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Quality Engineering for Plantation White Sugar with Taguchi Quality Function Approach – A Case Study in Pg.Xyz

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***Abstract* – Sugar is one of the basic human needs. Sugar consumed daily is Plantation White Sugar (Gula Kristal Putih/GKP). Therefore the role of sugar is very important in human life. As a food product must meet the quality standards that have been set so it is worth to be consumed. Quality engineering in this research is done by using two approaches: Taguchi Quality Loss Function and Capability Process.**
Based on the results of the research on PG.XYZ, sugar quality parameters that are beyond the specification limits of SNI 3140.3: 2010 are the turbidity, the particle size distribution, the polarization and the moisture content. Such deviation causes the hidden cost of losses to be borne by the company due to the non-conformity of value generated by PG.XYZ against SNI 3140.3: 2010. The amount of Quality Loss Function generated PG.XYZ the moisture content losses are in the highest order of Rp.697,244.49 / kg followed by the turbidity Rp. 39,659.45 / kg, polarization Rp.6,758.15 / kg, and particle size distribution Rp. 1,633.71 / kg. Based on the calculation of the ability of the process, then as a whole needs to make improvements to the process of making white crystal sugar and increase the performance of plant equipment.

Keyword:* *Taguchi Quality Loss Function, Capability Process, Plantation White Sugar

I. INTRODUCTION

Sugar is one of the basic human needs as energy for the human body. The function of sugar is as a sweet taste converter for food and drink. As a food product, of course, must meet the quality standards that have been set so it is worth to be consumed and provide benefits for the health of the body. Sugar consumed daily is Plantation White Sugar (Gula Kristal Putih/GKP).

In AFTA (ASEAN Free Trade Agreement), sugar commodity becomes one of commodities that enter into highly sensitive list. In order to compete with imported sugar, Indonesia's production quality requires a significant increase for both the agricultural, industrial or sugar factory, technology and government policy.

The Regulation of the Minister of Agriculture No. 68 / Permentan / OT.140 / 6/2013 concerning Compulsory Enforcement of National Standard of Plantation White Sugar. Based on SNI 3140.3: 2010 Plantation White Sugar, the quality requirements for plantation white sugar can be seen in TABLE I. [1]

Table I. Quality Requirement For Plantation White Sugar Based On Sni 3140.3:2010

No.	Characteristics	Unit	Requirement	
			GKP 1	GKP 2
1.	Colour			
1.1	Crystal colour	CT	4,0 – 7,5	7,6 – 10,0
1.2	Turbidity (ICUMSA)	IU	81 – 200	201 – 300
2	Particle size distribution	mm	0,8 – 1,2	0,8 – 1,2
3	Moisture content (b/b)	%	Max 0,1	Max 0,1
4	Polarization (°Z, 20°C)	"Z"	Min 99,6	Min 99,5
5	Ash Conductivity (b/b)	%	Max 0,10	Max 0,15
6	Food Additives			
6.1	Sulphur dioxide (SO_2)	mg/kg	Maks 30	Max 30
7	Metal Contaminants			
7.1	Lead (Pb)	mg/kg	Max 2	Max 2
7.2	Copper (Cu)	mg/kg	Max 2	Max 2
7.3	Arsenic (As)	mg/kg	Max 1	Max 1

PT.XYZ is one of the sugar factories in Indonesia which was established as one of the realization of the sugar industry development target set by the government in order to achieve national sugar self-sufficiency. Based on the Regulation of the Minister of Trade No.24 / M-DAG / PER / 4/2016 concerning Standardization of Trade Sector regulating the supervision of compulsory SNI for domestic production or imported goods traded domestically, PG.XYZ shall pay attention to the quality of plantation white sugar produced.

Plantation white sugar is said to have met the quality if the value of test parameters meets the value of test parameters listed in SNI 3140.3: 2010 (TABLE I). The deviation of the test parameter values creates hidden quality costs including consumer dissatisfaction, loss of market share, and the cost of product repairs.

To calculate the hidden losses of plantation white sugar produced by PT.XYZ, the researcher calculated using both approaches of Taguchi Quality Loss Function and Capability Process. Taguchi defines this hidden quality cost as: A number of losses that arise and should be borne by the company if the resulting product deviates from the target value, even though the product is within the limits of the resulting product specification. [2]

Capability Process is a calculation through the comparison between product output with design specifications. If the equipment has the ability to consistently meet the range of expected quality range, then the quality and cost of production can be optimal.

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II. RESEARCH METHOD

Methodological steps in this research are as follows: (Figure 1.)

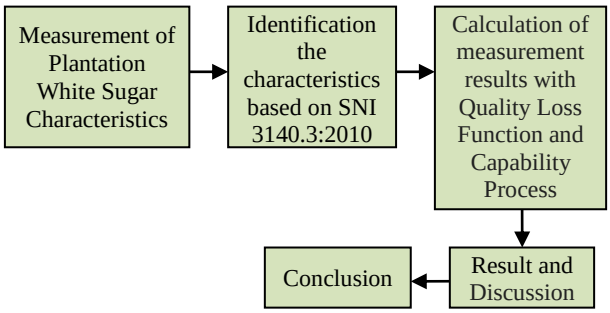

Figure 1. Steps of Research Methodology

III. RESULT AND DISCUSSION

A. *Results of Plantation White Sugar Measurement*

Based on the laboratory test result of plantation white sugar, the results obtained that from 10 (ten) test parameters there are 4 (four) test parameters that are not in accordance with requirements of GKP 2. The test parameters that do not meet the requirements are shown in TABLE II.

B. *Identification the characteristics based on SNI 3140.3:2010*

Based on the result of the test, the turbidity test parameter is the top of the GKP 2 deviation followed by the particle size distribution, the polarization and the moisture content. The effect of the turbidity, the particle size distribution, the polarization and the moisture content to Plantation White Sugar quality is shown in TABLE III 3.[3][4]

TABLE III. EFFECT CHARACTERISTICS TO PLANTATION WHITE SUGAR QUALITY

No.	Characteristic	Effect to Plantation White Sugar Quality
1.	Turbidity	Turbidity that indicates the purity and the amount of dirt (clarity of sugar solution) contained in the sugar. This parameter is very useful to determine the price of sugar and is needed by the sugar processor to be further processed into pure sugar (refined sugar).
2.	Particle size distribution	The particle size distribution of plantation white sugar will affect the process of storing sugar. Small size of plantation white sugar will absorb more moisture.
3.	Polarization	Polarization shows the level of sucrose contained in the sugar. The higher the polarization value the higher the sugar content.
4.	Moisture content	The moisture content will accelerate the growth of microorganisms, color changes and clumps that will affect the decrease of sugar quality.

C. *Quality Loss Function*

Evaluate the quality level of products using the loss function approach with three types of tolerance:[5]

1. *The-Nominal-The-Best (N Type).*
   a. When Two-Way Tolerance is Equally Large.

The formula used to determine the loss function is as follows:

$$k = \frac{A}{\Delta^2} \quad (1)$$

$$L = \frac{A}{\Delta^2} v^2 \quad \text{..... (2)}$$

$$\hat{v}^2 = \frac{1}{n}[(y_1 - m)^2 + (y_2 - m)^2 + \cdots + (y_{1n} - m)^2] \quad (3)$$

Information:

2Δ = tolerance limit

A = the cost incurred due to the resulting product does not match the specified target

k = cost coefficient

v^2 = mean square deviation of product value from the target value m.

L = quality level or loss function

M = target

y = characteristic value

b. When Plus and Minus Tolerances Are Not Equally Large.

The formula used to determine the loss function is as follows:

$$k = \frac{A}{\Delta^2} \quad (4)$$

$$L(y) = \left[\frac{A_1}{\Delta^2{}_1}\Sigma' (y - m)^2\right] \qquad if\ y \le m \quad (5)$$

$$L(y) = \left[\frac{A_2}{\Delta^2{}_2}\Sigma'' (y - m)^2\right] \qquad if\ y > m \quad (6)$$

$$L = \frac{1}{n}\left[\frac{A_1}{\Delta^2{}_1}\Sigma' (y - m)^2 + \frac{A_2}{\Delta^2{}_2}\Sigma'' (y - m)^2\right] \quad \text{..... (7)}$$

2. *The-Smaller-The-Better (S Type).*

The formula used to determine the loss function is as follows:

$$k = \frac{A}{\Delta^2} \quad (8)$$

$$L = \frac{A}{\Delta^2}\hat{v}_1{}^2 \quad (9)$$

$$\hat{v}_1{}^2 = \frac{1}{n_1}\Sigma(y^2{}_i) \quad (10)$$

3. The-*Larger-The-Better (L Type).*

The amount of loss caused by the deviation of the y data on the target value is shown in Figure 5. The formula used to determine the loss function is as follows:

$$k = \frac{A}{\Delta^2} \quad (11)$$

$$L = A\Delta^2\hat{v}^2 \quad (12)$$

$$\hat{v}^2 = \frac{1}{n_1}\Sigma\frac{1}{y^2{}_i} \quad (13)$$

D. *Capability Process* [6]

1. Process Capability Index, Cp.

$$C_p = \frac{USL - LSL}{6\sigma} \quad (14)$$

Cp criteria, as follows:

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Cp > 1.33	Capability process is very good.
1,00 ≤ Cp ≤ 1.33	Capability process is good, but it needs strict control when Cp approaches 1.00.
Cp < 1	Capability process is low, performance needs to be improved through process improvement.

2. Kane Performance Index, Cpk.

$$C_{pk} = min\left(\frac{USL-\bar{X}}{3\sigma}, \frac{\bar{X}-LSL}{3\sigma}\right) \quad (15)$$

Cpk criteria, as follows:

Cpk < 1	The process still produces products that deviate from the specification
Cpk > 1	The process has produced the product in accordance with the specifications.
0 ≤ Cpk ≤ 1	The average process is within the specification limit but there are still those outside of the specification.
Cpk = Cp	The average process is on the specification value

3. Process Capability Index Cpm (Taguchi Capability Index)

$$C_{pm} = \frac{USL-LSL}{6\sqrt{\sigma^2+(\bar{X}-T)^2}} \quad (16)$$

Cpm criteria, as follows:

Cpm ≥ 2,00	The process is considered capable and competitive.
1,00 ≤ Cpm ≤ 1,99	The process is considered to be quite capable, but it is necessary to improve the quality
Cpm < 1,00	The process is considered incapable and uncompetitive

E. Result and Discussion

1. Quality Loss Function

The result of Quality Loss Function calculation is shown in TABLE IV.

TABLE IV. THE RESULT OF QUALITY LOSS FUNCTION CALCULATION

No.	Characteristics	Loss Function (Rp/Kg)			
		Turbidity	Particle size distribution	Polarization	Moisture content
1.	Turbidity (*Capability Process*) Target ≤ 300 IU	39,659.45			
2.	Particle size distribution (*The Nominal The Best)* 0.8 < Target < 1.22 mm		1,633.71		
3.	Polarization (*The Larger The Better)* Target ≥ 99.5 "Z:			6,758.15	
4.	Moisture content (*The Nominal The Best)* 0.03 < Target < 0.05%				697,244.49

2. Capability Process

Capability Process calculation results are shown in TABLE V.

IV.CONCLUSION

The result of measurement of plantation white characteristic, the turbidity is in the order of the most inconsistency with the requirements of GKP 2 followed by the type of particle size distribution, the polarization and the moisture content. Based on the calculation of quality loss function, moisture content losses are in the highest order of Rp.697,244.49/ kg followed by the turbidity Rp. 39,659.45/kg, polarization Rp.6,758.15/kg, and particle size distribution Rp. 1,633.71/kg. This is due to the greater deviation of the value generated from the target, the hidden quality cost will be greater even though the value is still within the limits of GKP 2 requirements.

Judging from the calculation of overall process capability for Cp value, low capability process, performance needs to be improved through process improvement. For Cpk value, production process still produce product not yet according to specification. For Cpm value, process is considered incapable and uncompetitive.

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TABLE V. CAPABILITY PROCESSCALCULATION RESULTS

Characteristics Specifications		The Result Cp	CpK	CpM	Analysis
Turbidity (IU)	m_1 = 201	0.227	-1.606	0.036	Capability process is low, The process still produces products that deviate from the specification, The process is considered incapable and uncompetitive
	m_2 = 300	0.227	-1.606	0.046	
Particle size distribution (mm)	m_1 = 0,8	1.021	-0.540	0.537	Capability process is good, The process still produces products that deviate from the specification, The process is considered incapable and uncompetitive
	m_2 = 1,2	1.021	-0.540	0.131	
Polarization (%)	m_1 = 0,03	0.033	-0.308	0.022	Capability process is low, The process still produces products that deviate from the specification, The process is considered incapable and uncompetitive
	m_2 = 0,05	0.033	-0.308	0.024	
Moisture content ("Z")	m_1 = 99,5	0.033	-0.600	0.218	Capability process is low, The process still produces products that deviate from the specification, The process is considered incapable and uncompetitive
	m_2 = 100	0.033	-0.600	0.098	

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TABLE II. RESULTS OF PLANTATIONT WHITE SUGAR MEASUREMENT

No.	Turbidity (IU)	Particle size distribution (mm)	Moisture content (%)	Polarization ("Z")	No.	Turbidity (IU)	Particle size distribution (mm)	Moisture content (%)	Polarization ("Z")
1	748.05*	0.75*	0.30*	99.20*	40	822.80*	0.59*	0.10	98.90*
2	987.70*	0.60*	0.36*	99.10*	41	743.70*	0.68*	0.10	99.00*
3	946.10*	0.53*	0.10	99.30*	42	565.70*	0.70*	0.06	99.40*
4	825.10*	0.53*	0.14*	99.00*	43	519.90*	0.69*	0.06	99.00*
5	583.20*	0.76*	0.80*	98.90*	44	811.90*	0.75*	0.08	98.70*
6	524.40*	0.76*	0.04	99.60	45	912.00*	0.68*	0.06	99.00*
7	578.40*	0.74*	0.03	99.40*	46	688.40*	0.64*	0.10	99.20*
8	612.80*	0.76*	0.04	99.40*	47	619.60*	0.69*	0.08	99.10*
9	609.50*	0.67*	0.04	99.20*	48	537.80*	0.70*	0.06	99.30*
10	536.40*	0.64*	0.06	99.40*	49	495.30*	0.59*	0.60	99.10*
11	543.90*	0.75*	0.18*	99.60	50	553.20*	0.74*	0.08	99.20*
12	515.50*	0.84	0.04	99.60	51	667.00*	0.61*	0.09	99.00*
13	524.40*	0.89	0.06	99.50	52	654.40*	0.66*	0.08	98.70*
14	520.00*	0.80	0.06	99.40*	53	770.50*	0.58*	0.14	98.80*
15	452.40*	0.85	0.04	99.50	54	645.60*	0.66*	0.10	99.50
16	467.20*	0.82	0.06	99.60	55	737.60*	0.66*	0.20	99.00*
17	461.90*	0.78*	0.08	99.30*	56	685.40*	0.74*	0.13	98.90*
18	440.40*	0.92	0.04	99.40*	57	656.21*	0.66*	0.07	99.10*
19	445.70*	0.77*	0.06	99.50	58	691.04*	0.74*	1.00	99.20*
20	470.10*	0.69*	0.04	99.60	59	578.38*	0.68*	0.22	99.30*
21	436.50*	1.00	0.04	99.50	60	588.05*	0.71*	0.22	99.10*
22	586.40*	0.73*	0.08	99.40*	61	575.60*	0.77*	0.14	99.10*
23	597.90*	0.88	0.04	99.50	62	614.50*	0.75*	0.10	98.80*
24	409.50*	0.74*	0.04	99.50	63	735.60*	0.71*	0.15	99.00*
25	533.30*	0.84	0.04	99.30*	64	770.50*	0.64*	0.08	98.90*
26	694.80*	0.69*	0.08	98.90*	65	640.30*	0.67*	0.08	99.30*
27	612.90*	0.62*	0.08	99.20*	66	596.20*	0.56*	0.10	98.90*

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TABLE II. RESULTS OF PLANTATIONT WHITE SUGAR MEASUREMENT

No.	Turbidity (IU)	Particle size distribution (mm)	Moisture content (%)	Polarization ("Z")	No.	Turbidity (IU)	Particle size distribution (mm)	Moisture content (%)	Polarization ("Z")
28	589.70*	0.69*	0.06	99.30*	67	683.00*	0.59*	0.08	98.80*
29	906.80*	0.70*	0.04	99.20*	68	781.00*	0.72*	0.10	98.90*
30	764.20*	0.60*	0.06	99.30*	69	816.10*	0.66*	0.16	98.70*
31	727.70*	0.68*	0.06	99.20*	70	661.60*	0.67*	0.10	99.00*
32	896.70*	0.65*	0.08	99.30*	71	674.30*	0.63*	0.10	98.70*
33	881.90*	0.69*	0.06	98.90*	72	658.50*	0.65*	0.09	99.00*
34	904.30*	0.65*	0.54*	98.50*	73	652.60*	0.60*	0.08	99.20*
35	626.40*	0.59*	0.08	99.10*	74	499.60*	0.62*	0.06	99.20*
36	770.50*	0.64*	0.12*	99.00*	75	511.10*	0.73*	0.08	99.30*
37	827.40*	0.57*	0.10	99.00*	76	533.30*	0.71*	0.10	99.00*
38	906.80*	0.56*	0.11*	98.90*	77	573.60*	0.59*	1.40	99.90*
39	729.70*	0.67*	0.08	99.10*					

* Test results not complying with the requirements of GKP 2 based on SNI 3140.3: 2010