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Measurement of effectiveness of food processing machine through overall equipment effectiveness (OEE)

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ABSTRACT

Machinery and equipment are critical facilities for the sustainability of production. The company needs to conduct intensive evaluation and maintenance of production machinery to maintain engine performance to work optimally. PT. XYZ is a manufacturing company engaged in food producers in Indonesia. The problem that often occurs is a breakdown of the production machine. This causes the company to be unable to meet the production target so that the company's productivity decreases. The method used is Overall Equipment Effectiveness (OEE) to determine how effective the machine is on Kuroma PC-211 machines and proposed repairs. This study aims to determine the value of Overall Equipment Effectiveness (OEE), find out the causes of six big losses, and provide suggestions for improvement. The results showed the average percentage availability rate on Kuroma PC-211 machines was 84.40%, performance rate with 93.23%, quality rate with 98.59%, and OEE with 77.53% percentage.

1. Pendahuluan

The rapid development of technology encourages every business actor, especially the manufacturing industry, to continue developing their initiatives to compete in the global market [1], [2]. The company must be able to increase its productivity. One of the efforts that could be done to improve the company's productivity is to evaluate the performance of the production floor [3], [4], [5]. In general, problems from production facilities that cause production disrupted or stopped altogether can be categorized into three: human, machine, and environmental factors. These three things can affect each other [6], [7].

In the manufacturing industry, machinery and equipment are very important for the sustainability of production to achieve the company's targets. The most significant contribution to the total cost of production is derived from the cost of carrying out equipment maintenance, either directly or indirectly [8]. Therefore, it is crucial to evaluate and maintain the production machine intensively to maintain engine performance to work optimally [9]. However, the maintenance and repair of machinery have been done periodically; there are still many problems in a company [10], [11], [12]. Modern treatment methods have been introduced by Japan and are known as Total Productive Maintenance (TPM), the concept of which was introduced by Seiichi Nakajima [13], [14], [15], [16]. One of its products is one calculation (Overall equipment effectiveness), which measures using a device or system by including several points of view in the calculation process. Some of the points of view or factors used are availability rate, performance rate, and quality rate [17], [18], [19], [20].

PT. XYZ is a manufacturing company engaged in food producers in Indonesia. PT. XYZ produces 2 (two) main products, including dry categories such as spice flour, sprinkle spicy chili, pudding, and beverage (premix beverage), and wet categories such as sauces. The company's main activities other than food service are retail, export, and manufacturing cooperation. Problems that occur in the company still often experience obstacles caused by machines. Many production machines experience a breakdown even though improvements have been made; this causes the company to be unable to meet production targets so that the company's productivity decreases. To overcome this problem, in this study, measurements of machine effectiveness are taken using the OEE (Overall Equipment Effectiveness) method to find out how many effective machines can be taken in the future [21].

The measurements were made on the Kuroma PC-211 machine. Furthermore, finding out the losses that occur in the production machine is done by analyzing Six Big Losses. After knowing the most significant losses on the device, a cause-and-effect analysis of losses is performed with a fishbone diagram [22]. The proposed improvement is made using the FMEA method to determine the action planning of each mode of failure experienced by the machine [23]. This study aims to find out the value of Overall Equipment Effectiveness (OEE), find out the cause of six big losses, and provide proposed improvements.

2. Material and method

The study used qualitative and quantitative data. The data collected are production data, product defects, and machine downtime. Furthermore, it will process the data contained in this process. The processed data will produce performance rate values, availability rate, quality rate, OEE, and Six Big Losses values and identification using a fishbone diagram and FMEA research stage shown in Figure 1. Data from production produced by PT. XYZ for BonCabe, Kobe Flour, and Quaker products are shown in Table 1. In Table 1, boncabe production, Kobe Flour, and Quaker from January to December 2020. BonCabe production has a significant difference between the total production target and the actual production.

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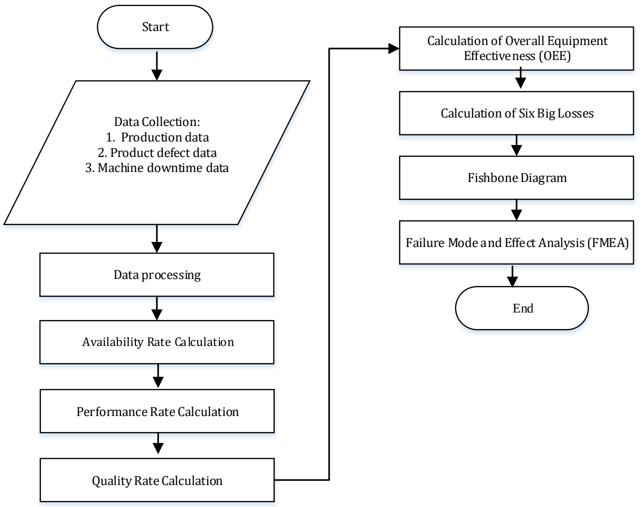

Figure 1. Research framework

It means that the company only achieved 80.27% of the production target. The total actual production for BonCabe is 1672.61 tons, while the company's target is 2083.60 tons. Data defects are data of defective or failed products experienced during production. The following is presented a table of product defect data and total production produced by the Kuroma PC-211 machine shown in Table 2. The following is machine downtime data in January-December shown in Table 3.

Performance rate is one of the parameters in measuring OEE values, taking into account total product processed, ideal cycle time, and operation time [24]. Total product processed is the number of products produced with QC criteria in PT XYZ.

3. Results and discussions

The availability rate is one of the standards in measuring OEE values, considering the total time of damage resulting from loading time, downtime, and operation time [25]. Availability rate calculation of Kuroma PC-211 machine shown in Table 4. After knowing the percentage of working hours, it is necessary to calculate the ideal cycle time by multiplying the percentage of working hours by the machine cycle time. The performance rate can be calculated after getting the ideal cycle time value. The table of performance rate calculations is shown in Table 5.

Quality rate is one of the parameters in measuring OEE values, which considers the total product processed and total scrap [26]. Quality rate measurements on Kuroma PC–211 machines from January to December are shown in Table 6. After calculating the availability, performance, and quality level of Kuroma PC-211 machines, and finally calculating the overall equipment effectiveness value (OEE) to determine the effectiveness of Kuroma PC-211 machine usage is shown in Table 7.

The table of overall equipment effectiveness (OEE) values of Kuroma PC-211 machines shows that the machine got the lowest OEE value in June at 66.64% and in August at 68.10%. Meanwhile, the average OEE value only reached 77.55%. This figure is below the OEE standard set by JIPM (Japan Institute of Plant Maintenance), which sets the ideal OEE value of ≥ 85%.

The Six Big Losses are six losses that any company should avoid that can reduce the effectiveness of the machine. The Six Big Losses are usually categorized into three main categories based on aspects of losses, namely downtime, speed loss, and disability [27]. Calculating the six major losses helps identify a company's losses, especially in maintenance. The results of the Six Big Losses are shown in Table 8.

Table 1.
Production data (in tons)

Months	BonCabe		Kobe Flour		Quaker	
	Target	Actual	Target	Actual	Target	Actual
January	223,1	181,9	427	412,5	373,2	333,9
February	156,8	133,4	509,3	508	507,6	468,5
March	163,7	143,6	554,3	538,5	551,4	474,9
April	170,8	151,7	626,6	626,7	427,9	397,9
May	190,4	160,1	746,5	742,2	436,8	305,4
June	201	155,3	674,8	652	544,9	493,3
July	215	182,2	901,3	895,7	402,8	357,1
August	145,4	123,2	765,8	737,8	441,5	321,5
September	187,2	137,7	442,7	466,2	275,9	244
October	111,7	81,4	383,7	400,5	411,2	396,3
November	144,1	108	546,5	539,8	304,5	240
December	174,4	114,1	559	586	457,2	414,4
Total	2083,6	1672,6	7137,6	7105,9	5134,9	4447,1

Table 2.
Product defect data (in tons)

No	Months	Production	Defect
1	January	39,49	0,39
2	February	30,78	0,2
3	March	38,75	0,02
4	April	46,49	0,54
5	May	30,6	0,51
6	June	16,05	0,39
7	July	12,42	0,37
8	August	1,91	0,03
9	September	7,27	0,11
10	October	16,38	0,24
11	November	24,53	0,25
12	December	28,35	0,4

Table 3.
Machine breakdown data (in minutes)

Months	Available time	Breakdown	Set-up	Planned downtime	Downtime
January	43690	4240	280	3713	4520
February	31545	2185	175	2518	2360
March	37620	3304	245	2903	3549
April	42710	3193	160	2603	3353
May	38663	7328	565	2269	7893
June	35030	9308	280	1509	9588
July	18630	3245	140	1227	3385
August	4230	880	165	255	1045
September	13800	1850	180	950	2030
October	19350	1870	355	1225	2225
November	29940	3085	405	2250	3490
December	27085	3053	90	2002	3143

Table 4.
Availability rate

No	Months	Loading Time (Minute)	Downtime (Minute)	Availability rate
1	January	39977	4520	88.69%
2	February	29027	2360	91.87%
3	March	34717	3549	89.78%
4	April	40107	3353	91.64%
5	May	36394	7893	78.31%
6	June	33521	9588	71.40%
7	July	17403	3385	80.55%
8	August	3975	1045	73.71%
9	September	12850	2030	84.20%
10	October	18125	2225	87.72%
11	November	27690	3490	87.40%
12	December	25083	3143	87.47%

Table 5.
Performance rate

Months	Production (tons)	Loading time (minute)	% Working hours	ICT (minute/tons)	Operating time (minute)	Performance rate
January	39,49	39977	81.16%	821.59	35457	91.50%
February	30,78	29027	84.54%	797.29	26667	92.02%
March	38,75	34717	82.85%	742.23	31168	92.28%
April	46,49	40107	86.05%	742.47	36754	93.91%
May	30,6	36394	73.72%	876.61	28501	94.13%
June	16,05	33521	68.32%	1427.02	23933	95.69%
July	12,42	17403	75.24%	1054.67	14018	93.41%
August	1,91	3975	69.27%	1439.08	2930	93.97%
September	7,27	12850	78.41%	1386.53	10820	93.12%
October	16,38	18125	82.17%	909.15	15900	93.67%
November	24,53	27690	80.83%	912.35	24200	92.48%
December	28,35	25083	81.00%	716.68	21940	92.61%

Table 6.
Quality rate

No	Months	Production (tons)	Defect (tons)	Quality rate
1	January	39,49	0,39	99,02%
2	February	30,78	0,2	99,36%
3	March	38,75	0,02	99,94%
4	April	46,49	0,54	98,84%
5	May	30,6	0,51	98,34%
6	June	16,05	0,39	97,54%
7	July	12,42	0,37	97,03%
8	August	1,91	0,03	98,31%
9	September	7,27	0,11	98,53%
10	October	16,38	0,24	98,54%
11	November	24,53	0,25	99,00%
12	December	28,35	0,4	98,60%

Table 7.
Overall equipment effectiveness value

Months	Availability rate	Performance Rate	Quality Rate	OEE
January	88.69%	91.50%	99,02%	80.36%
February	91.87%	92.02%	99,36%	84.00%
March	89.78%	92.28%	99,94%	82.80%
April	91.64%	93.91%	98,84%	85.06%
May	78.31%	94.13%	98,34%	72.50%
June	71.40%	95.69%	97,54%	66.64%
July	80.55%	93.41%	97,03%	73.01%
August	73.71%	93.97%	98,31%	68.10%
September	84.20%	93.12%	98,53%	77.25%
October	87.72%	93.67%	98,54%	80.97%
November	87.40%	92.48%	99,00%	80.02%
December	87.47%	92.61%	98,60%	79.87%
		Average		77,55%

Table 8.
Six big losses

Months	Breakdown losses	Setup & Adjustment Losses	Idling and Minor Stoppage	Reduced Speed losses	Defect in Process	Reduced Yield
January	10.61	10.61	0.41	7.54	0.80	0%
February	7.53	7.53	1.41	7.33	0.54	0%
March	9.52	9.52	0.94	6.93	0.05	0%
April	7.96	7.96	3.23	5.59	1.00	0%
May	20.14	20.14	0.76	4.60	1.22	0%
June	27.77	27.77	1.00	3.08	1.68	0%
July	18.65	18.65	1.18	5.31	2.24	0%
August	22.14	22.14	0.50	4.44	1.17	0%
September	14.40	14.40	1.28	5.80	1.15	0%
October	10.32	10.32	0.74	5.55	1.20	0%
November	11.14	11.14	0.70	6.57	0.81	0%
December	12.17	12.17	0.26	6.47	1.14	0%

Table 9.
Average percentage of each loss

Types of Losses	Average	Percentage	Cumulative
Breakdown losses	14.36	61.14%	61.14%
Reduced Speed losses	5.77	24.55%	85,69%
Setup & Adjustment Losses	1.24	5.30%	90,99%
Defect in Process	1.08	4.61%	95,6%
Idling and Minor Stoppages	1.04	4.41%	100%
Reduced Yield	0	0%	100%
Total	23,49	100%	

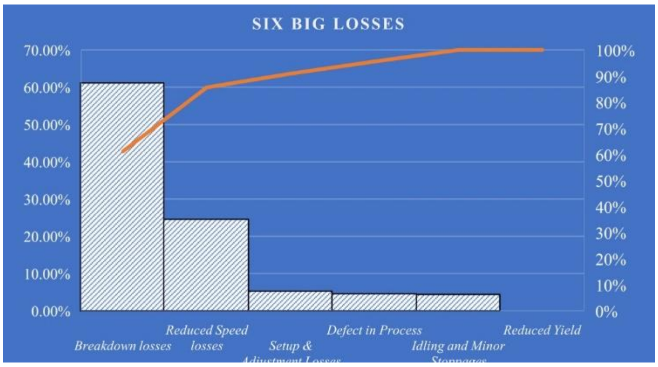

Figure 2. Pareto diagram of six big losses

The identification of losses will be easily known by sorting the number of events (percentage) and presented in the Pareto diagram shown in Table 9 and Figure 2. Based on the Figure 2 diagram of Pareto's six big losses that occur in Kuroma PC-211 machines above, it can be known that breakdown is the highest loss factor that occurs in the machine during the period January to December with a value of 61.14%. The second position is occupied by reduced speed losses, with an event percentage of 24.55%. The next position is occupied by setup and adjustment with a percentage of 5.30%, defect in process 4.61%, idling and minor stoppages with a percentage of 4.41%, and reduced yield, which has a percentage of 0% or is not included in machine losses. After calculate the percentage of dominant losses on the Pareto Diagram before, it is known that breakdown losses occupy the first position as the most dominant loss with a percentage of 61.14%. Next, this loss will be identified using a fishbone diagram that shows the cause and effect of breakdown losses from some aspects: man, material, machine, method, and environment. The following is a fishbone diagram of breakdown losses on the Kuroma PC-211 machine shown in Figure 3.

FMEA is used to determine the highest Risk Priority Number (RPN) as the priority of improvement by determining the priority value of the failure mode: Severity (S), Occurrence (O), and Detection (D) indicators are multiplied and produce an RPN. The result of this method is a proposed improvement based on the problems that have been identified using the previous fishbone diagram shown in Table 10. From Table 10 it is known that the most potential failure mode comes from a high machine idle time with an RPN value of 384 which caused the company to be unable to achieve its target. After finding the cause of the main problem along with the value of the RPN, the next step is to determine an action plan as a corrective step that will be implemented by the company to overcome the problems that have been identified previously. The mode of failure is a failure mode that occurs that causes breakdown. The potential effect of failure shows the impact that arises due to the failure mode, and the potential cause explains the cause of the failure mode. The action planning or recommendations for improvement are given based on the results of brainstorming together with the operator and several MTC (maintenance) teams.

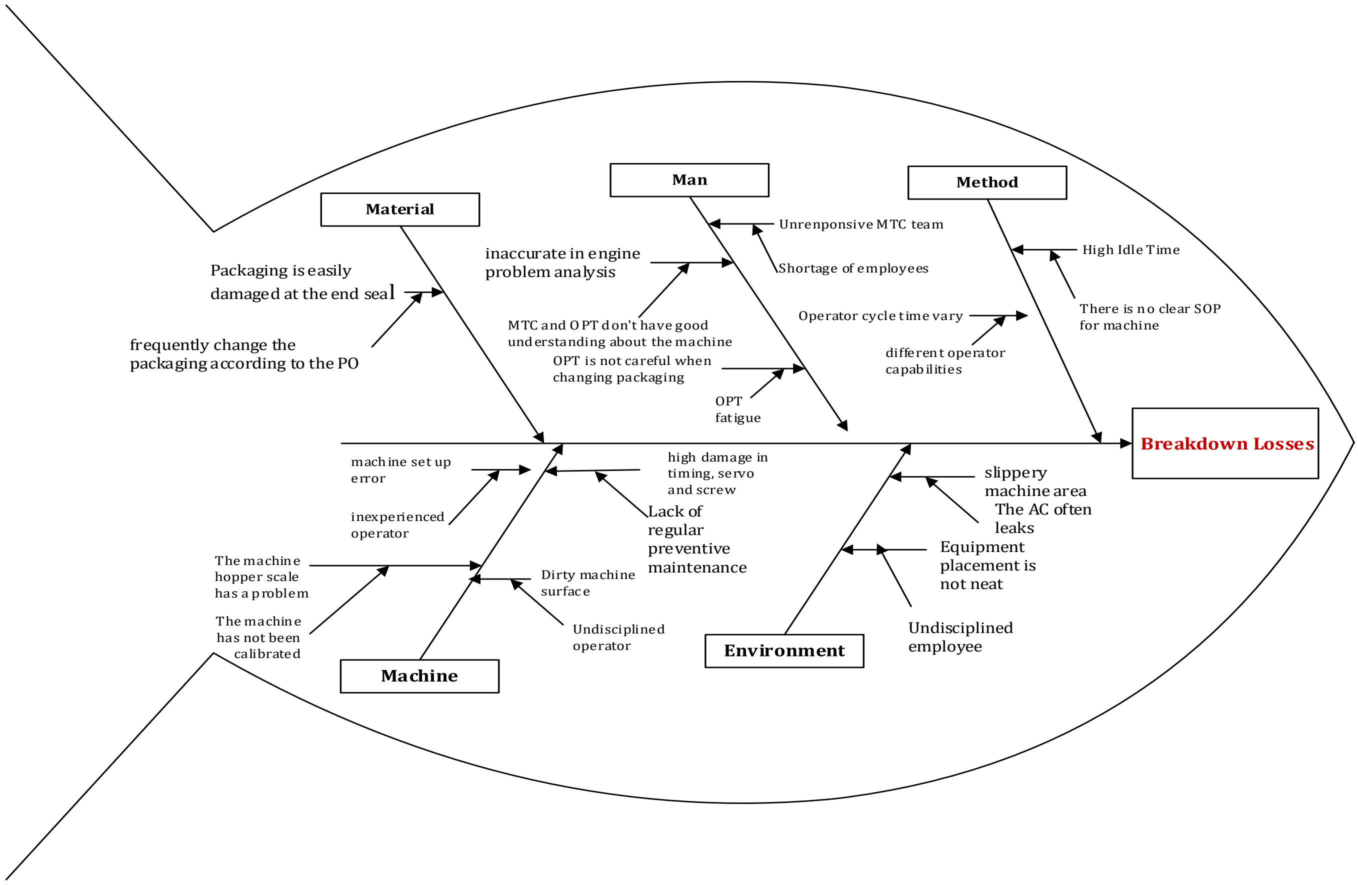

Figure 3. Fishbone diagram

Table 10.
Failure mode and effect analysis

Loses	Mode of failure	Cause of failure	Effect of failure	F	S	C	RPN	Rank
Breakdown Losses	Unrenponsive MTC team	Shortage of employees	Machine damage can't be dealt with in time	7	6	4	168	5
	Inaccurate engine problem analysis	MTC and OPT don't have a good understanding of the machine	The fixes made did not solve the problem	7	6	6	252	3
	OPT is not careful when changing packaging	OPT fatigue	The package changed to waste	3	4	7	84	8
	Machine set up error	Inexperienced operator	The machine is not normal and the product is defective	4	4	9	144	6
	The machine hopper scale has a problem	The machine has not been calibrated	Machine performance is not optimal	8	6	5	240	4
	High damage in timing, servo and screw	Lack of regular preventive maintenance	Roll packaging becomes waste and the machine is often clogged when running	5	5	5	125	7
	High idle time	There is no clear SOP to handle machine trouble	Production target not achieved	8	8	6	384	1
	Dirty machine surface	Undisciplined operator	Reduced engine air pressure	3	4	4	48	11
	Operator cycle time vary	Different operator capabilities	Production output for each shift is not the same	9	6	7	378	2
	Packaging is easily damaged at the end seal	Frequently change the packaging according to the PO	Packaging becomes waste	6	3	4	72	9
	Slippery machine area	The AC often leaks	Employee slips	3	9	2	54	10

Note: F = Frequency of occurrence, S = Severity of occurrence, C = Chance of detection

Table 11.
Action planning of FMEA

Rank	Failure Mode	Potential Effect of Failure	Potential Cause	Action Planning (Recommended Action)
1	High idle time	Production target not achieved	There is no clear SOP to handle machine trouble	Training needs to be held professionally for the maintenance team and the operators, as well as the need for making Standard Operating Procedures (SOP) for some maintenance & repair activities that often experience damage or periodic maintenance
2	Operator cycle time vary	Production output for each shift is not the same	Different operator capabilities	Training needs to be held professionally for operators and make machine operating SOP
3	Inaccurate engine problem analysis	The fixes made did not solve the problem	MTC and OPT don't have a good understanding about the machine	Providing machine introduction materials based on machine manuals by vendors for operators and technicians to get a better understanding of machine components and possible causes of damage to these machine parts
4	The machine hopper scale has a problem	Machine performance is not optimal	The machine has not been calibrated	Make a checklist to do for each MTC team in each shift so they don't forget to calibrate the machine
5	Unrenponsive MTC team	Machine damage can't be dealt with in time	Shortage of employees	There needs to be an addition to the MTC team and a clear division of job descriptions
6	Machine set up error	The machine is not normal and the product is defective	Inexperienced operator	Make a fault detection device or Poka-Yoke which is input into the machine setup that will make the operator realize the error before the machine operates
7	High damage in timing, servo, and screw	Roll packaging becomes waste and the machine is often clogged when running	Lack of regular preventive maintenance	There is a need for periodic PM evaluations with the production supervisor, engineering, and the executor team (operator and MTC team)
8	OPT is not careful when changing packaging	The package changed to waste	OPT fatigue	There needs to be an increase in facilities for workers and can apply the Kanban system to find out the next production order
9	Packaging is easily damaged at the end seal	Packaging becomes waste	Frequently change the packaging according to the PO	Making a poka-yoke that detects packaging installation errors on the machine before the machine is running
10	Slippery machine area	Employee slips	The AC often leaks	Repairs by the MTC team and periodic checks to prevent the same damage
11	Dirty machine surface	Reduced engine air pressure	Undisciplined operator	apply 5R on the production floor

4. Conclusion

The average value of the percentage availability rate on BonCabe Kuroma PC-211 production machine from January to December is 84.40%, the performance rate with 93.23%, the quality rate has a percentage of 98.59%, and OEE with a percentage value of 77.53%. This value has not reached the machine's standard or ideal OEE value set by JIPM (Japan Institute of Plant Maintenance) ≥85%. The main losses factor that causes the low OEE value of the Boncabe PC-211 production machine based on the calculation of six big losses is the downtime losses factor which is a loss due to breakdown with a percentage loss of 61.14%.

The fishbone diagram identifies the cause of the loss at the breakdown. In fishbone analysis, the causal factors of losses include human factors (Maintenance team is less responsive, inaccuracies in the analysis of machine problems, and operators are not careful when changing packaging), engine factors (Engine setup errors, machine scale hoppers are often problematic, dirty engine surfaces, and great damage to timing, servo, and screw), method factors (high idle time and operator cycle time vary), material factors (packaging is easily damaged) and environmental factors (Slippery engine area and equipment placement are not neat).Based on the results of FMEA analysis obtained several suggestions or recommendations for improvements that can be done including conducting professional training for the team of technicians and operators, making operational standards of machine procedures, making Poka-Yoke detect errors in the beginning, and applying the principle of 5R in employee discipline.

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