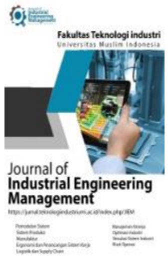

E-ISSN 2503 - 1430
ISSN 2541 - 3090

Journal of Industrial Engineering Management

(Jiem Volume 9. No 3 Tahun 2024)

MILLED CASSAVA PRODUCTION CAPACITY MODEL THROUGH MACHINE EFFECTIVENESS ANALYSIS

Sesar Husen Santosa[1]*, Agung Prayudha Hidayat[2], Ridwan Siskandar[3], Annisa Rizkiriani[4]

Industrial Management Study Program, College of Vocational Studies[12], IPB University, Computer Engineering Study Program[2], College of Vocational Studies, IPB University, Management of Food Service and Nutrition Study Program, College of Vocational Studies, IPB University[3]

Jl. Kumbang No.14, RT.02/RW.06, Babakan, Kecamatan Bogor Tengah, Kota Bogor, Jawa Barat 16128

E-mail: sesarhusensantosa@apps.ipb.ac.id[1], agungprayudha@apps.ipb.ac.id[2], ridwansiskandar@apps.ipb.ac.id[3], annisarizkiriani@apps.ipb.ac.id[4]

Article History:
Submitted May 24, 2023
Revised January 11, 2024
Accepted December 5, 2024
Available online December 13, 2024

ABSTRACT

The very high demand for the tapioca flour industry causes good quality and quantity tapioca flour. This condition causes the tapioca flour SMIs have to manage production activities to meet the needs of the industry. This causes Tapioca SMEs to be able to maximize production so that the product can compete in the market. The flour production process cannot be separated from the cassava milling machine effectiveness. Based on the results of the milling machine analysis for one year, the availability = 65,16%, performance = 53.62%, Quality Rate = 89.60% and OEE = 31.88%. This condition shows that there are machine performance problems in producing cassava porridge products, namely only 53.2% of the raw materials are used to make the product. Based on the OEE value and the amount of production, the regression equation model is obtained, namely ground cassava (Kg) = 5155 + 11037 OEE with Determination value (R2) = 94,8 %. This determination value 94,8% shows that there is a relationship between the OEE value of the milling machine and the productivity of the ground cassava produced. According to Seiichi Nakajima's standard ideal OEE, which is 85%, so that the ideal production capacity of ground cassava base on regression model in SMIs is 14,536 kg/month. Based on these ideal conditions, SMEs must be able to plan the right cassava raw material suppliers to meet the production of 14,536 kg/month ground cassava.

Keywords: *OEE, Regression*

Published By:
Fakultas Teknologi Industri
Universitas Muslim Indonesia
Address :
Jl. Urip Sumoharjo Km. 5 (Kampus II UMI)
Makassar Sulawesi Selatan.
Email :
Jiem@umi.ac.id
Phone :
+6281341717729
+6281247526640

DOI : http://dx.doi.org/10.33536/jiem.v9i3.1502

1. INTRODUCTION

Cassava is a raw material used to make various food ingredients because it has very good nutrition content. Cassava is a food source with very good dietary content (Costa *et al.*, 2020). Cassava is an agricultural product with high potential demand and can be processed into a food source with nutritional content because it has a high potential protein source (Sukara, Hartati and Ragamustari, 2020).

One of the processed cassava products needed by the food industry is tapioca flour. The need for tapioca flour in the food ingredients industry cannot be separated from the ability of Small and Medium Industry (SMI) in processing cassava raw materials into flour that will be used in the industry. The cassava processing industry can maintain food safety when processed into tapioca flour products (Prasara-A and Gheewala, 2021). One of the quality tapioca flour products is influenced by the Availability of cassava raw materials during the milling process.

The problem faced by tapioca flour SMIs today is the very low cassava yield caused by the quality of cassava raw materials. This condition causes the tapioca flour produced cannot meet consumer demand. Consumer demand can be met if the company can plan the optimal number of production needs by considering the optimal order of raw materials to suppliers(Santosa, Hidayat and Siskandar, 2021). Raw material management based on the bill of product material can determine the ideal amount of production capacity so that it can be used in the optimal raw material ordering schedule (Jodlbauer and Strasser, 2019). Optimal production planning is influenced by the condition of the cassava milling machine in producing ground cassava raw material, which will be used as the basic material for tapioca flour production. Optimal production planning is influenced by machine scheduling by the Availability of raw materials to meet consumer demand (Stevenson, Hendry and Kingsman, no date). The tapioca flour production process is controlled by the effectiveness of the cassava milling machine so that flour production is optimal. The amount of ground cassava produced from the machine will determine the amount of cassava yield during the soaking process. The effectiveness of production machines will be influenced by the company's ability to manage machine availability, performance and quality rate (Santosa *et al.*, 2020).

The effectiveness of the cassava milling machine can be analyzed using the Overall Equipment Effectiveness (OEE) method to produce ground cassava. The OEE method will identify the machine's ability in production so that the machine's ability to utilize production time to produce quality products (Husen, Irawan and Ardania, 2020). The results of the OEE analysis on the cassava milling machine can be used to plan the amount of ground cassava production so that SMIs can plan optimal raw material requirements.

The OEE analysis in this study analyses the milling machine's effectiveness. It is used to create an ideal production capacity model by looking at the relationship between cassava production and the OEE value. Regression analysis is used to make relationships between variables in the form of equations so that observations can be made based on the resulting errors (Huang and Hsieh, 2020).

Analysis of ideal production capacity using OEE and regression approaches is an approach that has never been used in previous studies and can be used by SMIs in planning the ideal production capacity of ground cassava based on the effectiveness of production machines. The novelty of this research is the development of a regression model to determine the ideal production amount of ground casava based on OEE values to provide information that supports SMEs in preparing cassava raw materials.

2. METHODS

The research design used was cross sectional, where the data used was secondary data on cassava milling machines in SMIs Bogor Regency. The method used in this study is divided into 2, namely the measurement of the Overall Equipment Effectiveness (OEE) value of the cassava milling machine and the linear regression method to see the relationship between the OEE value and the production of ground cassava. The stages of the research method used are as follows:

1. Availability
   Availability is a measuring tool to see the machine's ability to operate based on the

available effective time. Machine availability considers machine running load time against the amount of unplanned machine downtime (Nakhla and Nakhla, 2018). The formulation of machine availability is as follows: (Nakajima, 1988; Tsarouhas, 2018)

$$\text{Availability} = \frac{\text{Loading Time} - \text{Unplanned Time}}{\text{Loading Time}} \quad (1)$$

2. Performance

   Performance is a measuring tool to see the machine's performance in doing production. The effective use of the production machine time will be compared with the ideal condition of the machine to show the machine's ability to utilize the time available for production. The formulation of engine performance is as follows: (Nakajima, 1988; Tsarouhas, 2018)

$$\text{Performance} = \frac{\text{Cycle Time x Processed Amount}}{\text{Operating Time}} \quad (2)$$

3. Quality Rate
   Quality Rate is a measuring tool to see the machine's ability to produce quality products. The machine's ability to make quality products will be compared with the number of defective goods produced so that the quality of the products produced can be managed properly. The formulation of the machine's Quality Rate is as follows : (Nakajima, 1988; Tsarouhas, 2018)

$$\text{Quality Rate} = \frac{\text{Processed Amount} - \text{Defect}}{\text{Processed amount}} \quad (3)$$

4. Overall Equipment Effectiveness (OEE)
   The effectiveness of the machine can be measured using the OEE method, where this method pays attention to the ability of the machine to operate, the ability of the machine to produce and the ability of the machine to make quality products (Management, 2019). The ideal OEE value based on international standards is 85%. The formulation of OEE is as follows : (Nakajima, 1988; Tsarouhas, 2018)

   OEE = Availability x Performance x Quality Rate (4)

5. Regression
   Regression analysis is used to analyze the relationship between two variables. The regression equation is generated from the intercept and slope values based on the obtained regression relationship. The independent variable (x) will produce the value of the dependent variable (y) from the resulting equation (Di Leo *et al.*, 2020).
6. Hypothesis Test
   Hypothesis testing is used to analyze the relationship between the observed variables using the F Hypothesis Test. In this hypothesis test, the two variables will be analyzed for the feasibility of their relationship by comparing the F test statistics with the resulting critical region so that the hypothesis will be accepted (Kurniawan, 2008).
7. Determination (R^2)
   This test is used to see the relationship between the two observed variables. If the result ≥ 80%, then the two variables have a strong relationship (Kurniawan, 2008)

3. FINDINGS AND DISCUSSION

The object of this research development focuses on one of the small and medium tapioca flour industries in Bogor Regency. The tapioca flour production process is influenced by the ability of the cassava milling machine to produce ground cassava which will be soaked into tapioca flour yield. The capability of this machine must be analyzed to maintain the effectiveness of production so that SMIs can manage machines properly. Small and medium enterprises must carry out an analysis related to the problem of the flour yield produced from the machine's ability to make ground cassava so that the amount of cassava pulp produced can be managed properly.

The cassava milling machine in the tapioca flour production process will process the peeled cassava into a cassava mill which will be put into an immersion bath to produce cassava yield, which will be processed into tapioca flour. The number of cassava mills made by the milling machine is one of the determining factors in determining the amount of cassava yield. The number of cassava mills must be maintained properly.

The capacity of the milling machine must be identified so that SMIs have a production target in the milling process so that the amount of raw material and tapioca flour production can be planned optimally. The Availability of the cassava milling machine can be seen in Table 1.

Table 1 Availability of cassava milling machine

Month	Ground Cassava (kg)	Available Time (Hours)	Planned Downtime (Hours)	Unplanned Downtime (Hours)	Loading Time (Hours)	Operation Time (Hours)	Availability
January	7664,80	30	7	9	23	14	60,87%
February	7845,46	30	6	12	24	12	50,00%
March	8045,39	30	7	9	23	14	60,87%
April	9156,17	30	8	6	22	16	72,73%
May	7222,37	30	6	12	24	12	50,00%
June	7449,90	30	6	12	24	12	50,00%
July	9133,17	30	8	6	22	16	72,73%
August	10603,03	30	9	3	21	18	85,71%
September	9345,16	30	8	6	22	16	72,73%
October	10022,48	30	8	6	22	16	72,73%
November	9083,86	30	8	6	22	16	72,73%
December	8674,09	30	7	9	23	14	60,87%

Based on the Availability of the milling machine, the Average availability value for one year is 0.65 (65%). This condition shows that the milling machine only utilizes 65% of the operation time. The machine loses 35% of the operating time due to the Availability of cassava raw materials that cannot meet the production needs. The machine cannot operate according to the production target.

The production capability of the cassava milling machine is analyzed by looking at the machine's performance in utilizing the time available for production. The results of the performance of the cassava milling machine can be seen in Table 2.

Table 2 Performance results of cassava milling machine

Ground Cassava (kg)	Operation Time (Hours)	Ideal Cycle (Hours/kg)	Performance
7664,80	14	0,00086	47,31%
7845,46	12	0,00074	48,43%
8045,39	14	0,00086	49,66%
9156,17	16	0,00099	56,52%
7222,37	12	0,00074	44,58%
7449,90	12	0,00074	45,99%
9133,17	16	0,00099	56,38%
10603,03	18	0,00111	65,45%
9345,16	16	0,00099	57,69%
10022,48	16	0,00099	61,87%
9083,86	16	0,00099	56,07%
8674,09	14	0,00086	53,54%

Based on the Peformance of the milling machine, the average Performance value for one year is 0.536 (53,6%). The ability of the cassava milling machine to produce quality products is one of the variables used in the OEE calculation. Analysis related to the machine's performance in delivering quality products using the Quality Rate value by comparing the ground cassava production with the resulting cassava milled pulp. The results of the Quality Rate of the cassava milling machine can be seen in Table 3.

Table 3 Quality Rate of cassava milling machine

Month	Ground Cassava (kg)	Ground Cassava Pulp (Kg)	Quality Rate
January	7664,80	795	89,63%
February	7845,46	820	89,55%
March	8045,39	845	89,50%
April	9156,17	975	89,35%
May	7222,37	765	89,41%
June	7449,90	780	89,53%
July	9133,17	980	89,27%
August	10603,03	1050	90,10%
September	9345,16	978	89,53%
October	10022,48	1025	89,77%
November	9083,86	960	89,43%
December	8674,09	910	89,51%

Based on the Quality Rate of the milling machine, the average Quality Rate value for one year is 0.896 (89,6%). The results of the calculation of Availability, Performance, and Quality Rate, it is possible to analyze the effectiveness of the cassava milling machine using Overall Equipment Effectiveness (OEE). This OEE analysis is used to see the ability of the milling machine for one year to take advantage of the production time to produce tapioca flour. The results of the OEE milling machine can be seen in Table 4.

Table 4 OEE results of cassava milling machine

Month	Availability	Performance	Quality Rate	OEE
January	60,87%	47,31%	89,63%	25,81%
February	50,00%	48,43%	89,55%	21,68%
March	60,87%	49,66%	89,50%	27,05%
April	72,73%	56,52%	89,35%	36,73%
May	50,00%	44,58%	89,41%	19,93%
June	50,00%	45,99%	89,53%	20,59%
July	72,73%	56,38%	89,27%	36,60%
August	85,71%	65,45%	90,10%	50,55%
September	72,73%	57,69%	89,53%	37,56%
October	72,73%	61,87%	89,77%	40,39%
November	72,73%	56,07%	89,43%	36,47%
December	60,87%	53,54%	89,51%	29,17%

Based on the analysis of the OEE value of the cassava milling machine, the average OEE value for one year is 31.88%. This condition shows that the effectiveness of the milling machine is very low, so it is necessary to evaluate the optimum machine capacity based on the ideal amount of ground cassava production so that SMIs can plan the readiness of the milling machine for production.

Determination of the ideal production capacity based on the effectiveness of the machine can be done using regression analysis. The regression analysis process uses the Minitab 14 application using the OEE variable and ground cassava (Kg). The regression data input in the Minitab 14 application can be seen in Figure 1.

Worksheet 1 ***

↓	C1-D	C2	C3
	Month	Ground Cassava (kg)	OEE
1	January	7664,8	0,26
2	February	7845,5	0,22
3	March	8045,4	0,27
4	April	9156,2	0,37
5	May	7222,4	0,20
6	June	7449,9	0,21
7	July	9133,2	0,37
8	August	10603,0	0,51
9	Septembe	9345,2	0,38
10	October	10022,5	0,40
11	November	9083,9	0,36
12	December	8674,1	0,29

Figure 1 input regression data in the minitab 14 application

Regression analysis used a significant level (α = 0.05) where the resulting regression equation was used to determine the ideal capacity value of ground cassava based on the OEE value as the independent variable. The results of the production regression analysis and OEE of the cassava milling machine on the Minitab 14 application can be seen in Figure 2.

```
Session

Regression Analysis: Ground Cassava (kg) versus OEE

The regression equation is
Ground Cassava (kg) = 5155 + 11037 OEE

Predictor     Coef  SE Coef      T      P
Constant    5155,2    259,2  19,89  0,000
OEE        11037,5    780,0  14,15  0,000

S = 241,940   R-Sq = 95,2%   R-Sq(adj) = 94,8%

PRESS = 859535   R-Sq(pred) = 93,01%

Analysis of Variance

Source          DF        SS        MS       F      P
Regression       1  11719656  11719656  200,22  0,000
Residual Error  10    585352     58535
Total           11  12305008
```

Figure 2 Results of Regression Analysis

Based on the regression analysis results, the linear regression equation was ground cassava (Kg) = 5155 + 11037 OEE. The regression equation results were tested by hypothesis to see whether there was a relationship between the ground cassava variable (Kg) and the OEE value of the milling machine. The results of the hypothesis test are as follows:

1. H_0 : β_1=0 (There is no relationship between ground cassava and OEE)
2. H_1: $\beta_1 \neq 0$ (There is a relationship between ground cassava and OEE)
3. α = 0,05
4. Critical Area

   V1 = 1

   V2 = 10

   $F_{table\ (0,05\ ;\ 1\ ;\ 10)}$ = 4,96
5. Test Statistics

   Test statistics using the ANOVA method, where the results of F_{count} will be compared with F_{table} to test the hypothesis that will be accepted. The results of the analysis of the F_{count} value in the ANOVA table can be seen in Table 5.

Table 5 F-Test Calculation Results

Source	DF	SS	MS	F_{count}
Regression	1	11.719.656	11.719.656	200,22
Regression Error	10	585.352	58.535	
Total	11	12.305.008		

Based on the results of the F test using the ANOVA table using the Minitab 14 application, the F_{count} = 200.22. The value of F_{count} will be compared with the value of F_{table} to determine which hypothesis will be accepted.

6. Conclusion

   Based on the analysis results, $F_{count} > F_{table}$ is obtained. It can be concluded that Reject H_0 and accept H_1 that there is a relationship between the production of ground cassava and the OEE value of the milling machine.

Based on the hypothesis test results, it was concluded that there was a relationship between the production of ground cassava (Kg) and the OEE value of the milling machine. The next analysis is a determination test (R^2) to see how strong the relationship between the two variables is. The results of the determination test (R^2) = 94.8% showed that there was a strong positive relationship because the R^2 value was > 80%.

The ideal OEE condition of the milling machine can follow the international standard of Seiichi Nakajima, which is 85 %. This value indicates the condition of production resources, and the machine's condition is well maintained to work optimally. Based on the best standard value of OEE value, the ideal capacity that this milling machine can achieve in SMIs is 14,536 kg/month.

4. CONCLUSION AND SUGGESTION

The effectiveness of milling machines in SMIs can determine the ideal production capacity. Based on the analysis results, the ideal capacity model for cassava milling machines in SMIs is ground cassava (Kg) = 5155 + 11037 OEE. Based on the regression model, SMIs can achieve the ideal production capacity of 14,536 kg/month if the OEE value can meet the Seiichi Nakajima standard. This condition can be achieved if SMIs can properly manage the quality of cassava raw materials and carry out planned maintenance of cassava milling machines. Future research to develop a cassava inventory model to support maintain an ideal amount of production capacity base on evaluate suppliers to maintain the availability of cassava raw materials for optimal productionof ground cassava.

ACKNOLEDGEMENT

The author would like to thank the Vocational School of IPB University for supporting this research and IKM tapioca flour for providing meaningful information and data for the completion of this research.

References

Costa, V.C. *et al.* (2020) 'Proposition of Sample Preparation Procedure of Cassava Flour with Diluted Acid Using Mixture Design and Evaluation of Nutrient Profiles by Multivariate Data Analysis', *Food Analytical Methods*, 13(1), pp. 145–154. doi:10.1007/s12161-019-01559-8.

Huang, C.H. and Hsieh, S.H. (2020) 'Predicting BIM labor cost with random forest and simple linear regression', *Automation in Construction*, 118(December 2019), p. 103280. doi:10.1016/j.autcon.2020.103280.

Husen, S., Irawan, S. and Ardania, I. (2020) 'Determination of Overall Equipment Effectiveness Superflex Machine Using Fuzzy Approach', *International Journal Of Artificial Intelligence Reaserch*, 4(2). doi:10.29099/ijair.v4i2.142.

Jodlbauer, H. and Strasser, S. (2019) 'Capacity-driven production planning', *Computers in Industry*, 113, p. 103126. doi:10.1016/j.compind.2019.103126.

Kurniawan, D. (2008) 'Regresi Linier', *Statistic*, pp. 1–6.

Di Leo, S. *et al.* (2020) 'Regression analysis for energy demand projection: An application to TIMES-Basilicata and TIMES-Italy energy models', *Energy*, 196, p. 117058. doi:10.1016/j.energy.2020.117058.

Management, Q. (2019) 'Overall equipment effectiveness measurement of TPM manager model machines in flexible manufacturing environment : a case study of automobile sector Richa Sharma', 26(2), pp. 206–222.

Nakajima (1988) 'Seiichi Nakajima - Introduction to TPM (Total Productive Maintenance) (1988, Productivity Press)'.

Nakhla, M. and Nakhla, M. (2018) 'Designing extended overall equipment effectiveness : application in healthcare operations operations', *International Journal of Management Science and Engineering Management*, 00(00), pp. 1–10. doi:10.1080/17509653.2017.1373377.

Prasara-A, J. and Gheewala, S.H. (2021) 'An assessment of social sustainability of sugarcane and cassava cultivation in Thailand', *Sustainable Production and Consumption*, 27, pp. 372–382. doi:10.1016/j.spc.2020.11.009.

Santosa, S.H. *et al.* (2020) 'Fuzzy Logic Approach to Determine the Optimum Nugget Production Capacity', *Jurnal Ilmiah Teknik Industri*, 19(1), pp. 70–83. doi:10.23917/jiti.v19i1.10295.

Santosa, S.H., Hidayat, A.P. and Siskandar, R. (2021) 'Safea application design on determining the optimal order quantity of chicken eggs based on fuzzy logic', *IAES International Journal of Artificial Intelligence*, 10(4), pp. 858–871. doi:10.11591/ijai.v10.i4.pp858-871.

Stevenson, M., Hendry, L.C. and Kingsman, B.G. (no date) 'International Journal of Production A review of production planning and control : the applicability of key concepts to the make-to-order industry', (July 2013), pp. 37–41. doi:10.1080/0020754042000298520.

Sukara, E., Hartati, S. and Ragamustari, S.K. (2020) 'State of the art of Indonesian agriculture and the introduction of innovation for added value of cassava', *Plant Biotechnology Reports*, 14(2), pp. 207–212. doi:10.1007/s11816-020-00605-w.

Tsarouhas, P. (2018) 'Improving operation of the croissant production line through overall equipment effectiveness (OEE) A case study', *Emerald*, 68(1), pp. 1–22. doi:10.1108/IJPPM-02-2018-0060.