0	8.667	26.001	0	0	0
Unnecessary Inventory	2.334	0	0	0	7.002	2.334	0
Inappropriate Process	17.001	0	17.001	5.667	17.001	17.001	0
Excessive Transport	0	0	0	1.333	1.333	0	0
Waiting	19.998	0	0	0	6.666	6.666	0
Unnecessary Motion	0	0	0	0	0	0	2.222
Total	43.555	0	37.665	33.001	32.002	26.001	2.222
Rank	**1**	**7**	**2**	**3**	**4**	**5**	**6**

*PAM: Process Activity Mapping; SCRM: Supply Chain Response Matrix; PVF: Product Variety Funnel; FM: Quality Filter Mapping; DAM: Demand Amplification Mapping; DPA: Decision Poin Analysis; PS: Physical Structure

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3.2 Measure

To determine the root cause is done using the Pareto diagram 20:80 principle. The cause comes from 20% problem and 80% is an effect from the problem [12]. The result of measurement using Pareto diagrams can be seen in the figure 4. Through this principle, it found that the most take effect defects are spills (32.31%), underfills (31.8%), and leaks (14.33%). It's because all three have cumulative presentations under 80%.
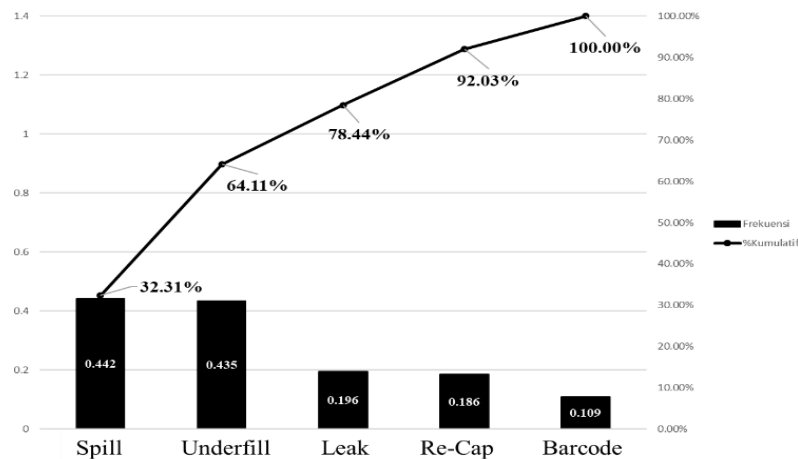

Figure 4. Pareto diagram

DPMO is used to ensure the performance of process production guava juice RTD. The results (Table 5) showed that the DPMO value for the production process of RTD guava juice at PT. XYZ is 6698.312. The result shows that the sigma value of the RTD guava juice production process is 3.973. This result can be said to be still quite low because the value obtained is not close to 6, the optimal number in the sigma value. The low sigma value indicates that it is still not optimal, and the resulting product is not good in quality [6].

Table 5. DPMO and sigma measure

Day	Vol	Tot. Unit	Filling		Packing				Total Defect	Proportion
			Spill	Underfill	Re-Cap	Leak	Barcode	Underfill		
1	575	1300	0	0	2	0	5	0	7	0.005
2	100	384	3	11	7	0	0	0	21	0.055
3	350	1242	12	19	8	18	21	1	79	0.064
4	100	391	7	10	6	0	0	0	23	0.059
5	350	350	3	0	0	0	0	0	3	0.009
6	100	405	11	11	0	0	0	0	22	0.054
7	350	336	5	9	0	1	8	2	25	0.074
8	100	353	11	8	3	0	0	0	22	0.062
9	1000	2800	10	26	16	27	0	0	79	0.028
10	100	394	11	4	12	0	0	0	27	0.069
11	270	270	7	13	3	0	4	0	27	0.100
12	150	585	10	2	1	0	0	0	13	0.022
13	200	751	7	11	3	0	0	0	21	0.028

14	300	295	12	0	0	0	0	0	12	0.041
15	600	2240	3	48	10	3	1	0	65	0.029
16	350	257	8	0	6	5	0	1	20	0.078
17	350	1400	45	14	1	20	6	1	87	0.062
18	180	186	5	3	0	12	2	1	23	0.124
19	150	570	5	3	8	0	0	0	16	0.028
20	150	600	10	16	4	0	0	0	30	0.050
21	500	604	7	5	6	6	4	2	30	0.050
22	1000	4067	4	24	0	8	0	0	36	0.009
23	350	1380	7	26	18	2	0	0		0.000
24	200	737	14	17	5	0	0	0	36	0.049
25	200	605	8	4	0	0	0	1	13	0.021
26	110	108	2	3	0	6	3	0	14	0.130
27	200	820	12	9	3	0	0	0	24	0.029
Total		23430							75	0.033
DPMO										**6615.450**
Sigma										**3.977**

3.3 Analyze

Based on the results of the analysis using five whys, it is known that the majority of root problems are from man and machine factors. Several problems of man-caused by environment not support, lack of support facility, and engine trouble. This is in line with the results of the rating factor which is below 1 which is more dominant due to the low condition value [10]. From FMEA, the production has four sub elements work which to be attention for improvement. These are spills, leaks (sealing), machine trouble, and underfills. Then four sub elements mapped to be the fishbone diagram. Based on the Fishbone principal, the majority of the cause are man, machine, and method.
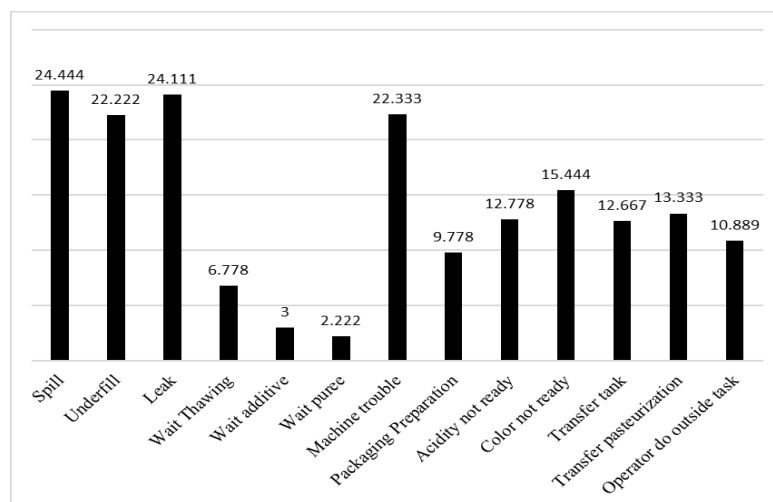

Figure 5. FMEA diagram

3.4 Improvement
Based on the analysis, man, machine, and method to be attention to find the solution. In man factor, all off the solution focus to make operator work comfortable. The way that can be done are turn on the fan and exhaust to give circulation and decrease the temperature of production area, decide to implementation of reward and punishment system, arrange placement of operator to the filling product, and conduct training for new employees who will work especially in the filling area production. In this case, the solution to the human factor is more emphasized in the psychological direction. Because when the work environment and the pressure exerted on the operator is lower, the operator will work better and more comfortably [13].
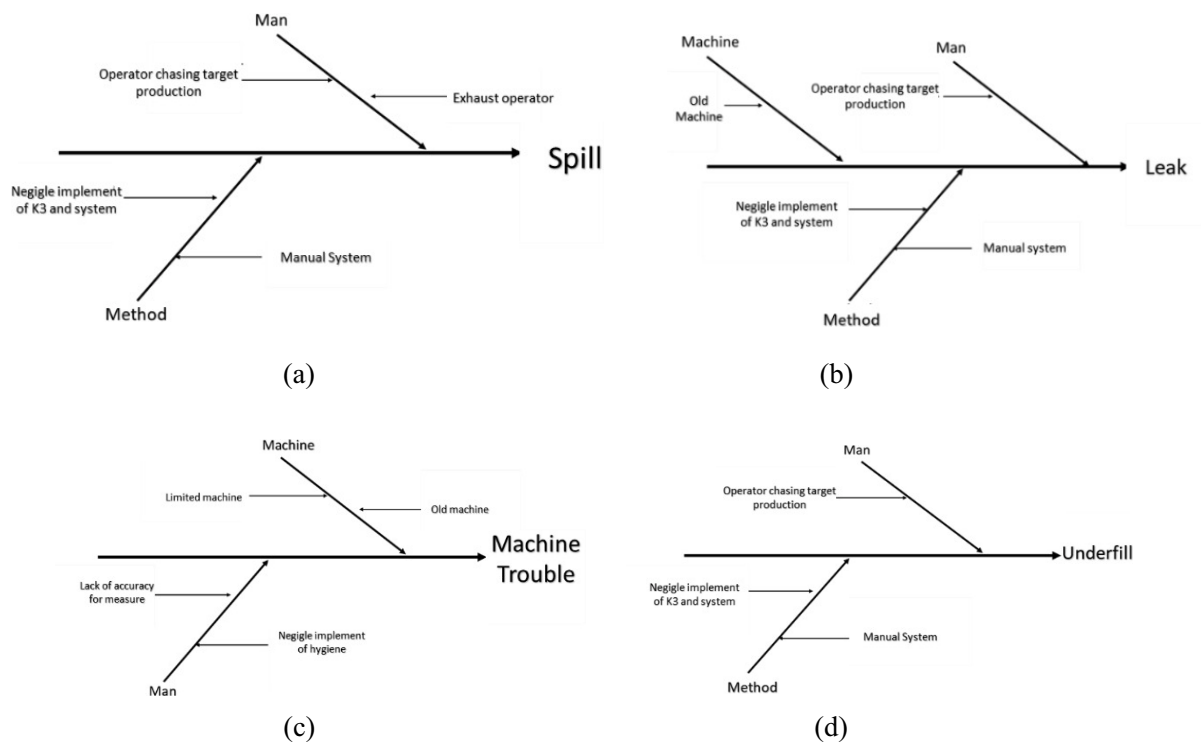

Figure 6. Fishbone diagram of non-optimization of RTD guava juice production process at pt. XYZ: (a) spilled product, (b) product leak, (c) machine disturbances, (d) underfill (insufficient product content)

On the method or system factor, the solution more towards to the company. Every instruction and policy issued by the company for the production process must be clear, can be responsible, and can be implemented nicely. CCTV can be used to check every production activity, if the operator has mistaken, communication between operator or employee must not judge. The operator will not feel reprimands are annoying. K3 system needed to safety while every worker works at company [13].

While on the machine factor, maintenance, inspection, and inventory routine of the machine are very important for the optimization process [14]. The Providing training to operators and administrative lines for maintenance is needed so that the work system becomes effective and efficient. As the result, the level of damage to the machine is reduced and the disruption during production is reduced.

4. Conclusion
The production process of guava juice drinks RTD at PT. XYZ is still not-optimal. Based on the lean six sigma method used in this study, it was found that the non-optimal forms occurred during the production

process of guava juice drink at PT. XYZ are defects, waiting, inappropriate processes, and unnecessary motion. These four things cause spilled products, product leaks, machine disturbances, and insufficient product content. To improve this problem, it is necessary to take corrective action on the factors that cause non-optimality during the production process that focuses on humans (man), methods (methods/systems), and machines.

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