

Research Article

Optimization of Quality Control for Non-Dairy Creamer Products at PT. XYZ Based on Statistical Process Control (SPC) to Improve Production Efficiency

Sulkhan¹, Alex²Universitas Buddhi Dharma, Indonesia ^{1,2}Corresponding Author, Email: sulkhan.sulkhan@ubd.ac.id**Abstract**

The competitive dynamics of the Fast-Moving Consumer Goods (FMCG) industry, particularly in the non-dairy creamer sector, necessitate stringent quality control to ensure production efficiency. This study aims to analyze process stability, evaluate process capability, and identify root causes of quality variability in the production of non-dairy creamer using the Statistical Process Control (SPC) approach. Critical to Quality (CTQ) parameters, including net weight and moisture content, were monitored over 30 production days with a total of 150 and 210 observations, respectively. The methodology employed Anderson-Darling normality tests, $\bar{X} - R$ control charts, and process capability indices (C_p and C_{pk}). The results indicated that the moisture content process was stable and highly capable ($C_{pk} = 1.85$). However, the net weight analysis revealed a special cause variation in subgroup 15, exceeding the Upper Control Limit (UCL), despite maintaining an overall excellent capability ($C_{pk} = 1.70$). Root cause analysis using a Fishbone Diagram identified dust accumulation on the load cell sensors and inadequate cleaning SOPs as the primary factors for the over-filling anomaly. This research formulates corrective recommendations, including the implementation of an automated self-cleaning system and digital monitoring, to minimize rework costs and optimize raw material usage, thereby enhancing overall production efficiency.

Keywords: Statistical Process Control (SPC), Process Capability (CPK), Non-Dairy Creamer, Production Efficiency, Rework Prevention.



INTRODUCTION

The Fast Moving Consumer Goods (FMCG) industry, particularly the non-dairy creamer sector, is currently facing highly competitive market dynamics. Changes in consumer lifestyles and the rapid expansion of the coffee and ready-to-drink beverage industries in Indonesia have triggered a significant surge in demand. However, this growing demand is accompanied by intense price competition among manufacturers. Under such market conditions, quality consistency is no longer merely a competitive advantage but has become an essential requirement to maintain consumer trust and to minimize the cost of poor quality.

The production of non-dairy creamer involves complex food processing technologies, in which the spray drying stage represents a critical point that determines the final product characteristics. Several Critical to Quality (CTQ) parameters must be precisely controlled, including moisture content, fat content, and net weight. In practice, parameters such as moisture content are highly susceptible to fluctuations caused by instability in inlet and outlet temperatures of the spray dryer, as well as variations in ambient air humidity. Instability in these variables directly affects product solubility, shelf life, and powder texture.

Previous studies have demonstrated the effectiveness of Statistical Process Control (SPC) in the food processing industry. Research by (Bakhtiar et al., 2013) found that the application of $\bar{X}$ -R control charts in powder packaging lines reduced off-spec products by up to 15% through early detection of temperature variation. Similarly, (Fernandes, 2025) emphasized that process capability analysis using the Cpk index is a crucial predictive tool to prevent raw material waste caused by overfilling in liquid products. Nevertheless, the application of SPC to the specific characteristics of non-dairy creamer—where complex interactions occur between net weight and moisture content under continuous production conditions—still requires further investigation to achieve optimal cost efficiency.

Although production lines may appear to operate continuously and generate acceptable output, undetected variability often persists beneath the surface. This situation creates a critical analytical gap: many companies assume their processes are stable because final products remain within specification limits, while statistically the processes exhibit high inconsistency. Excessive variability leads to frequent rework and raw material waste, indicating that the production process may lack adequate capability

despite meeting minimum quality standards.

To address these issues, Statistical Process Control (SPC) offers an essential methodological approach. Unlike conventional manual inspection, which is reactive in nature, SPC enables early detection of process deviations through the use of control charts. SPC allows management to distinguish between natural variation (common causes) and special-cause variation (assignable causes). Furthermore, process capability analysis using Cp and Cpk indices provides a quantitative measure of how consistently production equipment meets quality specifications, thereby improving production efficiency through variance reduction and waste minimization.

Based on the identified problems, this study aims to statistically evaluate the stability of the non-dairy creamer production process using $\bar{X}$ -R control charts, assess process capability through Cp and Cpk indices, identify the dominant root causes of quality variability across the six dimensions of Man, Machine, Method, Material, Measurement, and Mother Nature, and formulate improvement recommendations to reduce process variation, minimize rework, and enhance production efficiency in line with Total Quality Management principles.

METHOD

This study adopts a descriptive quantitative approach with direct technical observation conducted on the production line. The research framework is designed to capture real-time process variability in order to evaluate the capability of the production system to consistently meet established quality specifications.

Sampling Technique

The study was conducted over a period of 30 working days to capture inter-shift variability and fluctuations in production environmental conditions. The sampling technique applied was Systematic Subgroup Sampling, with the following specifications:

1. Sampling Location: Final packaging line (filling station) for 25 kg sack products after the spray drying process.
2. Sample Size (Net Weight Data): Seven samples were randomly collected per day as one subgroup, resulting in a total of $N = 210$ observations (30 days $\times$ 7 samples).
3. Sample Size (Moisture Content Data): Given the critical importance of moisture accuracy, seven samples per day were collected as one subgroup, yielding $N = 210$

observations (30 days $\times$ 7 samples). This sample size exceeds the minimum requirement to satisfy the assumptions of the Central Limit Theorem.

Identification of Critical to Quality (CTQ)

The critical quality variables measured in this study were determined based on the company's internal quality standards and customer requirements, namely:

1. Net Weight: The target specification was set at 25.00 kg with a tolerance of ± 0.05 kg (LSL = 24.95 kg; USL = 25.05 kg).
2. Moisture Content: The specification limits ranged from a minimum of 2.0% (LSL = 2.0%) to a maximum of 3.0% (USL = 3.0%). Measurements were conducted using a calibrated Moisture Analyzer.

Data Analysis Criteria and Procedures

Data analysis was conducted systematically using four primary evaluation criteria in accordance with Statistical Process Control (SPC) standards:

1. Anderson–Darling Normality Test: This test was applied to verify whether the data followed a normal distribution. A p-value > 0.05 was used as the acceptance criterion. This step is a prerequisite for subsequent process capability analysis.
2. $\bar{X}$ –R Control Charts: These charts were employed to monitor process mean stability ($\bar{X}$) and range variability (R). Control limits were calculated using the $\pm 3\sigma$ formula to detect the presence of special or assignable causes of variation.
3. Process Capability Indices (Cp and Cpk): These indices were used to evaluate process performance relative to specification limits. A process was considered capable if the Cpk value was ≥ 1.33 .
4. Cause-and-Effect (Fishbone) Diagram: This tool was utilized to investigate root causes of quality variation based on the 6M framework (Man, Machine, Method, Material, Measurement, and Mother Nature) when statistically out-of-control conditions were identified.

Supporting Software Tools

To ensure statistical accuracy and effective data visualization, the following software tools were employed:

1. Minitab v20.3: The primary software used for conducting the Anderson–Darling

- normality test, constructing $\bar{X}$ -R control charts, and generating process capability reports.
2. Microsoft Excel: Used for raw data tabulation, data entry, and preparation of supporting tables.

RESULT AND DISCUSSION

Identification and Collection of Critical to Quality (CTQ) Data

The initial stage in evaluating the quality of non-dairy creamer products involves identifying the parameters that have the greatest impact on consumer satisfaction, commonly referred to as Critical to Quality (CTQ) characteristics. Based on the company’s technical specifications and standard operating procedures, the primary CTQ parameters analyzed in this study were net weight and moisture content. Data were systematically collected over a 30-day production period to capture representative process variability arising from both machine performance fluctuations and environmental conditions within the production line.

The observed net weight data are presented in Table 1, summarizing product mass variation relative to the target specification of 25 kg. Meanwhile, physical characteristics related to storage stability and powder quality are represented by the moisture content observations in Table 2. These two sets of raw data serve as the empirical foundation for subsequent statistical analyses, including normality testing, control chart construction, and process capability evaluation.

Table 1. Net Weight Observation Data for Products for 30 Days (kg)

Day	Parameter	S1	S2	S3	S4	S5	S6	S7	Average
1	Weight (kg)	25.01	24.98	24.99	24.99	24.99	24.95	24.95	24.98
2	Weight (kg)	25.03	25.01	25.03	25.02	25.02	25.03	24.97	25.02
3	Weight (kg)	24.99	25.00	24.99	24.98	24.98	24.99	24.95	24.98
4	Weight (kg)	25.05	25.02	25.03	25.01	25.01	25.00	24.96	25.01
5	Weight (kg)	24.98	24.97	25.01	24.99	25.00	24.99	24.99	24.99
6	Weight (kg)	25.02	25.01	25.01	25.00	25.00	25.00	25.00	25.01
7	Weight (kg)	25.00	25.02	25.01	25.01	25.01	24.96	24.99	25.00
8	Weight (kg)	24.97	24.99	24.98	24.98	24.98	25.00	25.01	24.99
9	Weight (kg)	25.04	25.01	25.01	25.01	25.02	24.99	25.00	25.01

10	Weight (kg)	25.00	25.01	25.00	24.99	24.99	24.98	24.99	24.99
11	Weight (kg)	25.01	25.00	25.04	25.02	25.02	24.96	25.01	25.01
12	Weight (kg)	25.05	25.03	25.02	25.02	25.02	25.02	25.00	25.02
13	Weight (kg)	24.98	25.00	25.01	24.97	24.97	25.00	24.98	24.99
14	Weight (kg)	25.02	25.01	25.00	25.01	25.01	24.98	24.99	25.00
15	Weight (kg)	25.05	25.05	25.05	25.05	25.07	24.96	25.01	25.03
16	Weight (kg)	25.00	24.99	24.99	25.02	25.02	24.99	25.02	25.00
17	Weight (kg)	24.96	24.98	24.99	24.95	24.95	25.00	25.04	24.98
18	Weight (kg)	25.03	25.01	25.03	25.04	25.04	24.99	25.00	25.02
19	Weight (kg)	25.02	25.05	25.01	25.00	25.00	25.00	24.99	25.01
20	Weight (kg)	25.01	25.02	25.03	24.99	24.99	24.98	24.96	25.00
21	Weight (kg)	25.00	24.99	25.01	25.00	25.00	25.00	24.98	25.00
22	Weight (kg)	25.02	25.01	25.02	25.01	25.01	24.97	24.96	25.00
23	Weight (kg)	24.99	24.98	24.98	24.99	24.99	24.98	25.00	24.99
24	Weight (kg)	25.01	25.02	25.02	25.01	25.01	25.02	24.99	25.01
25	Weight (kg)	25.00	25.00	25.00	25.00	25.00	25.01	25.00	25.00
26	Weight (kg)	25.03	25.02	25.00	25.02	25.02	25.00	24.98	25.01
27	Weight (kg)	24.98	24.99	25.05	24.99	24.99	24.98	25.01	25.00
28	Weight (kg)	25.00	25.01	25.01	24.98	24.98	24.97	25.03	25.00
29	Weight (kg)	25.01	25.00	25.01	24.99	24.99	24.99	25.01	25.00
30	Weight (kg)	24.99	25.00	25.00	24.99	24.99	24.99	25.00	24.99

Table 2. Observation Data on Product Moisture Content for 30 Days (%)

Day	Parameter	S1	S2	S3	S4	S5	S6	S7	Average
1	MC (%)	2.80	2.60	2.70	2.63	2.70	2.60	2.67	2.67
2	MC (%)	2.85	2.68	2.75	2.66	2.64	2.72	2.75	2.72
3	MC (%)	2.90	2.72	2.69	2.71	2.73	2.63	2.71	2.73
4	MC (%)	2.88	2.60	2.62	2.63	2.61	2.70	2.62	2.67
5	MC (%)	2.86	2.50	2.74	2.76	2.77	2.80	2.85	2.75
6	MC (%)	2.81	2.65	2.63	2.61	2.64	2.66	2.69	2.67
7	MC (%)	2.84	2.42	2.67	2.69	2.71	2.62	2.68	2.66
8	MC (%)	2.90	3.00	2.63	2.70	2.72	2.65	2.63	2.75
9	MC (%)	2.96	2.62	2.75	2.63	2.60	2.65	2.68	2.70
10	MC (%)	2.93	2.74	2.71	2.73	2.75	2.78	2.77	2.77
11	MC (%)	2.80	2.85	2.82	2.84	2.81	2.84	2.85	2.83
12	MC (%)	2.88	2.85	2.83	2.81	2.85	2.83	2.69	2.82
13	MC (%)	2.82	2.81	2.83	2.83	2.70	2.82	2.81	2.80
14	MC (%)	2.80	2.35	2.74	2.76	2.78	2.82	2.84	2.73
15	MC (%)	2.86	2.70	2.69	2.71	2.67	2.76	2.73	2.73
16	MC (%)	2.80	2.81	2.71	2.80	2.75	2.90	2.87	2.81

17	MC (%)	2.80	2.72	2.81	2.90	2.89	2.82	2.87	2.83
18	MC (%)	2.87	2.79	2.76	2.78	2.80	2.83	2.89	2.82
19	MC (%)	2.81	2.68	2.66	2.99	2.64	2.75	2.79	2.76
20	MC (%)	2.70	2.72	2.71	2.69	2.73	2.85	2.79	2.74
21	MC (%)	2.76	2.60	2.59	2.61	2.57	2.68	2.61	2.63
22	MC (%)	2.79	2.50	2.63	2.61	2.61	2.64	2.78	2.65
23	MC (%)	2.82	2.83	2.80	2.73	2.86	2.60	2.62	2.75
24	MC (%)	2.84	2.70	2.69	2.71	2.67	2.78	2.80	2.74
25	MC (%)	2.89	2.74	2.73	2.75	2.71	2.80	2.85	2.78
26	MC (%)	2.90	2.70	2.61	2.63	3.00	2.65	2.63	2.73
27	MC (%)	2.87	2.72	2.59	2.61	2.57	2.69	2.78	2.69
28	MC (%)	2.88	2.67	2.66	2.68	2.64	2.69	2.74	2.71
29	MC (%)	2.93	2.56	2.71	2.73	2.69	2.75	2.77	2.73
30	MC (%)	2.91	2.63	2.63	2.65	2.61	2.69	2.73	2.69

Normality Test Analysis

Prior to conducting control chart analysis and process capability evaluation, verification of the normal distribution assumption was performed to ensure that the observed data variation represented natural (common-cause) variation and satisfied the statistical requirements for variable data analysis. The normality test was conducted using the Anderson–Darling (AD) method with the assistance of Minitab version 20.3. Data from both CTQ parameters were divided into seven sample subgroups to examine the consistency of data distribution throughout the observation period.

1. Normality Test for Net Weight

The results of the normality test for the net weight parameter are summarized in Table 3. The primary statistical indicator considered in this analysis is the p-value, evaluated at a significance level of $\alpha = 0.05$.

Table 3. Summary of Net Weight Normality Test Statistics

Sample	Mean (kg)	StDev (kg)	AD	P-Value	Decision
1	25,01	0,02335	0,324	0,511	Normal
2	25,01	0,01868	0,620	0,097	Normal
3	25,01	0,01845	0,610	0,102	Normal
4	25,00	0,02040	0,578	0,121	Normal
5	25,00	0,02239	0,669	0,073	Normal
6	24,99	0,01874	0,599	0,109	Normal

7	24,99	0,02208	0,605	0,106	Normal
---	-------	---------	-------	-------	--------

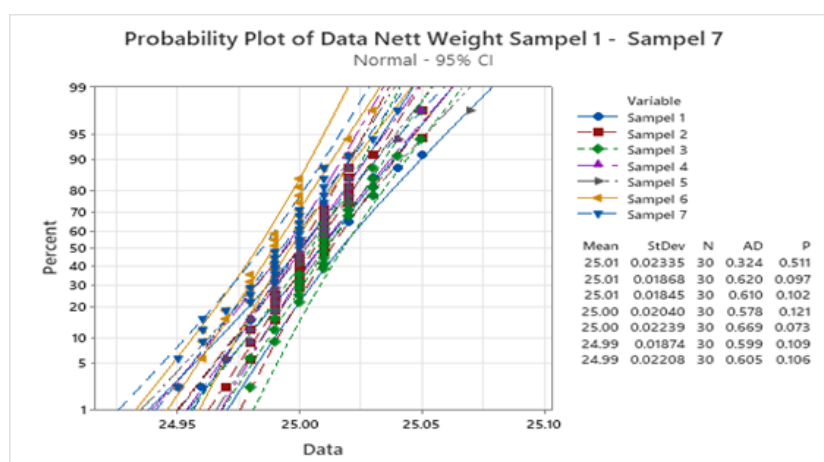


Figure 1. Normal Probability Plot of Net Weight of Vegetable Creamer Products

Interpretation: Based on Table 3, all samples exhibit p-values greater than 0.05, indicating that the null hypothesis (H_0) is accepted. This result confirms that the net weight data follow a normal distribution, with a mean that is highly precise relative to the 25 kg target specification.

2. Normality Test for Moisture Content

Normality verification for the moisture content parameter was conducted to ensure the accuracy and reliability of subsequent analyses related to the spray drying process. The test results are presented in Table 4.

Table 4. Summary of Statistics of Normality Test of Water Content

Sample	Mean (%)	StDev (%)	AD	P-Value	Decision
1	2,849	0,05667	0,342	0,469	Normal
2	2,682	0,13460	0,382	0,377	Normal
3	2,703	0,07091	0,368	0,408	Normal
4	2,719	0,09241	0,602	0,107	Normal
5	2,714	0,10060	0,415	0,315	Normal
6	2,733	0,08555	0,625	0,094	Normal
7	2,750	0,08438	0,393	0,354	Normal

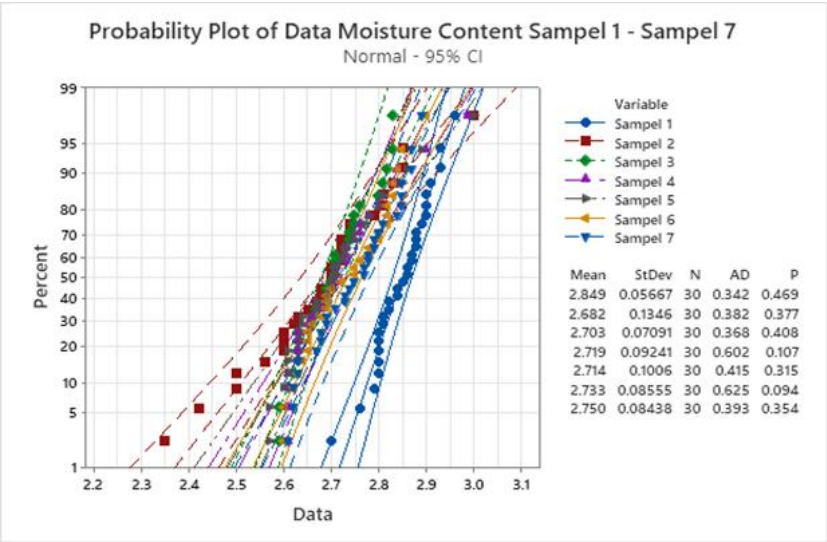


Figure 2. Normal Probability Plot of Water Content of Vegetable Creamer Products

Interpretation: The results presented in Table 4 indicate that the lowest p-value is 0.094 (Sample 6), which remains above the significance level of 0.05. Visually, the data points in Figure 2 closely follow the reference straight line, further reinforcing the conclusion that the moisture content data are normally distributed and therefore suitable for process capability analysis.

Process Stability Analysis Using $\bar{X}$ -R Control Charts

After the normality assumption was satisfied, the next critical step was to statistically evaluate process stability using $\bar{X}$ -R control charts. This analysis aims to determine whether fluctuations in the Net Weight and Moisture Content parameters remain within the statistical control limits of $\pm 3\sigma$ or are influenced by special (assignable) causes of variation.

1. $\bar{X}$ -R Control Charts for Net Weight

The control charts for the net weight parameter were constructed based on 30 observational subgroups. The resulting statistical parameters include the Central Line (CL), Upper Control Limit (UCL), and Lower Control Limit (LCL).

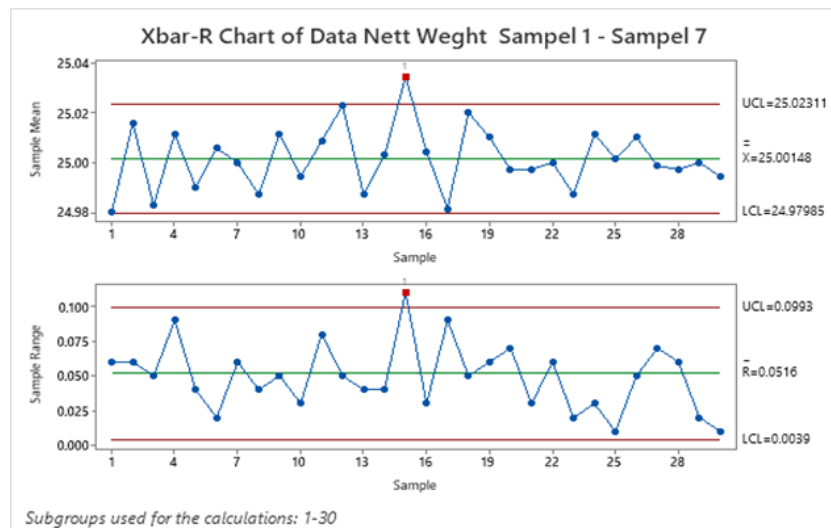


Figure 3. $\bar{X}$ – R Control Chart Net Weight of Vegetable Creamer

Interpretation of Net Weight Control Charts:

- a. $\bar{X}$ –R Chart (Mean): One data point in subgroup 15 was found to exceed the Upper Control Limit (UCL = 25.02311 kg). This indicates the presence of a special (assignable) cause that triggered an overfilling condition. This finding warrants further investigation using a fishbone (cause-and-effect) diagram.
 - b. R Chart (Range): All data points fall within the established control limits (UCL = 0.0993; LCL = 0.0039). This result indicates that although a temporary shift in the process mean occurred, the internal variability or precision of the process within each subgroup remained stable and under control.
2. $\bar{X}$ –R Control Charts for Moisture Content

The evaluation of process stability for the moisture content parameter was conducted to ensure the consistency of spray dryer performance throughout the 30-day production period.

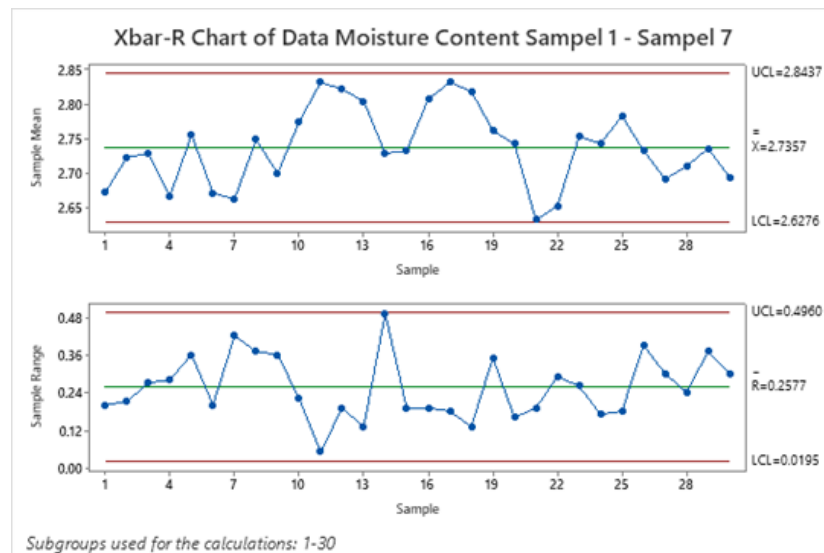


Figure 4. $\bar{X}$ –R Control Chart of Vegetable Creamer Water Content

Interpretation of Moisture Content Control Charts:

- $\bar{X}$ –R Chart (Mean): All 30 observation points fall within the control limits (UCL = 2.8437%; LCL = 2.6276%) with a Central Line (CL) of 2.7357%. No non-random patterns such as runs or trends were detected, indicating that the process mean is statistically stable.
- R Chart (Range): The subgroup ranges fluctuate randomly around the Central Line (CL = 0.2577%) and remain below the UCL of 0.4960%. This result indicates that the natural variation of the drying process is statistically acceptable and well controlled.

Process Capability Analysis (Cp and Cpk)

Process capability analysis was conducted to evaluate the technical performance of the non-dairy creamer production line in meeting the company's established quality specifications. The primary focus at this stage was the calculation of the Cp (potential capability) and Cpk (actual capability) indices. A process is considered to exhibit excellent performance when the Cpk value exceeds 1.33, indicating that the data distribution is well within the specification limits.

1. Process Capability of Net Weight

The capability analysis for the net weight parameter was based on the target specification of 25 kg with a strict tolerance range. The results of data processing using Capability Analysis in Minitab are presented as follows:

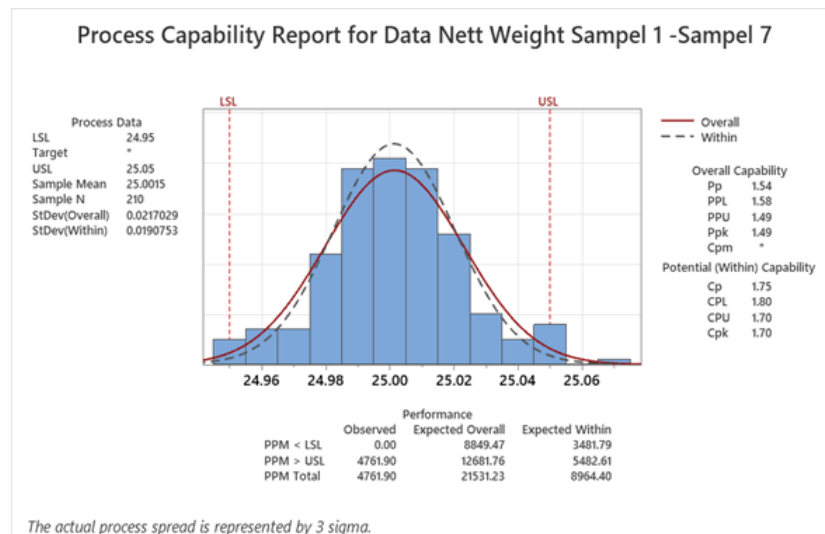


Figure 5. Process Capability Report Net Weight (Net Weight)

Interpretation of Net Weight Process Capability:

- a. **Capability Indices:** Based on Figure 5, the calculated values of $C_p = 1.75$ and $C_{pk} = 1.70$ indicate that the net weight filling process is highly capable, as the C_{pk} value exceeds the benchmark threshold of 1.33.
 - b. **Accuracy and Precision:** The very small difference between C_p and C_{pk} suggests that the process mean is well centered around the specification midpoint, reflecting both high accuracy and precision.
 - c. **Defect Potential:** The Expected Overall Performance shows an extremely low defect rate (PPM), indicating that the risks of consumer complaints due to underweight products or financial losses resulting from product giveaway (overfilling) are significantly minimized.
2. **Process Capability of Moisture Content**

This analysis aims to ensure that the product moisture content consistently remains below the maximum specification limit of 3.0%, thereby maintaining product stability and extending shelf life.

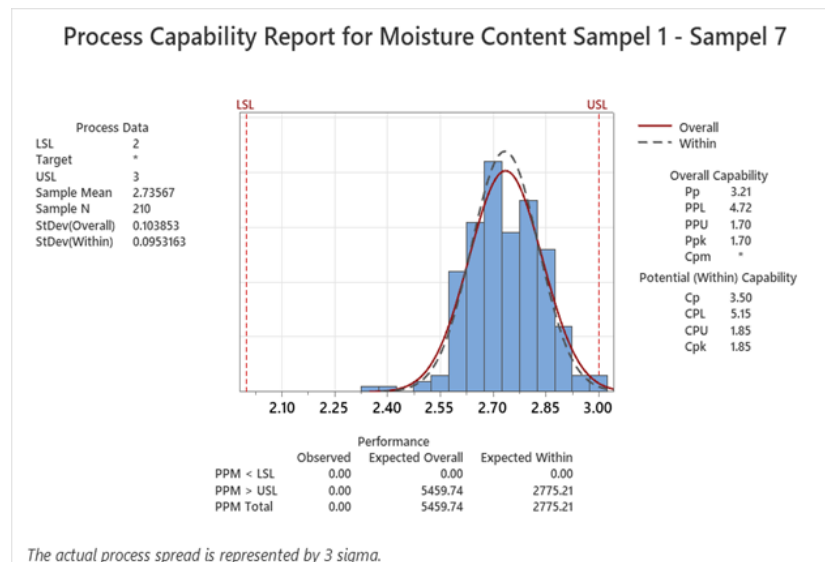


Figure 6. Process Capability Report Water Content (Moisture Content)

Interpretation of Moisture Content Process Capability:

- Capability Indices:** The analysis results indicate $C_p = 3.50$ and $C_{pk} = 1.85$. These values substantially exceed the industry benchmark of 1.33, classifying the spray drying process for moisture control as excellent.
- Chemical Stability:** With a C_{pk} value of 1.85, the probability of products falling outside the specification limits (exceeding 3.0% moisture content) is nearly zero. This provides strong assurance that the physical and chemical stability of the creamer powder will be maintained throughout packaging and distribution processes.

To provide a comprehensive comparison of process capability performance across both CTQ parameters, the calculated results are summarized in the following table.

Table 5. Summary of Net Weight and Moisture Content Process Capability Index

Parameter	USL	LSL	Cp	Cpk	Description
Net Weight	25,10	24,99	1,75	1,70	Very Capable
Moisture Content	3,00	-	3,50	1,85	Very Capable

Root Cause Analysis Using Fishbone Diagram

Although the overall process capability results indicate excellent performance, the presence of a data point exceeding the Upper Control Limit (UCL) in subgroup 15 of

the Net Weight control chart suggests the occurrence of a special (assignable) cause of variation. To identify the root causes of this anomaly, an in-depth analysis was conducted using a fishbone (Ishikawa) diagram, examining the 6M factors: Man, Machine, Method, Material, Measurement, and Mother Nature.

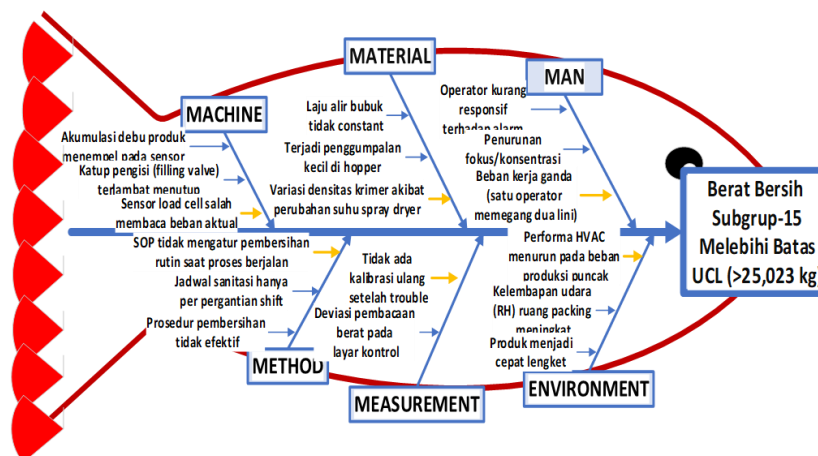


Figure 7. Fishbone Diagram of the Cause of Over-filling Anomaly in Net Weight

1. Interpretation of Root Cause Analysis

Based on the results of field investigations and technical observations summarized in Figure 7, the following root causes were identified:

- Machine:** Accumulation of fine non-dairy creamer powder dust was observed around the load cell (weighing sensor) area. The adhered dust created a static load that interfered with the sensor's sensitivity and accuracy.
- Method:** The Standard Operating Procedure (SOP) for machine sanitation was implemented only at the end of each shift, resulting in insufficient handling of residue accumulation during ongoing production.
- Man:** Operators demonstrated limited awareness in monitoring control chart trends, causing shifts in the process mean to go undetected at an early stage.
- Measurement:** The absence of an automated alarm system integrated with the filling machine prevented timely warnings when measurement data approached the outer specification limits.
- Mother Nature:** Fluctuating ambient humidity in the packaging area accelerated powder agglomeration on static electronic components.

Table 6. Root Cause Matrix and Corrective Action Plan

Category	Root Cause	Process Impact	Recommended Corrective Actions
Machine	Accumulation of fine product dust in the load cell sensor area.	Decreased sensor sensitivity, which can lead to overfilling.	Installation of an Air Jet Cleaner system (automatic air spray) on the sensors.
Method	Sensor sanitation is only performed once at the end of the shift.	Undetected residue buildup mid-process.	Revised SOP: Mandatory sensor cleaning and verification every four hours.
Man	Low operator competency in reading control chart trends.	Response delays as data approaches the UCL limit.	Intensive training on Control Chart interpretation and anomaly response.
Measurement	Lack of an early warning system.	Operators only discover the problem after the product is packaged.	Implementation of an automatic alarm if data reaches the $\pm 2\sigma$ limit (Warning Limit).
Mother Nature	Humidity fluctuations in the packing area accelerate dust agglomeration.	Product dust adheres and hardens more quickly to machine components.	Optimization of the dust collection system and temperature/humidity control in the packaging room.

Discussion on the Integration of SPC-Based Quality Control in Creamer Production

The series of Statistical Process Control (SPC) analyses conducted on non-dairy creamer products represents a unified framework for evaluating the overall health of the production system in a holistic manner. This discussion integrates findings related to process stability, process capability, and operational efficiency improvement strategies.

1. Process Stability Analysis and the Phenomenon of Assignable Causes

Based on monitoring results using $\bar{X}$ -R control charts, the production process generally demonstrated a stable trend. However, a closer examination of the Net Weight parameter revealed an anomaly in subgroup 15, where the observation exceeded the Upper Control Limit (UCL). Referring to Montgomery (2013), this condition indicates that the process was no longer influenced solely by natural variation (common causes), but had been affected by special or assignable causes. This phenomenon confirms that even when the majority of data points remain

within control limits, the absence of real-time monitoring may allow minor deviations in the filling line to accumulate into broader process failures, ultimately compromising product quality consistency at the consumer level.

2. Technical Performance Evaluation through Process Capability Analysis

Despite the identified deviation in a specific subgroup, the long-term process capability analysis provides an optimistic perspective. The obtained Cpk values of 1.70 for Net Weight and 1.85 for Moisture Content exceed the ideal threshold of 1.33 as defined by Oakland (2014). These results demonstrate that, from a technical standpoint, the filling machine and spray dryer system exhibit very high precision, classified as excellent. The implication of this finding is that the anomaly observed in the control chart does not reflect a systemic weakness in machine capability, but rather an isolated technical-operational disturbance. When such disturbances are addressed through improved machine governance and maintenance practices, the superior process capability can provide sustainable quality assurance.

3. Root Cause Identification through the 6M Perspective

Investigation of the anomaly in subgroup 15 was conducted using a Fishbone Diagram to dissect interactions among production factors. The analysis revealed that the Machine and Method categories were the primary contributors. Environmental factors (Mother Nature), specifically the accumulation of fine powder dust in the production area, were found to mechanically interfere with the Measurement system at the load cell. Dust accumulation created static loads that impaired sensor accuracy, a condition exacerbated by sanitation methods (Method) that were performed only at the end of each shift. This analysis highlights that in powder-based FMCG industries, microscopic cleanliness of weighing sensor components is a critical variable in ensuring net weight accuracy.

4. Synthesis of Operational Efficiency Improvement Strategies

As the culmination of the SPC analysis, these statistical findings were synthesized into operational efficiency improvement strategies aligned with Total Quality Management (TQM) principles (Gaspersz, 2001):

- a. Variance Reduction: Improvements in sensor sensitivity through the proposed technical recommendations will stabilize net weight values closer to the 25 kg target. This directly minimizes product giveaway, which often represents a hidden cost resulting from overfilling.

- b. Rework Reduction: The high consistency of moisture content, evidenced by a Cpk value of 1.85, ensures that products do not require re-drying processes. This leads to significant savings in electrical and gas energy consumption associated with spray dryer operations.
- c. Strategic Recommendations: The proposed implementation of self-cleaning systems and automated alarm mechanisms is not merely a technical enhancement but a strategic cost optimization initiative. By minimizing manual intervention and accelerating anomaly detection, the company can achieve maximum production efficiency with minimal risk of process failure.

CONCLUSION

This study aimed to evaluate the process stability and capability of production operations using Statistical Process Control (SPC) on two key quality characteristics, namely net weight and moisture content, based on company operational data.

The normality test results confirmed that both variables followed a normal distribution ($p\text{-value} > 0.05$), fulfilling the prerequisite for variable control chart analysis. The $\bar{X}$ -R control charts indicated that both processes were statistically controlled, with only one temporary special-cause indication observed in the net weight mean, which did not affect overall process variability.

Process capability analysis showed that the net weight process was highly capable ($C_p = 1.75$; $C_{pk} = 1.70$), with the process mean well centered within specification limits and a low risk of nonconforming products. Overall, the findings demonstrate that SPC is an effective quality control tool for monitoring process stability, detecting early deviations, and supporting data-driven decision making to ensure sustainable process performance.

Recommendations

The company is recommended to consistently implement SPC as a routine monitoring tool for critical quality characteristics, particularly net weight and moisture content, to enable early detection of special-cause variation. Periods indicating abnormal variation should be further investigated using root cause analysis methods, such as fishbone diagrams or the 5-Why approach, to prevent recurrence.

The achieved stability of the moisture content process should be maintained

through strict control of raw materials, drying parameters, and measurement systems. Additionally, integrating SPC results with continuous improvement programs, such as Quality Control Circles (QCC) or Kaizen, is recommended to translate statistical findings into structured improvement actions.

Future studies are encouraged to expand the analysis by incorporating long-term process capability evaluation and examining the relationship between process stability and operational performance.

Bibliography

- Amiruddin, N. H., et al. (2021). Process capability analysis in food production: A case study on consistency. *International Journal of Lean Six Sigma*.
- Antony, J., & Taner, T. (2003). A conceptual framework for the effective implementation of statistical process control. *Business Process Management Journal*, 9(4), 477–489.
- Badan Standardisasi Nasional. (2020). *Krimmer Nabati (Non-Dairy Creamer)* (SNI 8921:2020). Jakarta: BSN.
- Does, R. J. M., & Schippers, W. A. J. (1997). A general approach to process control charts. *Quality Engineering*, 9(3), 425–434.
- Gaspersz, V. (2005). *Total Quality Management*. Jakarta: PT Gramedia Pustaka Utama.
- Grant, E. L., & Leavenworth, R. S. (1996). *Statistical Quality Control*. New York: McGraw-Hill Education.
- Hidayat, R. (2021). Analisis kapabilitas proses produksi pada industri makanan bubuk menggunakan indeks Cp dan Cpk. *Jurnal Standardisasi*, 23(1), 89–98.
- Kurniawan, D., & Prabowo, A. (2021). Pengendalian kualitas proses produksi dengan metode SPC. *Jurnal Ilmiah Teknik dan Manajemen Industri*, 5(2), 112–120.
- Lestari, D., & Putra, R. (2017). Analisis cacat produk menggunakan statistical process control. *Jurnal Manajemen Industri*, 6(1), 45–53.
- Lim, S. A. H., Antony, J., & Albliwi, S. (2017). Statistical process control implementation in the food manufacturing industry: A systematic diagrams approach. *Food Control*, 73, 155–171.
- Montgomery, D. C. (2013). *Introduction to Statistical Quality Control* (7th ed.). New York: John Wiley & Sons.
- Oakland, J. S. (2014). *Statistical Process Control*. London: Routledge.
- Pearn, W. L., & Kotz, S. (2006). *Encyclopedia of Process Capability Indices*. Singapore: World Scientific Publishing.
- Prasetyo, E., & Winarno, A. (2018). Penerapan Statistical Process Control (SPC) dalam pengendalian kualitas produk. *Jurnal Teknik Industri*, 19(2), 145–154.
- Pratama, M. R. (2023). Optimasi efisiensi produksi FMCG melalui pengurangan variance pada lini filling otomatis. *Jurnal Manajemen Produksi dan Operasi*, 11(1), 22–35.
- Putri, A. M., & Setiawan, I. (2023). Implementasi I-MR Chart dalam memantau kadar air pada industri pengolahan susu. *Jurnal Rekayasa Proses*, 17(2), 110–122.
- Rahmawati, N., & Susanto, H. (2022). Analisis pengendalian kualitas produk menggunakan p-chart. *Jurnal Teknik Industri dan Manajemen*, 14(1), 34–42.
- Ramadhan, F. (2020). Pengaruh variabilitas parameter spray drying terhadap kualitas produk serbuk nabati. *Jurnal Teknologi Pangan*, 11(3), 201–215.

- Sari, R. P., & Nugroho, S. (2019). Analisis pengendalian kualitas dengan metode peta kendali p. *Jurnal Ilmiah Teknik Industri*, 18(1), 67–75
- Setiawan, A., & Hidayat, T. (2020). Pengendalian kualitas produk menggunakan metode SPC. *Jurnal Rekayasa Sistem Industri*, 9(2), 101–110.
- Suryaningrat, I. B. (2022). Quality control implementation in food agro-industry: Current status and future challenges. *IOP Conference Series: Earth and Environmental Science*, 959, 012010.
- Tan, M., et al. (2024). Digital transformation of SPC in FMCG manufacturing: A roadmap for real-time quality monitoring. *Journal of Industrial Engineering and Management*, 17(1), 55–70.
- Wijaya, T., & Santoso, B. (2018). Penerapan peta kendali dalam pengendalian kualitas produksi. *Jurnal Teknologi Industri*, 12(3), 189–198.
- Woodall, W. H. (2000). Controversies and contradictions in statistical process control. *Journal of Quality Technology*, 32(4), 341–350.