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Optimization of Tobacco Warehouse Temperature to Reduce Defects in Hand-Rolled Kretek Cigarette Products at PT XYZ

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Abstract. The quality of tobacco is a critical component in cigarette production, with moisture content standards ranging from 18% to 19% to prevent production issues caused by tobacco being too dry or too moist. At PT XYZ, a cigarette manufacturing company, storage room temperature was identified as a key factor affecting tobacco moisture content. This study aimed to determine the optimal storage room temperature to maintain tobacco quality using quality control techniques and experimental design. A correlation test revealed a very strong negative relationship (91.812%) between storage room temperature and tobacco moisture content. Using a Completely Randomized Design (CRD) and a one-way ANOVA test, the analysis showed that the storage room temperature significantly impacted moisture content. The optimal temperature for maintaining tobacco quality was found to be 21˚C. These findings underscore the importance of precise temperature control in ensuring tobacco quality, contributing to improved production processes and product consistency in the cigarette industry.

Keywords: Correlation; One-Way ANOVA; Optimization; Warehouse Temperature

1. Introduction

PT XYZ is a cigarette company established in 1946 in East Java, Indonesia. It is known as the oldest producer of hand-rolled kretek cigarettes. The manual rolling process requires workers to meet standards such as weight, diameter, density, and appearance of the cigarettes. The factors that influence the occurrence of defective and damaged products in the production process include human factors, machinery, and raw materials (Suharyanto *et al.*, 2022). The main raw material for cigarette production is tobacco. The quality of raw materials is determined by obtaining materials from nature or from suppliers that have been quality-tested (Erdi & Haryanti, 2023). One of the problems with tobacco in PT XYZ was that the moisture content of the tobacco did not meet the established standard. The moisture content that is above or below the standard can cause a decrease in cigarette quality. One of the factors that influences the moisture content of the tobacco at PT XYZ was the temperature of the tobacco storage room.

Therefore, the research was conducted to address the issue of tobacco moisture content due to temperature factors, using quality control techniques and experimental design. Experimental

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design involves conducting activities by applying treatments to an object to determine the effect of these treatments on other factors under controlled conditions (Sugiyono, 2012). The research used an experimental design with the One-Way ANOVA method. The Analysis of Variance (ANOVA) is a test that can be used to analyze the differences among more than two independent population groups (Rahmawati & Erina, 2020). ANOVA was used to find the optimal setting level to minimize variation deviations. One-Way ANOVA is an analysis of variance that results from the effect of a single factor (Rahmattulah & Khaerudin, 2020).

2. Method

The research method conducted at PT. XYZ involves specific steps. The data used consists of primary data. Primary data was obtained through field observations, research, and interviews with the Quality Control department. The steps for problem-solving in this research are as follows.

2.1. Correlation Test

The correlation test is used to find evidence of whether there is a correlation between variables, to assess the strength of the relationship between variables, and to gain clarity and certainty about whether the relationship is significant or not (Wulansari, 2019). If the correlation coefficient is close to the value of one, the correlation between the two variables will be stronger (Morris, 2020). The variables tested in this research were warehouse temperature and tobacco moisture content. Correlation analysis is a statistical method used to determine the magnitude that indicates a strong relationship between one variable and another (Uma & Roger, 2016). The formula for the correlation coefficient can be seen in formula (1) to (4).

1. $r = \frac{s_{xy}}{\sqrt{s_{xx}s_{yy}}}$ (1)
2. $s_{xx} = \sum x^2 - (\frac{(\sum x^2)}{\text{Number of data points x}})$ (2)
3. $s_{yy} = \sum y^2 - (\frac{(\sum y^2)}{\text{Number of data points y}})$ (3)
4. $s_{xy} = \sum xy - (\frac{(\sum x)(\sum y)}{\text{Number of data points xy}})$ (4)

2.2. Determining Factors and Levels of Experimental Factors

The factors and levels of experimental factors were determined to identify the factors and levels that would be used for the experiment with the assistance of the Quality Control department of PT. XYZ.

2.3. Creating Randomization and Layout of Completely Randomized Design Experiment

Completely Randomized Design (CRD) is the simplest design among standardized experimental designs (Riadi et al., 2021). The creation of the layout of the CRD experiment begins with determining the number of factors, levels, and replications. Next is the randomization stage. This design is called "randomized" because each experimental unit has an equal chance of receiving a treatment, and it is referred to as "completely" because all treatments planned in the experiment are utilized (Hasdar *et al*., 2021). Randomization can be done by drawing lots or using random number tables.

2.4. One-Way ANOVA

ANOVA stands for Analysis of Variance, which is a statistical analysis used to test the differences in means among more than two populations. ANOVA that used a single factor is called One-Way ANOVA (Suharjo, 2008). The final result of the ANOVA analysis was the computed F value. This computed F value was then compared with the value in the F table. If the computed F value was greater than the F table value, it could be concluded that the null hypothesis (H0) was rejected and the alternative hypothesis (H1) was accepted, indicating a significant difference in means among all groups. ANOVA calculations were performed using Minitab version 19 application.

2.5. Fisher’s Least Significant Difference (LSD) Test

After the ANOVA calculation was performed, it was followed by the Fisher's LSD test. The Fisher's LSD test was used to test the differences among the means of the simplest and most commonly used treatments (Rahmadeni et al., 2019). This test also utilized the Minitab version 19 application.

3. Results and Discussion

3.1. Measurement of Correlation between Warehouse Temperature and Tobacco Moisture Content

Based on the brainstorming conducted with the Quality Control department, one factor that could influence the moisture content of tobacco was identified as the temperature of the tobacco warehouse. Before the research was conducted, it was necessary to provide evidence to determine whether there was a correlation between the warehouse temperature and the tobacco moisture content. Room temperature and tobacco moisture content data in SKT for 30 days is shown in Table 1.

Table 1 Room Temperature and Tobacco Moisture Content in SKT

No	Date	Tobacco Room Temperature (˚C)	Tobacco Moisture Content (%)
1	14 August 2023	30,3 ˚C	17,6%
2	15 August 2023	31,5 ˚C	17%
3	16 August 2023	30,9 ˚C	17,3%
4	18 August 2023	31,7 ˚C	16,9%
5	19 August 2023	31,9 ˚C	16,7%
6	21 August 2023	31,7 ˚C	16,8%
7	22 August 2023	31,8 ˚C	16,9%
8	23 August 2023	32,7 ˚C	15,8%
9	24 August 2023	32,6 ˚C	16,2%
10	25 August 2023	32,4 ˚C	16,6%
11	26 August 2023	32,1˚C	16,7%
12	28 August 2023	32,7˚C	15,9%
13	29 August 2023	32,1˚C	16,8%
14	30 August 2023	32,2˚C	16,8%
15	31 August 2023	32,8˚C	15,5%
16	1 September 2023	30,3˚C	17,4%
17	2 September 2023	30,4˚C	17,2%
18	4 September 2023	31,5˚C	16,9%
19	5 September 2023	31,2˚C	17%
20	6 September 2023	30,9˚C	17,1%
21	7 September 2023	30,5˚C	17,5%
22	8 September 2023	30,6˚C	17,3%
23	9 September 2023	30,4˚C	17,4%
24	11 September 2023	29,6˚C	17,7%
25	12 September 2023	29,4˚C	17,8%
26	13 September 2023	31,5˚C	16,8%
27	14 September 2023	31˚C	17%
28	15 September 2023	31,7˚C	16,5%
29	16 September 2023	30,7˚C	17,1%
30	18 September 2023	31,6˚C	16,7%

Based on Table 1, the correlation between warehouse temperature and tobacco moisture content was calculated. The correlation was as follows:

1. Sxx

$$Sxx = \sum x^2 - \left(\frac{(\sum x)^2}{Number\ of\ data\ point\ x}\right)$$
$$Sxx = \sum 29521{,}61 - \left(\frac{(940{,}7)^2}{30}\right)$$
$$Sxx = 24{,}39367$$

2. Syy

$$Syy = \sum y^2 - \left(\frac{(\sum y)^2}{Number\ of\ data\ point\ y}\right)$$
$$Syy = \sum 8573{,}31 - \left(\frac{(506{,}9)^2}{30}\right)$$
$$Syy = 8{,}389667$$

3. Sxy

$$Sxy = \sum xy - \left(\frac{(\sum x)(\sum y)}{Number\ of\ data\ point\ xy}\right)$$
$$Sxy = \sum 15881{,}56 - \left(\frac{(940{,}7)(506{,}9)}{30}\right)$$
$$Sxy = -13{,}1343$$

4. r

$$r = \frac{Sxy}{\sqrt{Sxx\ Syy}}$$
$$r = \frac{-13{,}1343}{\sqrt{(24{,}39367)(8{,}389667)}}$$
$$r = -0{,}91812$$

Based on the calculation, the value of r was -0.91812 or -91.812%, indicating a negative correlation between warehouse temperature and tobacco moisture content by 91.812% (very strong). The negative correlation indicated that as the temperature of the tobacco storage warehouse increased, the tobacco moisture content decreased.

3.2. Experimental Planning

Experimental planning was carried out as the initial stage or preparation stage in the Experimental Design method. This initial stage was crucial to ensure the smooth execution of the experiment. Several steps were involved in experimental planning, starting from data collection to creating the layout of the experiment using the Completely Randomized Design (CRD) method.

3.3. Determining Experimental Factors

The determination of experimental factors aimed to identify which factors would be used for the experiment. After discussing with the Quality Control department of PT. XYZ, it was found that one factor influencing the moisture content of tobacco was the temperature of the tobacco warehouse. If the temperature of the tobacco storage room rose, the moisture content of the tobacco would decrease, leading to dry tobacco that was difficult to process into cigarettes. Dry tobacco could also cause defects in cigarettes.

3.4. Creating Factor Levels

At this stage, levels or parameters were established for the factors determined in the previous stage. The determination of levels was done with the assistance of the Quality Control department of PT. XYZ. The factor levels that had been established could be seen in Table 2.

Table 2 Experimental Factor Levels

Factor	**Levels**		
	1	2	3
Warehouse Temperature	18° C	21° C	24° C

From Table 2, it could be seen that there were three levels to be used for the experiment. Each level represented the AC temperature to be used in the experiment to observe its effect on tobacco moisture content. These levels were chosen assuming that if the temperature was too cold or too hot, it would cause a decrease in tobacco moisture content, resulting in dry tobacco. Therefore, the selection of the appropriate temperature level was crucial to maintain the tobacco moisture content according to the company's standard. This research also involved replication six times to ensure the accuracy and precision of the obtained results.

3.5. Creating Randomization and Layout of Completely Randomized Design (CRD) Experiment

The final stage in experimental planning was to create randomization and the layout of the experiment using the Completely Randomized Design method. This research utilized randomization and the layout of the experiment using the CRD method because the data in this experiment were homogeneous and it was assumed that there was no influence of different days on the experiment results. Creating the layout of the CRD experiment began with determining the number of factors, levels, and replications. This determination had been made in the previous stage where this research consisted of one factor, three levels, and six replications. After the factors, levels, and replications had been determined, the next stage was randomization. Through randomization, each experimental unit had an equal chance of receiving a treatment. Randomization could be done by drawing lots or using random number tables. Table 3 showed the layout of the one-factor, three-level, and six-replication experimental design from the randomization results using a random number table.

Table 3 Layout of Completely Randomized Design Experiment with 3 levels and 6 replications

1. 18°C	2. 21°C	3. 24°C
4. 18°C	5. 21°C	6. 21°C
7. 24°C	8. 21°C	9. 24°C
10. 24°C	11. 18°C	12. 24°C
13. 21°C	14. 18°C	15. 18°C
16. 24°C	17. 18°C	18. 21°C

It can be observed that experimental units with numbers 1, 4, 11, 14, 15, and 17 received treatment at 18°C, units with numbers 2, 5, 6, 8, 13, and 18 received treatment at 21°C, and units with numbers 3, 7, 9, 10, 12, and 16 received treatment at 24°C.

3.6. Experiment Execution

The experiment execution phase was carried out according to the previous planning. As per the designated notation, the number of experiments conducted in this study was 18. The experiments were conducted according to the layout of the experiment previously created, as shown in Table 3. The AC temperature in the tobacco warehouse was set according to the level being tested. The experiment began by setting the AC temperature in the tobacco warehouse in the morning according to the experimental level for that day. Subsequently, the tobacco moisture content was checked and recorded regularly at 9 a.m., 12 p.m., and 3 p.m. The recording three times a day aimed to obtain the average tobacco moisture content for that day, resulting in more accurate results.

During the experiment, the tobacco moisture content was checked using a moisture meter. The results of the checks appeared as numerical values and were recorded as testing data. The results of the tobacco moisture content testing for each experiment can be seen in Table 4.

Table 4 Results of Tobacco Moisture Content Testing

Experiment	Tobacco Room Temperature (˚C)	Tobacco Moisture Content (%)			
		09.00 AM	12.00 PM	03.00 PM	Means
1	18˚C	18%	18,5%	18,3%	18,26%
2	21˚C	18,6%	18,4%	18,7%	18,56%
3	24˚C	18,5%	17,8%	17,6%	17,96%
4	18˚C	18,2%	18,5%	18,5%	18,4%
5	21˚C	19%	18,6%	18,7%	18,76%
6	21˚C	18,8%	18,2%	18,4%	18,46%
7	24˚C	18,6%	17,7%	17,9%	18,06%
8	21˚C	18,6%	18,2%	18,4%	18,4%
9	24˚C	18,3%	17,8%	17,9%	18%
10	24˚C	18,5%	17,9%	18%	18,13%
11	18˚C	17,8%	18,3%	18,2%	18,1%
12	24˚C	18,6%	17,8%	17,9%	18,1%
13	21˚C	18,7%	18,4%	18,8%	18,63%
14	18˚C	18,2%	18,6%	18,5%	18,43%
15	18˚C	18%	18,4%	18,2%	18,2%
16	24˚C	18,2%	17,7%	17,9%	17,93%
17	18˚C	18,1%	18,5%	18,4%	18,33%
18	21˚C	18,7%	18,1%	18,3%	18,36%

3.7. Data Processing of Experimental Results

The data obtained from the experiments was analyzed and calculated using ANOVA to determine whether the temperature factor influences tobacco moisture content. After conducting the ANOVA analysis, if the results indicate that there was an effect of the temperature factor on the tobacco moisture content, the Fisher's test would be conducted to determine which levels have a significant effect on tobacco moisture content.

3.8. ANOVA

In this section, hypothesis testing was conducted regarding the average tobacco moisture content factor used in the experiment. The six steps of hypothesis testing used in decision-making in this research was as follows.

1. H0 : There is no effect of warehouse temperature on tobacco moisture content.
   H1 : Warehouse temperature affects tobacco moisture content.
2. α : 0,05 or 5%
3. CR : P-value < α
4. The ANOVA calculation was conducted using Minitab version 19. The ANOVA results for the average moisture content can be seen in Figure 1.

Analysis of Variance

Source	DF	Seq SS	Contribution	Adj SS	Adj MS	F-Value	P-Value
suhu	2	0.7452	76.86%	0.7452	0.37262	24.91	0.000
Error	15	0.2244	23.14%	0.2244	0.01496		
Total	17	0.9696	100.00%				

Figure 1 The ANOVA for the average moisture content.

   P-Value : 0
5. Decision : Reject H0, because P-value < α or 0 < 0,05

6. Conclusion : P-value < α, Then H_0 is rejected, meaning that the warehouse temperature has an influence on the tobacco moisture content, and the difference among treatments is highly significant.

Based on the hypothesis testing conducted, it was concluded that the warehouse temperature factor used in the experiment significantly affects the tobacco moisture content. This can be observed from the P-value, which was smaller than 0.01, indicating a highly significant difference. The determination of the value of α depends on the confidence interval to be used, which is 95%. This means that if the confidence interval used is 95%, then the level of error or significance (α) used to find the F-value is 0.05. In this study, a confidence interval of 95% was used, implying that the tolerated level of error was 5%. On the other hand, this also meant that the research results have a 95% chance of being correct.

The determination of the effect of warehouse temperature on tobacco moisture content can also be seen from the calculated F-value and the tabulated F-value. If the calculated F-value is greater than the tabulated F-value, then reject H0. The tabulated F-value is determined using the F-table with the degrees of freedom for treatment being 2 (f1) and the degrees of freedom for error being 15 (f2). The tabulated F-values for degrees of freedom 2 and 15 (f1 = 2 and f2 = 15) at 5% and 1% significance levels are 3.68 and 6.36, respectively. If using the formula in Microsoft Excel, the formula entered would be FINV(α; df1; df2). The main effect plot results can be seen in Figure 2.

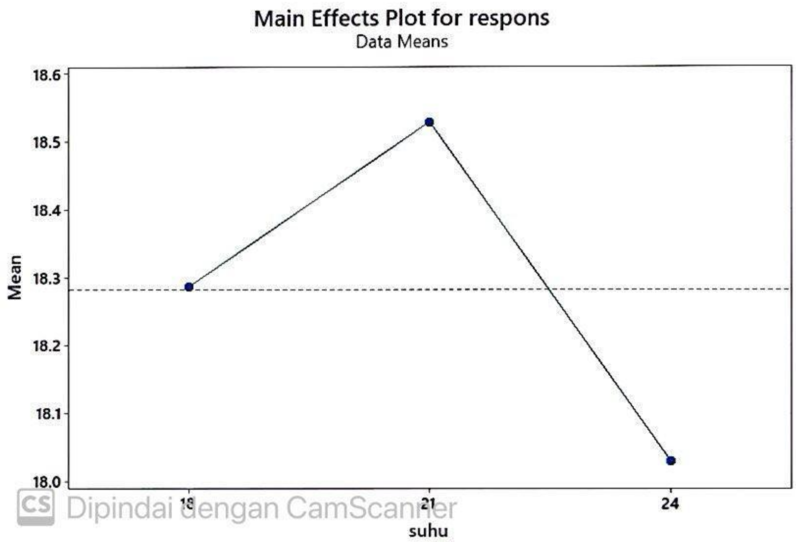

Figure 2 Main Effect Plot of Means

From Figure 2, it can be observed that when the warehouse temperature was 18°C, the average tobacco moisture content was at 18.2867%. Then, when the warehouse temperature rose to 21°C, the average tobacco moisture content also increased to 18.5283%. When the warehouse temperature was further increased to 24°C, the average tobacco moisture content decreased to 18.03%.

3.9. Fishers' Least Significant Difference (LSD) Test

After conducting the ANOVA calculation, the analysis continues with Fisher's LSD test to examine the differences among the simplest and most commonly used treatment means. The confidence interval used in this Fisher's test is 95%. This means that the research results have a 95% chance of being correct. The results of the Fisher's LSD test using Minitab version 19 can be seen in Figure 3.

Fisher Pairwise Comparisons: perlakuan

Grouping Information Using Fisher LSD Method and 95% Confidence

perlakuan	N	Mean	Grouping		
2	6	18.5283	A		
1	6	18.2817		B	
3	6	18.0300			C

Means that do not share a letter are significantly different.

Figure 3 Fisher's Test for Average Moisture Content

Based on Figure 3, it can be observed that all treatments differed significantly. Each treatment had a different letter, indicating a significant difference.

3.10. Determination of Optimal Level Setting

The determination of optimal level settings was conducted using Minitab version 19. The results of the optimal level setting can be seen in Figure 4.

Solution

Solution	suhu	respons Fit	Composite Desirability
1	21	18.5283	0.943333

Figure 4 Optimal Level Setting

Based on Figure 4, it was observed that the most optimal level was the warehouse temperature with an AC setting of 21°C. The Fit Response was determined not based on the "larger the better" or "smaller the better" criteria, but according to the company's standard, which specified a tobacco moisture content of 18% to 19%. Therefore, the middle value of 18.5% was selected. From Table 4, the experimental data results showed that at a temperature level of 21°C, the tobacco moisture content ranged from 18.1% to 19%, indicating that the tobacco moisture content was within the company's standard humidity range of 18% to 19%. Conversely, at a temperature level of 18°C, the tobacco moisture content ranged from 17.8% to 18.6%, indicating that some tobacco moisture content was below the company's standard. Similarly, at a temperature level of 24°C, the tobacco moisture content ranged from 17.6% to 18.6%, indicating that some tobacco moisture content was below the company's standard. Therefore, it was concluded that the most optimal tobacco warehouse temperature was the warehouse with an AC temperature of 21°C.

4. Conclusion

The correlation between tobacco warehouse temperature and tobacco moisture content had the value r of -0.91812 or -91.812%, indicating that the correlation was negatively correlated (very strong). The negative correlation indicated that the higher the tobacco warehouse temperature, the lower the tobacco moisture content. After establishing that there was a correlation between tobacco warehouse temperature and tobacco moisture content, an experiment was conducted using the RAL experimental design method and analyzed using ANOVA and Fisher's LSD test. It was found that the tobacco warehouse temperature significantly affected the tobacco moisture content, and the optimal AC temperature to maintain tobacco quality was 21°C.

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