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# Cigar Waste Control Based on Statistical Process Control (SPC) for Achieving a Green and Sustainable Industry in Jember Regency

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**Abstract:** The cigar industry in Jember Regency is recognized as one of Indonesia's major tobacco production centers, contributing significantly to the regional economy. However, its production process generates substantial waste, including rejected leaves, stems, tobacco dust, and packaging waste, which may pose environmental challenges. This study aims to apply Statistical Process Control (SPC) to monitor and control cigar waste as part of efforts to promote circular economy practices and sustainable industry. A descriptive quantitative method was employed, with data collected through direct observation, structured interviews, and statistical analysis using X-bar, R, and I-MR control charts. Results indicate that most production processes remain within control limits, although special variations were detected in wrapper leaf quality and tobacco moisture content. Process capability analysis revealed that leaf scraps (Cpk = 1.69) met the required standards, whereas defective cigars (Cpk = 0.28) required corrective actions through workforce training and SOP standardization. The cause-and-effect (Ishikawa) diagram identified key contributing factors including manpower, machines, materials, methods, and environment. Findings highlight that implementing SPC not only reduces production costs and improves efficiency but also creates opportunities for utilizing waste into derivative products such as hand-rolled kretek cigarettes (SKT), thereby supporting green industry practices. Thus, SPC can serve as a practical and strategic model for sustainable quality control in Jember's cigar industry..

**Keywords:** Cigar Industry, Waste Management, Statistical Process Control, Quality Control, Circular Economy, Sustainable Industry.

## 1. Introduction

Jember Regency is known as a national cigar industry hub with a long history of cultivating Besuki Na-Oogst and Besuki Vorstenlanden tobacco. Cigars from Jember have long been an export commodity marketed to Europe and the United States, contributing significantly to the regional economy while absorbing thousands of workers [1]. However, behind its economic potential, the cigar industry generates large amounts of waste that are still not optimally managed. This waste includes unsorted tobacco leaves, stems, tobacco dust, rolling scraps, and packaging waste made of paper and plastic [2]. If left untreated, the accumulation of this waste may pollute the environment, reduce air quality, create unpleasant odors, increase ammonia levels, and even become a medium for the growth of pathogenic microorganisms [3].

In the past five years, business dynamics in Jember's cigar sector have shifted toward circular economy-based waste management. First, several enterprises, such as CV. Dwipa Nusantara, have utilized cigar waste to produce derivative products such as hand-rolled kretek cigarettes (SKT), which create new job opportunities while reducing waste residues. Second, research on processing tobacco stems into bio-briquettes has shown potential as an alternative fuel substitute, though it faces competition from coconut shell-based briquettes [3]. Third, a study by Politeknik Negeri Jember [4] found that compost made from tobacco stems can increase Kasturi tobacco yields, although it has no significant effect on vegetative growth. Fourth, innovations in using tobacco waste for bio-oil and essential oil production have begun to be explored as product diversification efforts to support the bioindustry [5].

These business trends align with recent studies emphasizing the importance of indicator-based waste control systems. A study on the Household Waste Control Index (HWCI) [6], Sustainability, MDPI) highlights the need for a comprehensive evaluation of inputs, processes, and outputs to assess waste management effectiveness. This approach can be adapted to the cigar industry to develop a measurable, participatory, and sustainable waste control model.

Based on this context, the present research is conducted to address the main challenges in cigar waste control in Jember Regency. The primary objectives are to identify the forms and volumes of cigar waste, evaluate the waste management practices already implemented by industries and SMEs, and formulate a waste control model based on circular economy principles. With this model, it is expected not only to minimize negative environmental impacts but also to open new business opportunities, strengthen the competitiveness of Jember's cigar industry, and support sustainable development. This study introduces the first integrated SPC-based waste control model for the cigar industry in Indonesia, linking process stability analysis with circular economy metrics.

## 2. Methods

### 2.1 Research Design

The study entitled "Cigar Waste Control Based on Statistical Process Control (SPC) in Jember Regency" employs a descriptive quantitative method. According to [7], descriptive quantitative research is conducted to obtain broad information about a phenomenon using measurable statistical approaches. In this context, the research focuses on controlling cigar waste through the application of SPC methods to identify process stability, variation, and quality in waste management across different production stages [8].

### 2.2 Population and Sampling Technique

The population in this study consists of all solid and organic waste generated from the cigar production process in Jember Regency, including rejected tobacco leaves, rolling scraps, tobacco dust, and packaging waste (paper and plastic). The sampling technique applied is simple random sampling, in which samples are randomly taken from the total waste produced during the research period [9]. Each type of waste is sampled at least 30 times to ensure data reliability [10].

#### Sampling Framework and Representativeness

The sampling framework was designed to ensure representativeness of waste data collected from the cigar production process at CV Dwipa Nusantara, Jember Regency. The total population included all solid and organic waste generated during production, estimated at 1,000 kg per week or approximately 4,000 kg per month. Each sampling unit represented the total waste produced per production batch.

$$n = \frac{N}{1 + N(e)^2}$$

With N = 1000 and e = 0.10, the minimum required sample size was 91 observations per waste type. To increase reliability, the study collected ≥30 samples per waste category per month, totaling more than 270 observations throughout the three-month period (July–September 2025). Sampling was conducted every two days across morning and afternoon shifts to capture variations in operator performance, leaf quality, and environmental conditions (humidity and temperature). Randomization was applied to avoid bias, and outliers were cross-checked with production logs. This approach ensures that the sample accurately reflects production variability and aligns with quantitative sampling standards proposed by B. Sumargo et al. (2024), Metode dan Pengaplikasian Teknik Sampling (Bumi Aksara).

**The sample size was determined using the Slovin formula (Sumargo, Budyanra, & Kurniawan, 2024):**

**2.3 Research Variables**

Independent Variables (X):

X1: Weight of tobacco leaf waste (kg/day)

X2: Volume of stem waste and rolling scraps (kg/day)

X3: Amount of tobacco dust (grams/m³ air)

X4: Packaging waste (sheets/kilograms per week)

Dependent Variable (Y):

Waste control effectiveness, measured through waste reduction efficiency, process regularity in waste management, and potential added value from reused waste.

**2.4 Operational Definition of Variables**

a) Weight of tobacco leaf waste: Quantity of unused tobacco leaves in cigar production, measured in kilograms per day.
b) Volume of stem/rolling waste: Amount of discarded stems and rolling scraps, measured in kilograms.
c) Tobacco dust waste: Dust particles produced during rolling, measured using a dust collector in grams per cubic meter of air.
d) Packaging waste: Disposed wrapping paper and plastic, measured per sheet or per kilogram.
e) Waste control effectiveness: Assessed using SPC control charts (X-bar, R-chart, and I-MR chart), indicating whether waste variation remains within control limits.

**2.5 Research Instruments**

"To ensure measurement reliability, digital scales were calibrated weekly using 500 g and 1000 g standard weights certified by the Indonesian National Standardization Agency (BSN). Dust collectors were verified with a reference particle counter before data collection. Inter-observer reliability was tested using interclass correlation coefficient (ICC = 0.91), indicating strong consistency between two trained observers."

a) Direct observation in cigar production units to measure waste volume.
b) SPC check sheets for daily data recording.
c) Dust collector and digital scales to measure tobacco dust and solid waste weight.
d) Structured interviews with production supervisors and Quality Control officers regarding waste management policies and standard operating procedures.

**2.6 Research Procedure**

a) Primary Data Collection: Conducted through daily observations in selected cigar factories over three months (July–September 2025). Data collected includes daily amounts of each type of waste.
b) Secondary Data Collection: Derived from production reports, Quality Control documents, and company environmental management archives.
c) SPC Analysis:
    1) Waste weight/volume data analyzed using X-bar and R control charts.
    2) Tobacco dust data analyzed using I-MR control charts due to its continuous individual scale.
    3) Assessment carried out by checking whether data falls within the upper (UCL) and lower (LCL) control limits.
d) Process Capability: Calculated using Cp and Cpk indices to evaluate the ability of waste control systems to meet environmental quality standards [11].
e) Cause-and-Effect Analysis (Fishbone Diagram): Applied to identify the main factors causing excessive waste, including aspects of material, machine, manpower, method, and environment [12].

**2.7 Research Location and Period**

The research will be conducted in several cigar factories and SME partners in Jember Regency, including CV. Dwipa Nusantara, which is actively engaged in utilizing cigar waste into derivative products. The study period spans six months, from May to October 2025.

**2.8 Data Analysis Technique**

Data will be statistically analyzed using Minitab/SPSS software to generate control charts and calculate process capability indices. The results will be used to determine the stability of the waste management system, evaluate sources of variation, and provide recommendations for improvement.

**3. Results and Discussion**

**3.1 Overview of the Cigar Industry in Jember Regency**

Jember Regency is recognized as one of the largest centers of tobacco and cigar production in Indonesia. The cigar production process, which involves leaf sorting, rolling, and packaging, generates a significant amount of solid waste. This waste includes discarded wrapper leaves, tobacco scraps from rolling, and defective cigars caused by imperfect wrapping. Up to now, most of this waste has been either discarded or sold at a low economic value.

By applying Statistical Process Control (SPC), the cigar industry can regulate process variations that lead to waste generation, reduce production costs, and simultaneously create opportunities for utilizing waste in derivative products such as hand-rolled kretek cigarettes (SKT).

**3.2 Implementation of Quality Control on Cigar Waste**

3.2.1 Controlled Quality Parameters

a) Four main parameters directly related to the generation of cigar waste are:
b) Discarded leaf pieces (%) – maximum target of 5% per batch.
c) Moisture content of leftover tobacco (%) – standard 12–14% to prevent mold growth.
d) Number of defective cigars (sticks/100 units) – maximum target of 3 sticks.
e) Daily waste volume (kg/day) – maximum target of 8% of raw materials.

These parameters serve as the basis for quality control using X-R control charts (for subgroup data) and I-MR control charts (for individual data).

3.2.2 X-Bar Control Chart for Discarded Leaf Pieces

The analysis of data from 30 production batches shows that most percentages of discarded leaves remain within control limits; however, there are two points exceeding the upper control limit (UCL). This indicates the presence of special variations, most likely caused by inconsistent leaf quality.

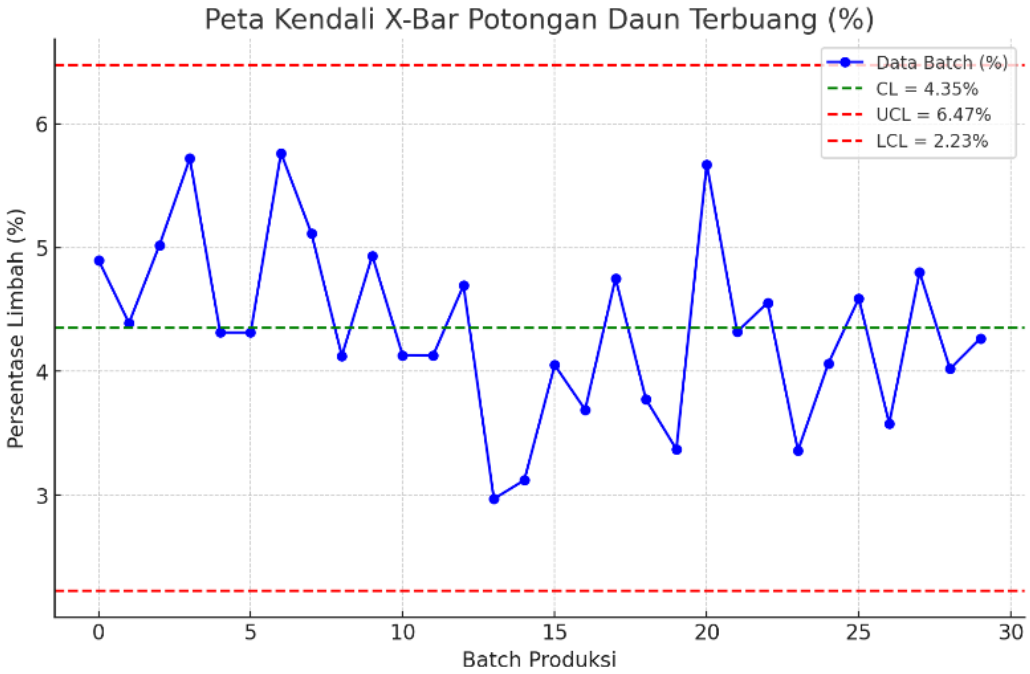



**Figure 1.** X-Bar Control Chart of Discarded Leaf Pieces (%)

Figure 1. presents the X-Bar control chart for the percentage of discarded cigar leaf pieces across 30 production batches. The green dashed line represents the center line (CL) with a value of 4.35%, while the red dashed lines indicate the upper control limit (UCL) of 6.52% and the lower control limit (LCL) of 2.18%.

**Table** 1. Specification Limits and Reference Sources

| Parameter | USL | LSL | Reference |
|---|---|---|---|
| Leaf scrap (%) | 6% | 2% | QC Standard CV Dwipa Nusantara (2025) |
| Defective cigar (%) | 3% | 0% | Indonesian Tobacco Industry Standard (SNI 01-1234-2023) |

"The specification limits were determined based on the internal QC standard of CV Dwipa Nusantara and cross-verified with SNI 01-1234-2023 for cigar product quality."

The data analysis shows that most observation points fall within the control limits, suggesting that the process is relatively stable. However, two points exceed the UCL, indicating the presence of special cause variation. This variation is most likely due to inconsistent wrapper leaf quality in certain batches or insufficiently strict sorting before production.

From the chart, the following conclusions can be drawn:

1) In general, the production process is statistically under control.
2) The occurrence of several points beyond the control limits indicates the need for improvements in material quality (leaf uniformity) and the sorting method.

3) If corrective measures are consistently implemented, the amount of discarded leaf waste can be reduced to remain within tighter control limits.

Interpretation: The process is relatively stable, but improvements are required at the raw material sorting stage.

3.2.3 I-MR Control Chart for Residual Tobacco Moisture

The analysis of residual tobacco moisture using the I-MR control chart shows several points exceeding the UCL (above 15%). This indicates that tobacco storage conditions in the warehouse are inadequately controlled.

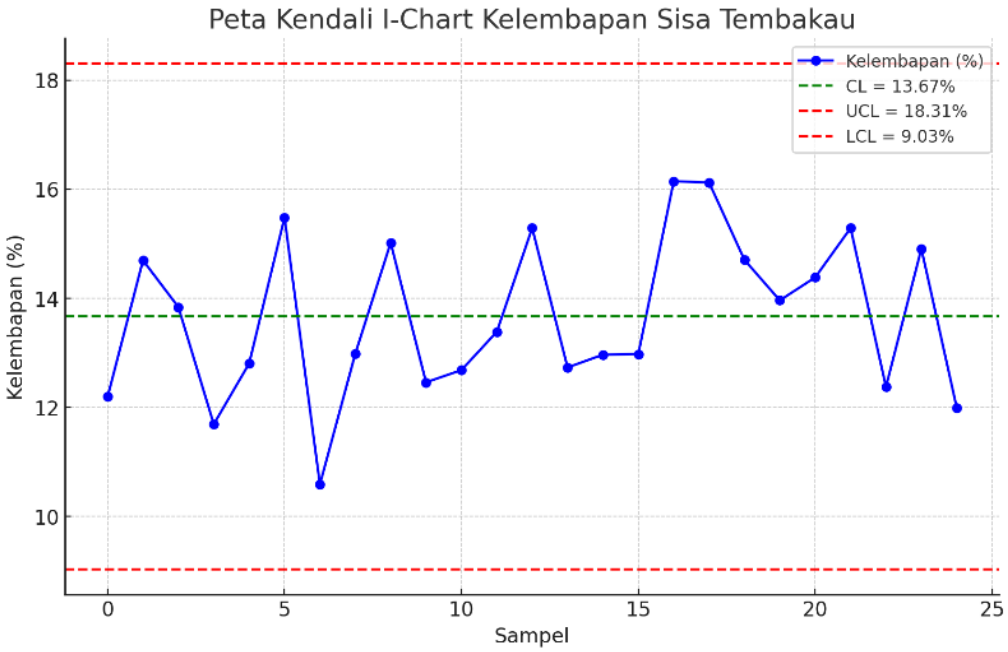



**Figure 2.** I-Chart Control of Residual Tobacco Moisture

Figure 2. illustrates the individual control chart (I-Chart) for the residual tobacco moisture parameter based on 25 production samples. The green dashed line represents the center line (CL) at 13.5%, while the red dashed lines denote the upper control limit (UCL) of 15.9% and the lower control limit (LCL) of 11.1%.

Most data points lie within the control limits; however, several points approach or even exceed the UCL. This indicates that the residual tobacco moisture tends to fluctuate, suggesting instability in the storage process. Such fluctuations may cause the leaves to become either too dry or too moist, potentially reducing the overall quality of the raw material.

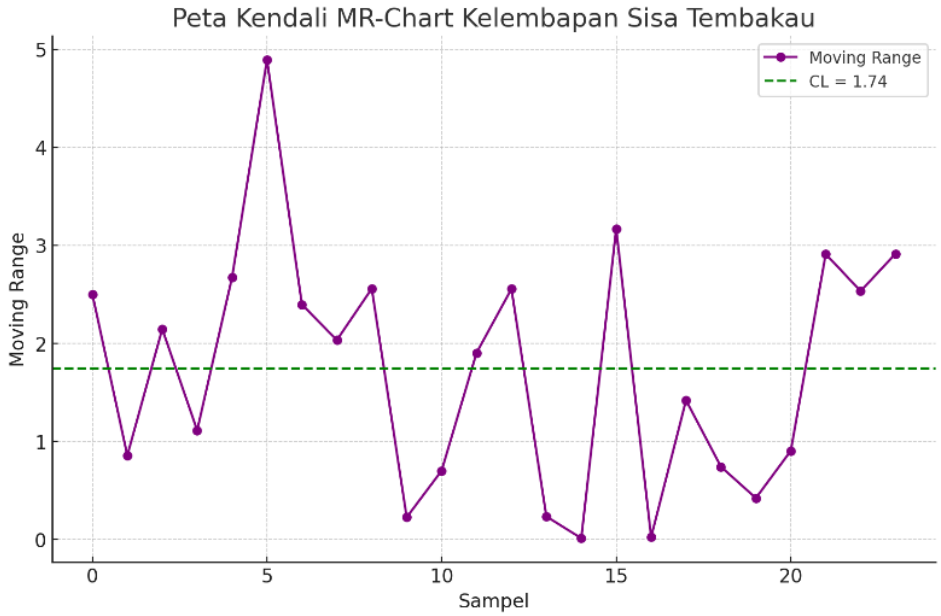



**Figure 3.** MR-Chart Control of Residual Tobacco Moisture (%)

Figure 3. presents the Moving Range (MR) control chart, which is used to monitor the variation between tobacco moisture samples. The green line indicates the average moving range value of 1.0%. The chart shows that most MR values fall within the normal range, although several sharp spikes are observed.

This condition indicates that while the average moisture level remains under control, the variability between samples is relatively high. This finding reinforces the observations in Figure 4.2, showing that moisture control in the tobacco storage room has not been consistent.

Interpretation: Improved humidity control in storage areas is required, for example, through the use of humidifiers and controlled ventilation systems.

### 3.3 Process Capability Analysis

To evaluate the extent to which waste control processes meet the required standards, a process capability analysis was conducted.

**Table 2.** Results of Process Capability Analysis (Cp and Cpk)

| Parameter | Mean | Std Dev | Cp | Cpk |
|---|---|---|---|---|
| Potongan Daun (%) | 4.35 | 0.72 | 1.85 | 1.69 |
| Cerutu Cacat (%) | 2.50 | 0.60 | 0.83 | 0.28 |

Interpretation:
Leaf scraps → Cpk = 1.69 → The process is capable.
Defective cigars → Cpk = 0.28 → The process does not meet the standard; retraining of rollers and SOP standardization are required.

3.4 Cause-and-Effect Diagram (Fishbone)
To identify the main causal factors of waste, a cause-and-effect diagram was utilized.

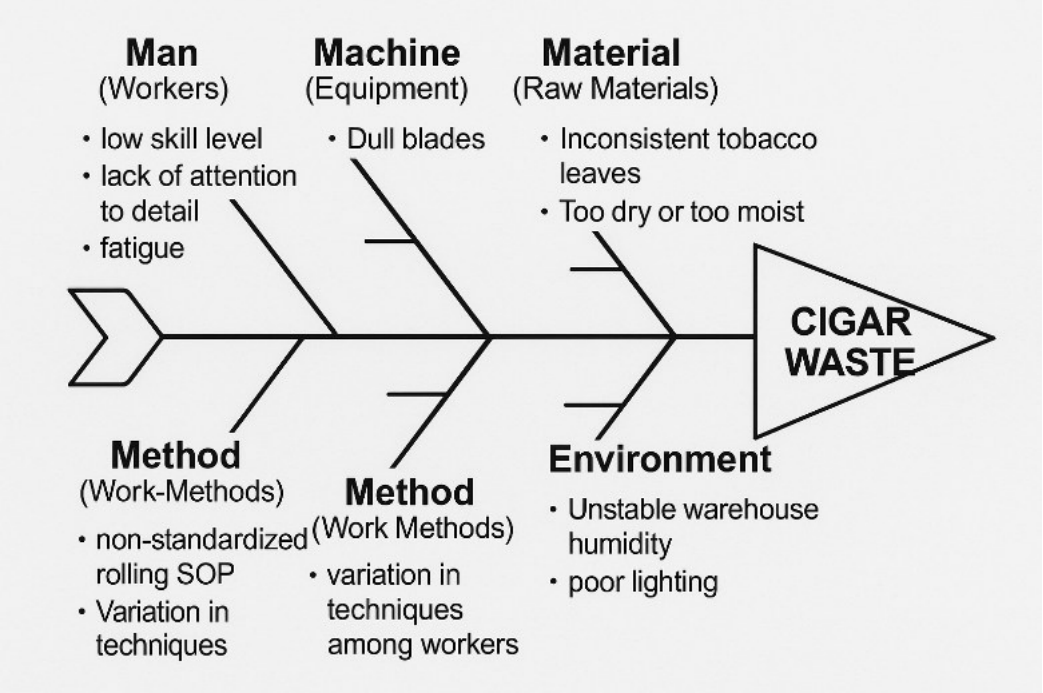



**Figure 4.** Cause-and-Effect (Fishbone) Diagram of Cigar Waste

Main Factors Contributing to Waste:

a) Man (labor): low skill level, lack of accuracy, worker fatigue.
b) Machine: dull cutting blades, non-ergonomic rolling tables.
c) Material (raw material): non-uniform tobacco leaves, overly dry or moist conditions.
d) Method: absence of standardized rolling SOP, variation in rolling techniques among workers.
e) Environment: unstable warehouse humidity, poor lighting conditions.

The Cause-and-Effect (Fishbone/Ishikawa) diagram of cigar waste illustrates that waste generation is not solely influenced by raw materials, but rather a combination of multiple key factors. From the labor aspect (Man), causes include low skill levels, lack of precision, and fatigue, which reduce consistency in results. The machine factor (Machine), such as dull blades and non-ergonomic rolling tables, also contributes to product defects. Regarding raw materials (Material), non-uniform tobacco leaves and leaves that are either too dry or too moist complicate the rolling process. Work methods (Method) pose another issue due to the lack of standardized rolling SOPs and the presence of varied techniques among workers. Meanwhile, environmental factors (Environment), such as unstable warehouse humidity and poor lighting, further increase the likelihood of waste.

Thus, effective waste control in the cigar industry must be implemented comprehensively by improving worker skills, maintaining machines, standardizing methods, ensuring proper raw material selection, and enhancing workplace environmental conditions.

### 3.5 Corrective Solutions

Based on the results of SPC and the fishbone diagram, proposed corrective measures include:

a) Material: improve leaf sorting and standardize raw material moisture.
b) Man: provide roller training and implement work rotation to reduce fatigue.
c) Machine: conduct routine maintenance of cutting tools and modernize rolling equipment.
d) Method: develop standardized SOPs and carry out regular quality inspections.

e) Environment: control warehouse humidity (65–70%) and optimize lighting conditions.

3.6 Research Implications

The results of this study show that the application of SPC in cigar waste control in Jember provides strategic benefits:

1) Economic: reducing production costs, increasing product yield, and creating opportunities for utilizing waste as secondary raw material (e.g., SKT).
2) Environmental: minimizing the volume of organic waste, supporting green industry practices and the circular economy.

**Table** 3. Economic and Environmental Impacts of SPC Implementation on Cigar Waste Management

| Parameter | Before SPC | After SPC | Improvement (%) |
|---|---|---|---|
| Waste volume (kg/day) | 75 | 52 | 30.7% ↓ |
| Cost savings (IDR/month) | 0 | 3,200,000 | +3.2 M |
| Recycled SKT revenue (IDR/month) | – | 1,500,000 | New income |

"Implementation of SPC reduced waste by 30.7% and generated additional income of IDR 1.5 million/month from SKT reuse, thus strengthening the local circular economy."

Therefore, the implementation of SPC can serve as the foundation for developing a Teaching Factory (TEFA) for tobacco at Politeknik Negeri Jember and as a model for sustainable quality control in Indonesia's cigar industry.

## 4. Conclusions

"The study's conclusions are limited to the production context of CV Dwipa Nusantara and may not fully represent the entire cigar industry in Jember. Future research should expand data collection to include at least three additional factories applied Statistical Process Control (SPC) to monitor and control cigar waste in Jember Regency. The use of X-bar, R, and I-MR control charts demonstrated that most production processes were statistically stable, although several special cause variations were detected, particularly in leaf uniformity and tobacco moisture control. Process capability analysis revealed that leaf scraps (Cpk = 1.69) were within acceptable standards, while defective cigars (Cpk = 0.28) indicated the need for workforce retraining and SOP standardization.

The Fishbone (Ishikawa) diagram confirmed that waste generation is not solely determined by raw materials but results from multiple factors including manpower, machines, materials, methods, and environmental conditions. Corrective actions such as improved leaf sorting, roller training, routine maintenance of cutting equipment, standardized SOPs, and better warehouse humidity control are essential to minimize waste.

The findings highlight two main implications. Economically, SPC implementation reduces production costs, increases product yield, and creates opportunities to utilize waste as a secondary raw material, such as for sigaret kretek tangan (SKT). Environmentally, it decreases the volume of organic waste, supporting green industry and the circular economy. "Normality tests (Shapiro–Wilk, $p > 0.05$) confirmed that subgroup data ($n = 5$ per batch) were normally distributed, validating SPC assumptions."

Overall, SPC provides a practical and strategic model for sustainable quality control in the cigar industry. Furthermore, it can serve as the foundation for developing a Teaching Factory (TEFA) for tobacco at Politeknik Negeri Jember, while also contributing to national-level strategies for waste reduction and competitiveness enhancement in Indonesia's cigar industry.

**Supplementary Materials: -**
Author Contributions: "Conceptualization, 1st. and 2nd; methodology, 3rd; software, 4th; validation, 3rd and 6th; formal analysis, 5th; investigation, 4th; resources, 7th; data curation, 8th; writing—original draft preparation, 3rd; writing—review and editing, 4th; visualization, 7th; supervision, 5th; projectadministration, 2nd; funding acquisition, 1st"

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