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ANALYSIS OF THE IMPLEMENTATION OF STATISTICAL QUALITY CONTROL IN QUALITY CONTROL OF ARABICA COFFEE PRODUCTION PROCESS (A Case Study at PT. XYZ, Madiun Regency)

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ABSTRACT

The purposes of this study are to identify the quality control of Arabica's production process, to determine the factors causing mismatches in the production process, and to formulate the strategies in improving Arabica A/WP 1 L's product quality at PT. XYZ. The quality control uses Statistical Quality Control method with a variety of attributes. The study revealed that the quality control was in controlled conditions since the p-chart shown that the number of actual data samples were in the statistical control range with the value of 0.3206 for UCL and 0.1714 for LCL. Type of mismatch that had significant influence occurred in grain patterned coffee with a value of 869. Besides, the highest percentage of mismatches were patterned grain by 29.4%, perforated grain by 27.3%, and the outer skin with the small size by 26.6%, with the cumulative percentage was 83.3%. The factors affecting the mismatches were human, machine, method, raw material, and the environment. Thus, the proposed improvement strategies for the company are technical training, intensive sanitation scheduling, the Standard Operation Procedures formulation especially for the separation station (vis pulper and huller). Tempering HS dried coffee implementation, selective sorting of the coffee float on siphon tub, and adding 4 pieces LED lamp with power 40 watt as well as fan as the air conditioner.

Keywords: Coffee Arabica; Pareto; p-chart; Statistical Quality Control.

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INTRODUCTION

One important aspect of a product component is quality. Product quality has become one of the key decision-making factors for customers when selecting a product. Therefore, quality improvement programs must be integral to an overall business strategy. Based on Total Quality Management (TQM), the most effective way to improve product or service quality is by managing the production process and minimizing the causes of product nonconformities as much as possible.

Indonesia is an agrarian country with several agricultural subsectors, one of which is plantations. Coffee is one of the plantation subsectors' commodities, with an average productivity growth rate of 7.5% per year. In global trade, two types of coffee are widely recognized: Arabica and Robusta coffee (Ceha et al., 2017). PT. XYZ, located in Madiun, is a private company operating in the plantation sub-sector, specializing in commodities such as coffee, cloves, rubber, and quinine. Coffee is the company's flagship commodity, and it produces both Arabica and Robusta coffee. However, in the production process of Arabica coffee, many product nonconformities still occur. The average nonconformity rate for Arabica coffee products is 8.43%, exceeding the allowable tolerance limit of 4% (Dinas Perkebunan, 2014).

Implementing quality control techniques is necessary to achieve effective quality control. This is because not all production outcomes meet the established quality standards. Quality control techniques are generally divided into two categories: Inspection and Statistical Quality Control (Dianawati & Akbar, 2021). Based on this, the present study focuses on the quality control of Arabica coffee using the Statistical Quality Control method.

Statistical Quality Control is a system developed to maintain a uniform standard of production quality at minimal cost and serves as a tool to achieve efficiency (Nugroho et al., 2023). It aids in quality monitoring and detecting production errors from upstream to downstream, enabling decision-making based on data analysis and processing (Simatupang et al., 2021). Given this, the statistical quality control method analysis is expected to provide valuable information and decision-making recommendations for the company to improve the quality of Arabica coffee production.

RESEARCH METHOD [SIZE 11 UPPERCASE]

The research was conducted at PT. XYZ is located in Kare District, Madiun Regency. This study employs a descriptive analysis method, which visually represents an ongoing situation and is based on solving actual problems in the present.

This research establishes several problem limitations to focus the study on achieving the intended objectives. The problem limitations in this study are as follows:

1. The quality control measurement instruments used include the p-chart control chart, process capability (Cp), histogram, Pareto diagram, and cause-and-effect diagram.
2. The research object is the quality type of Arabica Coffee A/WP 1 L.
3. Quality control is conducted only in the sorting process to produce Arabica Coffee A/WP 1 L quality.
4. The discussion does not include the cost of losses due to product nonconformities.
5. If a single coffee bean has more than one defect value, the defect classification is determined based on the highest defect weight.

Data Collection

The data required for quality control analysis using the Statistical Quality Control method includes:

1. The raw materials in the form of coffee cherries are used in production until they become green coffee beans (kg per production batch).
2. The number of nonconformities, types of nonconformities, and the sequence of production processes, from coffee cherries to green coffee beans (kg per production batch).

Sampling Method

In this study, the samples were taken from the sorting process of Arabica Coffee A/WP 1 L quality. This quality type refers to large-sized Arabica coffee processed using the Wet Process method, with the criterion of not passing through a 6.5 mm sieve and having a maximum defect value of 11 (National Standardization Agency, 2008).

The sample size used to determine the quality of Arabica coffee was 300 grams, according to SNI 01-2907-2008, which regulates the classification of coffee quality.

Data Processing Using Statistical Quality Control

The steps for data processing using the Statistical Quality Control method are as follows (Mulyono & Apriyani, 2021):

1. Calculating the Defect Percentage

$$p = \frac{np}{n}$$

Where:

- np = Number of defective items in a subgroup
- n = Total number of inspected items in a subgroup

2. Constructing the p-Chart

a. Calculating the Central Line (CL)

$$CL = \bar{p} = \frac{np}{n}$$

Where:

- np = Total number of defective products
- n = Total number of inspected products

b. Calculating the Upper Control Limit (UCL)

$$UCL = \vec{p} + 3\sqrt{\frac{\vec{p}\,(1-\vec{p})}{n}}$$

Where:

- p ⃗ = Average proportion of defective products
- n = Total number of inspected products

c. Calculating the Lower Control Limit (LCL)

$$UCL = \vec{p} - 3\sqrt{\frac{\vec{p}\,(1-\vec{p})}{n}}$$

Where:

- p ⃗= Average proportion of defective products
- n = Total number of inspected products

Note: If LCL<0LCL < 0, then LCLLCL is considered as **0**.

3. Data Sufficiency Test

In this test, the criterion used is that the sample size (N) must be greater than or equal to the required sample size (N'). In this study, the confidence level (Zc) used is 95% or 2σ, with an accuracy level of 5%. The formula for calculating data sufficiency is as follows (Rujianto & Hana, 2018):

$$N' = \frac{(Z)^2 x\,(\vec{p})\,x\,(1-\vec{p})}{(\alpha)^2}$$

Where:

- N' = Required sample size
- Z = Confidence level (for 95%, Zc = 1.96 or 2σ)
- p ⃗ = Standard deviation of the sample
- α = Desired margin of error (5%)

If N ≥ N', the collected data is considered sufficient for analysis.

4. Process Capability (Cp)

The determination of process capability for samples with attribute data can be evaluated based on the final yield percentage produced from the process. A process is considered good if:

- Final yield ≥ 69.2% (Indonesian standard)
- Final yield ≥ 99.99% (International standard)

The final yield percentage can be calculated using the following formula (Mahardika et al., 2023) :

$$CP = 100\% \left(\frac{Jumlah\ cacat}{Jumlah\ Inspeksi}\ x\ 100\%\right)$$

Where:

- P = Defect proportion (p ⃗) obtained from the p-chart calculation.
- Final Yield represents the percentage of products that meet quality standards.

If the final yield meets or exceeds the specified threshold, the process is considered capable.

5. Creating a Histogram

Product nonconformities are presented in the form of a bar chart (histogram), categorized based on the types of defects that occur. The height of each bar directly reflects:

- The number of defects for each type within a specific time period.
- The relative proportion of defects, serving as an indicator of quality issues.

This visualization helps in identifying the most frequent defect types, allowing for targeted improvements in the production process.

6. Determining Improvement Priorities (Pareto Diagram)

The Pareto diagram is used to identify key types of nonconformities using the 80/20 principle. This principle states that 20% of defect types contribute to 80% of process failures. Steps to create a Pareto diagram (Jaya et al., 2022):

1. List defect types and count their occurrences.
2. Sort defects from the most frequent to the least frequent.
3. Calculate the cumulative percentage of defects.
4. Plot the data in a bar chart, with defect types on the x-axis and their frequency on the y-axis.
5. Draw a cumulative percentage line to identify which defects contribute most to process failures.

By analyzing the Pareto diagram, the company can first focus on fixing the most critical defect types.

7. Identifying the Dominant Factor (Cause-and-Effect Diagram)

The cause-and-effect diagram (also known as a fishbone or Ishikawa diagram) is created through brainstorming.

- The main problem (e.g., defective coffee beans) is written on the right side.
- On the left side, branches representing significant factors (e.g., materials, methods, machines, workforce, environment) contribute to the problem (Suhartini, 2020).
- Sub-branches further detail specific causes under each factor.

This analysis helps identify the root causes of quality issues.

8. Developing Improvement Recommendations

Based on the cause-and-effect diagram, improvement recommendations are made by:

- Focusing on dominant factors affecting Arabica coffee quality.
- Suggesting corrective actions for each major cause.
- Implementing quality control measures to prevent reoccurrence.

This ensures that corrective actions are data-driven and targeted toward improving production quality.

RESULTS AND DISCUSSION

PT. XYZ is a company located in Kecamatan Kare, Kabupaten Madiun, specializing in producing coffee, cloves, rubber, and quinine. The company produces Arabica and Robusta coffee using the wet process method. The produced coffee is classified into three size categories:

- Large (L)
- Medium (M)
- Pixel (P)

Additionally, the coffee is further categorized into four quality classifications:

- Grade 1
- Grade 4
- Grade 5
- Grade 6

Historical Data

The Company's Historical Data section presents an overview of quality control reports from PT. XYZ, highlighting several nonconformities in the Arabica coffee production process.

Types of Nonconformities Identified:

1. Black beans (A1)

2. Small-sized coffee husks (A2)
3. Brown-colored coffee beans (A3)
4. Spotted beans (A4)
5. Beans with one hole (A5)
6. Small-sized horn husks (A6)

The data collection period covers July to September 2022, using production records from PT. XYZ. A detailed production dataset for this period is provided in Table 1.

Table 1. Arabica Coffee Production Data of PT. XYZ for the Period July 2022 - September 2022

Sub grup	Sample (Gram)	Types of Nonconformities						Amount	Proportion (%)
		A1	A2	A3	A4	A5	A6		
1	300	10	8	3	15	18	20	74	0.25
2	300	8	10	2	18	15	22	75	0.25
3	300	0	10	1	25	24	12	72	0.24
4	300	0	8	0	25	18	20	71	0.24
5	300	14	0	0	35	15	22	86	0.29
6	300	10	0	4	15	25	22	76	0.25
7	300	0	10	4	18	22	18	72	0.24
8	300	8	0	0	22	20	18	68	0.23
9	300	8	8	2	22	18	25	83	0.28
10	300	8	5	3	25	18	25	84	0.28
11	300	0	0	0	18	25	15	58	0.19
12	300	6	0	2	18	20	20	66	0.22
13	300	9	0	4	15	18	20	66	0.22
14	300	11	0	0	25	18	24	78	0.26
15	300	8	7	5	24	10	18	72	0.24
16	300	0	9	2	15	20	18	64	0.21
17	300	0	0	0	42	20	22	84	0.28
18	300	10	8	0	22	18	20	78	0.26
19	300	0	8	4	20	32	12	76	0.25
20	300	0	10	4	18	27	18	77	0.26
21	300	8	8	4	18	20	22	80	0.27
22	300	6	4	0	25	18	32	85	0.28
23	300	9	10	0	15	27	20	81	0.27
24	300	5	0	0	18	21	18	62	0.21
25	300	0	0	2	22	16	18	58	0.19
26	300	0	5	3	20	20	15	63	0.21
27	300	8	9	0	25	21	20	83	0.28
28	300	8	10	0	18	18	20	74	0.25
29	300	16	0	1	10	20	18	65	0.22
30	300	10	0	0	32	24	22	88	0.29
31	300	0	0	0	22	18	32	72	0.24
32	300	5	8	4	18	21	14	70	0.23
33	300	8	5	3	27	24	18	85	0.28
34	300	0	0	4	25	20	27	76	0.25
35	300	9	0	0	25	18	10	62	0.21
36	300	0	10	0	35	18	16	79	0.26
37	300	0	10	2	15	20	12	59	0.20
38	300	14	0	2	18	20	21	75	0.25
39	300	8	0	3	22	15	20	68	0.23
40	300	10	8	2	22	25	20	87	0.29
Total	**12000**	**234**	**188**	**70**	**869**	**805**	**786**	**2952**	**9.84**

Source: Processed Secondary Data (2023)

Control Chart p-Chart

The results of the p-chart control chart indicate that the proportion of nonconforming points falls within the statistical control limits, as all observed data points are within the Upper Control Limit (UCL) and Lower Control Limit (LCL). From the control chart analysis, the Center Line (CL) value is 0.2460, with a UCL of 0.3206 and an LCL of 0.1714. The proportion of nonconformities occurred in subgroups 5, 30, and 40, with a value of 0.29%. The quality control chart for Arabica Coffee A/WP 1 L is presented in Figure 1.

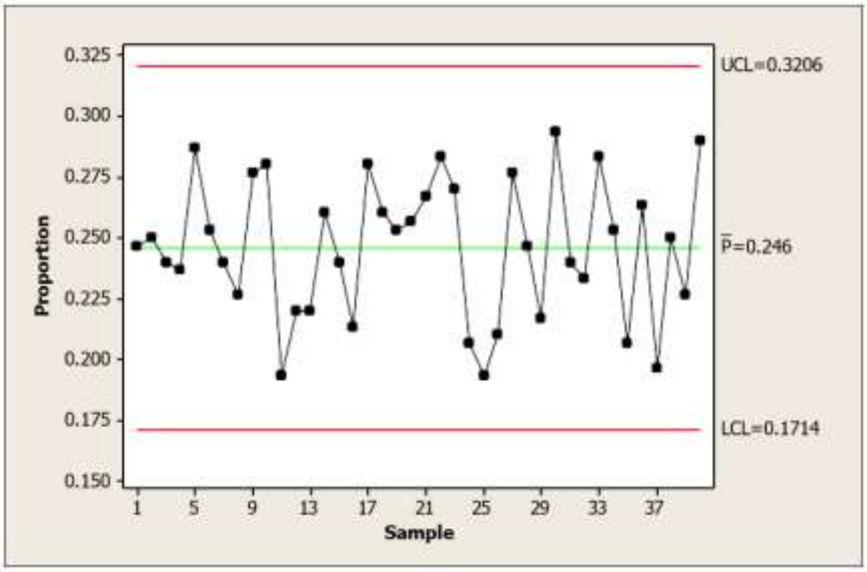

Figure 1. Control Map p-chart of Arabica Coffee A/WP 1 L

Data Sufficiency Test

The results of the data sufficiency test calculations indicate that the required sample size is 285 samples. Based on this, the value of N' from N is 285 < 12,000. This means that the number of samples taken is sufficient.

***Process Capability* (CP)**

The determination of process capability value can be observed from the final yield percentage obtained in the production process (Rimantho and Athiyah, 2019). Based on the calculations, the process capability for Arabica Coffee A/WP 1 L is 75.4%. This level of process capability meets the Indonesian standard. A process is acceptable if the final yield percentage is ≥ 69.15% according to the Indonesian standard and ≥ 99.73% for the International standard. Therefore, it can be interpreted that the production process capability of Arabica Coffee A/WP 1 L at PT. XYZ is adequate, as it meets the required Indonesian final yield percentage standard.

Histogram

The histogram results presented in Figure 2 show that the most dominant nonconformity is spotted coffee beans, totaling 869 occurrences. Spotted coffee beans usually result from improper pulper or washer adjustments (too tight), causing damage to the coffee bean surface. This is consistent with Fadri et al. (2022), which state that spotted coffee beans are caused by improper pulper or washer adjustments (too tight), leading to surface damage on the beans. If the pulper blade is set too tightly, it can cause spotted coffee beans during roasting (Mason).

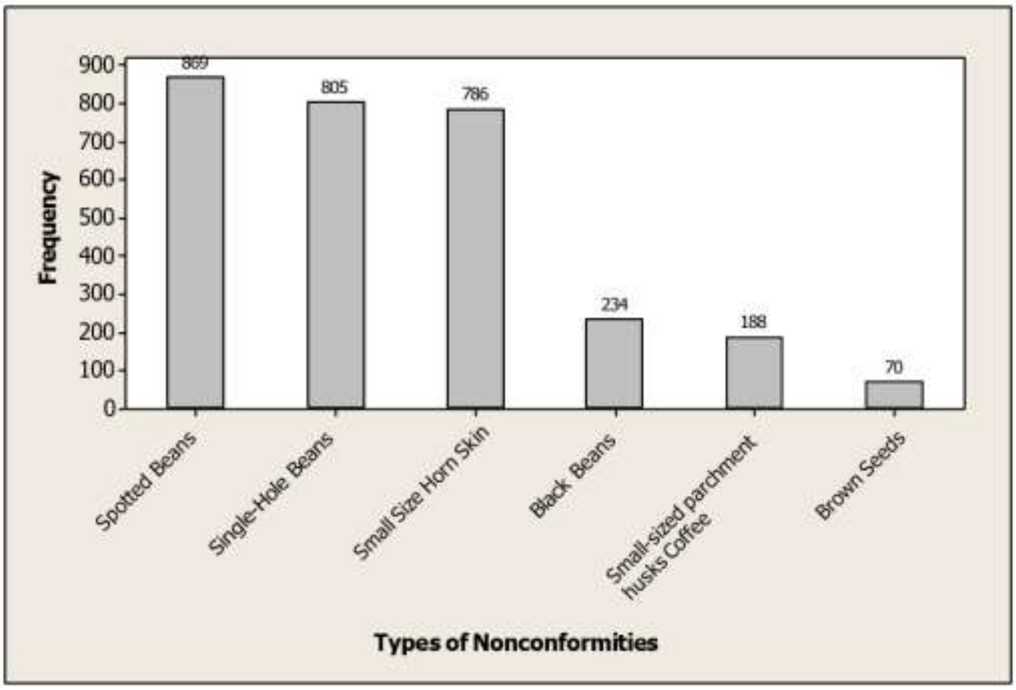

Figure 2. Histogram of Arabica Coffee A/WP 1 L

Pareto Diagram

In constructing the Pareto diagram, a data tabulation is first created, listing the types and frequencies of product nonconformities in Arabica Coffee. The tabulated data on quality defects for Arabica Coffee A/WP 1 L at PT. XYZ is presented in Table 2.

Table 2. Frequency of Non-Conformity of Quality Type of Arabica Coffee A/WP 1 L

No.	Nonconformity	Frekuensi	Frekuensi Kumulatif	Persentase Kumulatif (%)
1	Spotted Beans	869	869	0,29
2	Single-Hole Beans	805	1674	0,57
3	Small Size Horn Skin	786	2460	0,83
4	Black Beans	234	2694	0,91
5	Small-sized parchment husks Coffee	188	2882	0,98
6	Brown Seeds	70	2952	1,00

Source: Processed Secondary Data (2023)

The Pareto diagram presented in Figure 3 shows that the most dominant nonconformity is spotted coffee beans, accounting for 29% of the total defects found in Arabica Coffee A/WP 1 L. The contributing factors to this defect include improper pulper machine settings, fermentation process issues, and incomplete roasting in the mason machine (Sunarharum et al., 2019).

The relatively high rate of nonconformities in Arabica coffee processing is due to the lack of an organized production process regarding mechanisms and worker skills. A detected technical issue is the lack of selectivity in the sorting process, leading to defect rates nearing the acceptable threshold at certain stages of Arabica Coffee A/WP 1 L production.

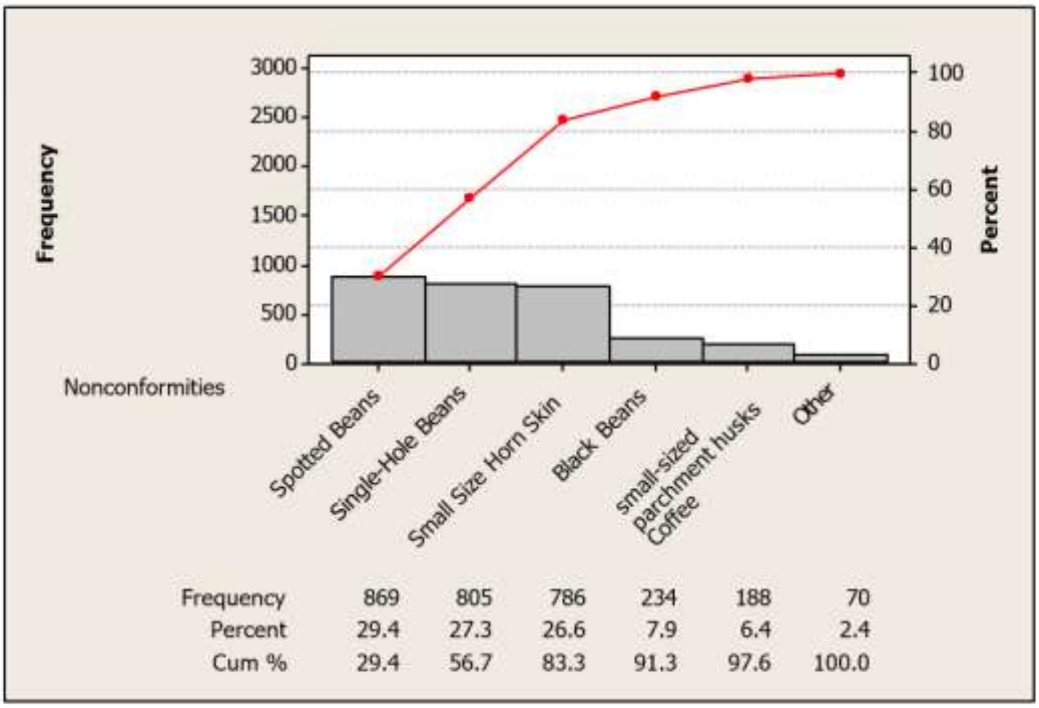

Figure 3. Pareto Diagram of Arabica Coffee A/WP 1 L

Based on the results of interviews with the company, several factors caused the discrepancy. Table 3 presents more complete information.

Table 3. Factors Causing Unsuitability of Arabica Coffee A/WP 1 L

No	Type of Nonconformity	Penyebab
1	Spotted Beans	Improper pulper machine settings
2	Single-Hole Beans	Attacked by coffee berry borer pests
3	Small Size Horn Skin	Imperfect sorting
4	Black Beans	Attacked by pests/picked too early
5	Small-sized parchment husks Coffee	Imperfect drying
6	Brown Seeds	Imperfect fermentation/drying

Source: Processed Secondary Data (2023)

Cause-and-Effect Diagram

Based on the Pareto diagram presented in Figure 3 and the 80/20 principle, nonconformities with a cumulative percentage reaching 80% are analyzed further to identify the factors causing these defects.

In this case, the main types of nonconformities—spotted beans, single-hole beans, and Small Size Horn Skin account for a cumulative total of 83.3%.

The results of this analysis serve as a reference for formulating improvement strategies to address the most dominant quality issues. These findings provide recommendations for quality improvement efforts.

The identified causes of nonconformities are illustrated in:

- Figure 4 for spotted coffee beans
- Figure 5 for single-hole beans
- Figure 6 for small-sized parchment husks coffee

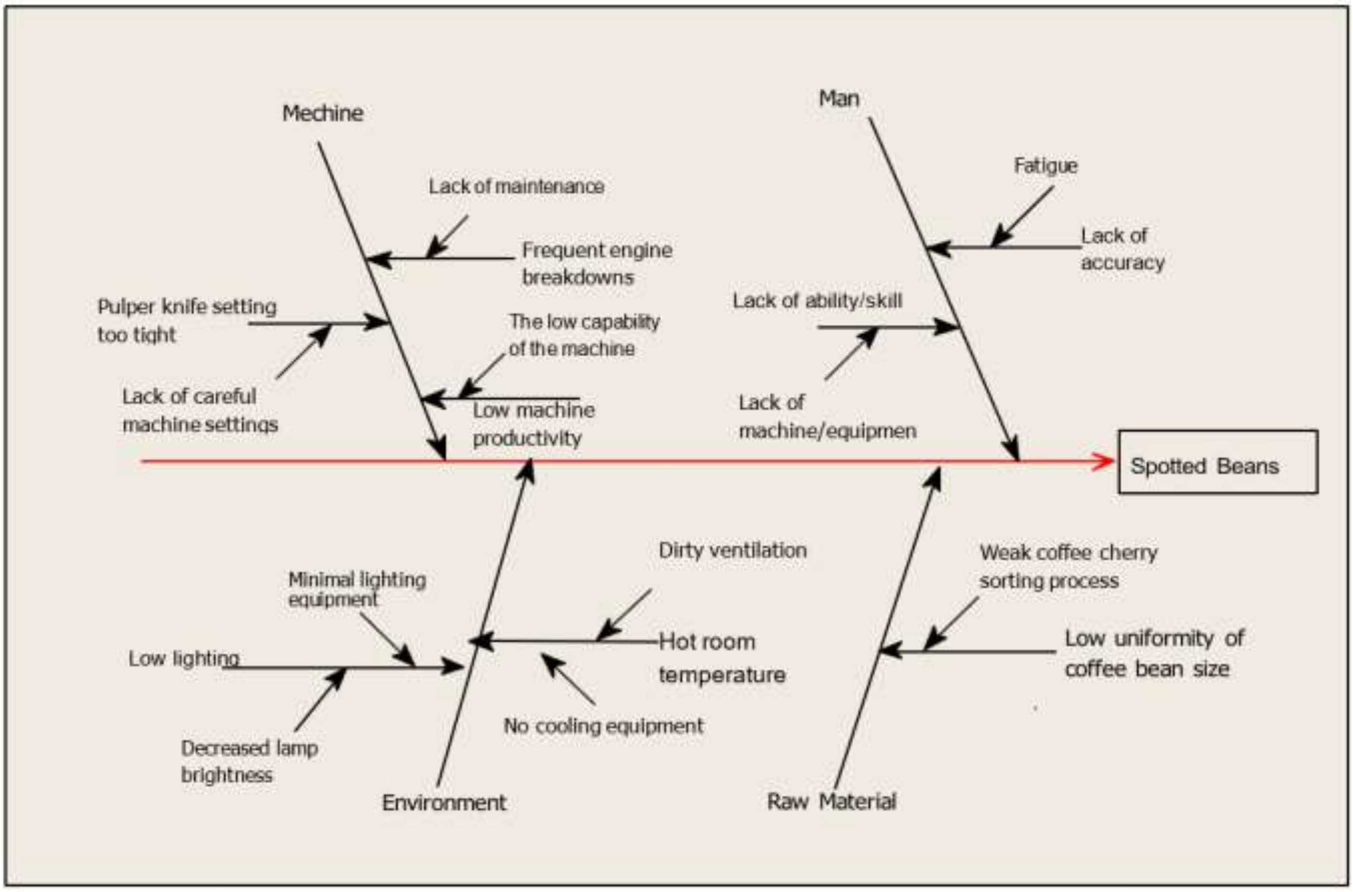

Figure 4. Cause and effect diagram of spotted beans Quality type Arabica coffee A/WP 1 L

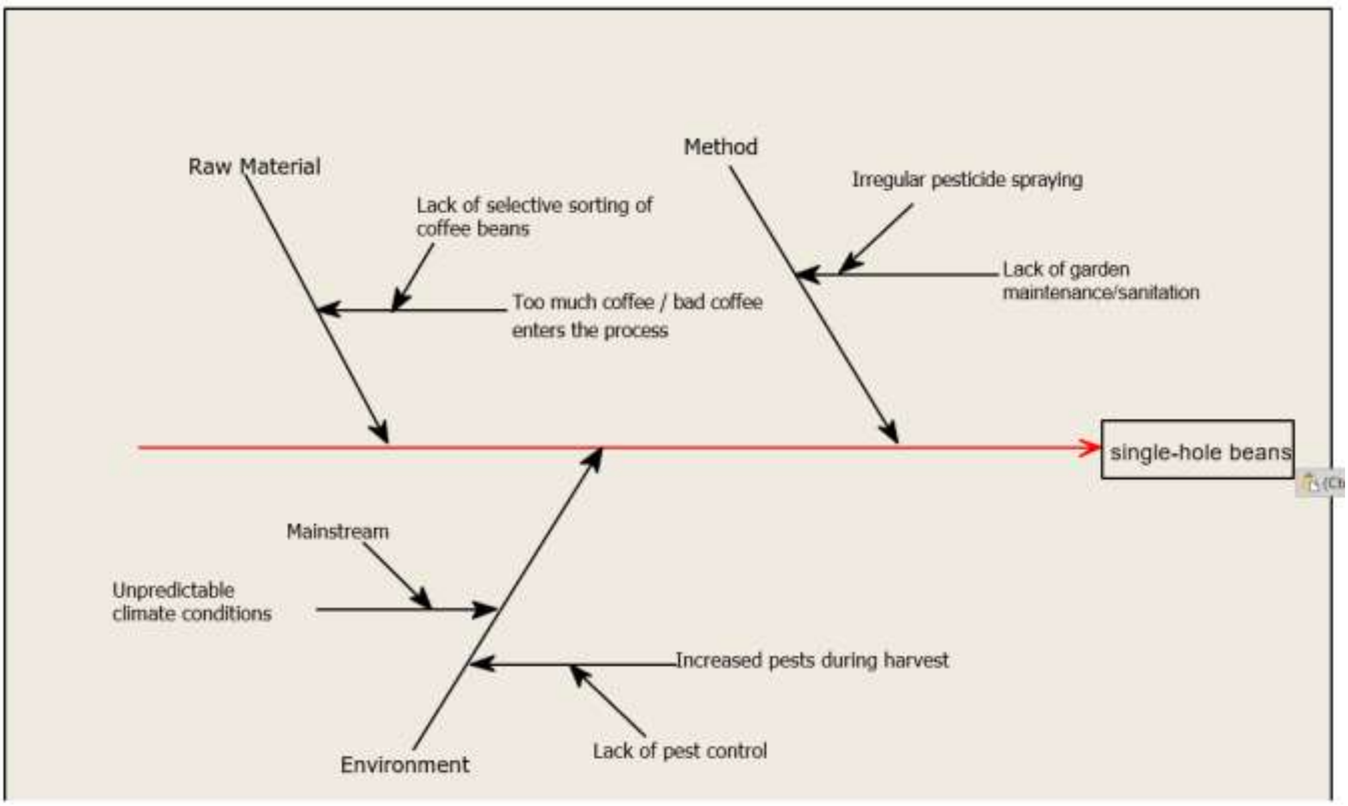

Figure 5. Cause and effect diagram of single-hole beans for 1 type of Arabica coffee quality A/WP 1 L

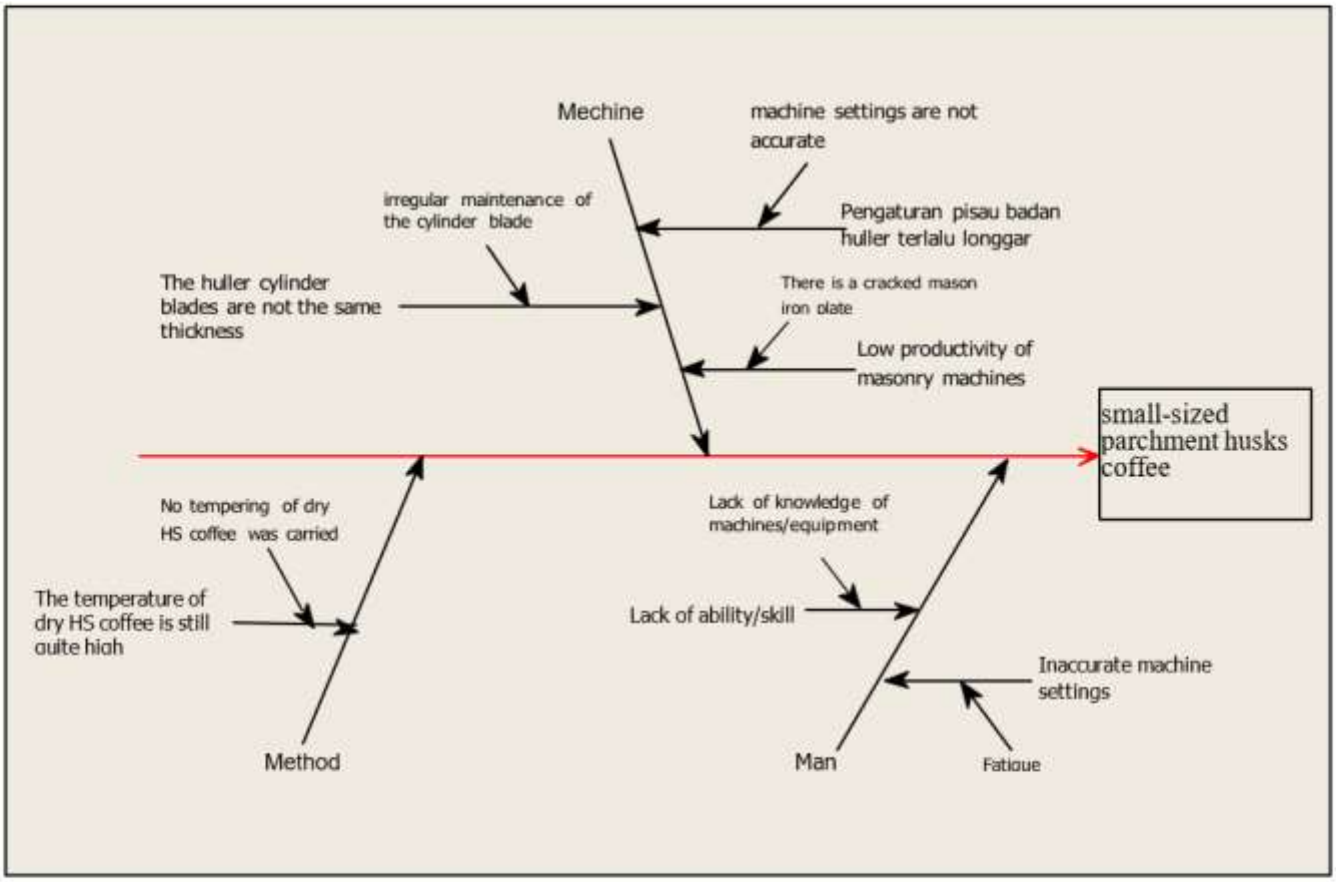

Figure 6. Cause-effect diagram of small-sized parchment husks coffee Arabica Coffee Quality Type A/WP 1 L

The analysis results show that several dominant factors influence the non-conformity of Arabica Coffee at PT. XYZ. These factors are:

1. Human
   a. Lack of accuracy: Operator error in the pulper process where the machine settings are too tight. For the sorting station, it is the workers' Lack of accuracy in sorting coffee.
   b. Ability (skill): Lack of operator ability/expertise in mastering machines and equipment, knowledge of material characteristics, and Standard Operating Procedures (SOP).
2. Machine
   The study's results reveal that the machine used is old. In addition, inappropriate settings also affect product results. Inadequate machine maintenance decreases machine capability.
3. Raw Materials
   The large number of coffee beans entering the production process and the uneven size of the coffee beans entering the pulp separation station (vis pulper) cause spotted beans and single-hole beans.
4. Environment
   Environmental factors include unclean places, poor lighting, ventilation, air circulation, climate change, and increased plant pests during harvest.
5. Method
   Poor sanitation scheduling for plants and garden areas is the main factor causing plants and coffee beans susceptible to pests. In addition, the implementation of HS Dry coffee tempering that is not appropriate causes the occurrence of small-sized parchment husks coffee that correlate with the huller machine settings on the pulper.

Improvement Suggestions

Based on the analysis and discussion results, several factors influencing the non-conformance of Arabica Coffee Quality A/WP 1 L have been identified. These findings serve as a reference for providing improvement suggestions. The proposed improvements are:

1. Spotted Beans
   a. Human Factor: Conduct technical training to enhance operators' ability to master machines and equipment.
   b. Mechine : Develop a Standard Operating Procedure (SOP) for proper machine settings according to machine conditions and desired coffee bean output, particularly for pulper blades (looseness/tightness).
   c. Raw Materials
   - Sort superior and inferior coffee beans for separate processing to prevent the presence of witboon coffee.
   - Afriliana (2018) states that the separation of superior coffee (ripe, full, and uniform) and inferior coffee (defective, black, broken, perforated, and pest-infected) should be done selectively to produce uniform and high-quality coffee beans.

   d. Environment
   - Install four 40-watt Light Emitting Diode (LED) bulbs to improve lighting.
   - Provide air-cooling equipment in the form of electric fans.
2. Single-Hole Beans
   a. Method
   - Schedule land and plant sanitation, including weed cleaning, branch pruning, and selective coffee picking to improve coffee plant quality.

   b. Raw Materials
   - Monitor the siphon tank regularly to control the amount of mixed coffee and manually separate it if necessary.
   - Control Hypothenemus hampei pest attacks through sanitation and population reduction by early picking of infected fruits, “rampasan” (harvesting all fruits at the end of the season), and “lelesan” (collecting fallen fruits from the ground at the end of the season) (Alikmawati et al., 2014).

   c. Environment
   - Implement land sanitation, pesticide spraying, and plant maintenance, as healthier plants are more resistant to environmental conditions.
   - Reduce the occurrence of single-hole beans through garden sanitation, fertilization, and periodic pest control (Solichah et al., 2020).
3. small-sized parchment husks coffee
   a. Human Factor : Provide technical training to enhance knowledge of machines and equipment.
   b. Method : Implement proper tempering at the huller station to ensure uniform material temperature.
   c. Machine :
   - Repair iron plates on the mason to ensure coffee is even roasted.
   - Adjust the cylinder blade and huller body settings to optimize parchment husks coffee separation.

CONCLUSION

From the research findings, it can be concluded that:

1. The quality control of the Arabica Coffee A/WP 1 L production process at PT. XYZ is statistically under control. The proportion of nonconformities falls within the UCL and LCL ranges, with respective values of 0.3206 and 0.1714.
2. The factors causing nonconformities in the Arabica Coffee A/WP 1 L production process include human factors (lack of worker precision and insufficient machine/equipment handling skills), machine factors (improper machine

settings, low machine capability, and lack of maintenance), and method factors (absence of tempering, less selective sorting, and insufficient scheduling of garden and plant sorting). Other influencing factors include raw materials (a high number of mixed coffee beans and inconsistent sizes of coffee cherries entering the process) and environmental aspects, such as inadequate lighting, excessively hot room temperatures, and increased pest activity during harvest.

3. The proposed strategies include conducting technical training, implementing intensive sanitation scheduling for both plants and plantations, developing SOPs, particularly at the separation station (vis pulper and huller), correctly implementing dry HS coffee tempering at the grebus station, performing selective sorting in the siphon tank for mixed coffee beans, and adding four LED lamps (40 watts each) at the sorting station as well as installing fans to improve room cooling.

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AUTHOR CONTRIBUTIONS

For research articles with several authors, a short paragraph specifying their individual contributions must be provided. The following statements should be used "Conceptualization, Ma’ruf Pambudi Nurwantara and Ridwan; Methodology, Investigation, Ma’ruf Pambudi Nurwantara; Resources, PT.XYZ.; Data Curation, Farchan Arif Rosadi; Writing – Original Draft Preparation, Ma’ruf Pambudi Nurwantara.; Writing – Review & Editing, Ma’ruf Pambudi Nurwantara; Visualization, Farchan Arif Rosadi; Supervision, Ma’ruf Pambudi Nurwantara; Project Administration, Ridwan; Funding Acquisition, Ma’ruf Pambudi Nurwantara.”.

DISCLOSURE

The author reports no conflicts of interest in this work.

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