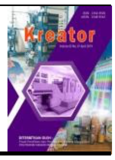
Kreator
Volume 13, Number 1, 2026 pp. 1-6
P-ISSN: 2354-9505 E-ISSN : 2548-9542
Open Access: https://doi.org/10.46961/kreator.v13i1.1722



Analysis of the Effect of Afval Material Composition on the Quality of Polyvinyl Chloride (PVC) Bottle Packaging in the Extrusion Blow Molding Process

Devita Danang Sari[1*], Mawan Nugraha[2], Mutia Hanum[3]

[1,2] Teknologi Rekayasa Pengemasan, Politeknik Negeri Media Kreatif, Jakarta, Indonesia.

ARTICLE INFO

Article history:
Received February 26, 2026
Revised April 29, 2026
Accepted April 30, 2026
Available online April 30, 2026

Kata Kunci:
Afval, kemasan PVC, extrusion blow molding, bintik hitam, SPC

Keywords:
Afval, Extrusion Blow Molding, Black Spot, Quality Control, SPC

ABSTRAK

Penelitian ini bertujuan untuk menganalisis pengaruh komposisi material afval terhadap kualitas kemasan botol PVC (Polyvinyl Chloride) yang diproduksi menggunakan mesin extrusion blow molding. Penelitian dilakukan di salah satu perusahaan manufaktur kemasan botol PT.X di Kabupaten Bogor, Jawa Barat, selama periode Januari hingga Maret 2025. Pendekatan yang digunakan adalah kuantitatif dengan analisis regresi linear untuk mengetahui hubungan antara variabel bebas (komposisi afval) dan variabel terikat (jumlah bintik hitam pada kemasan). Sebanyak 300 sampel botol diuji, terdiri dari enam variasi komposisi material (0%, 10%, 20%, 30%, 40%, dan 50%) dengan masing-masing 50 sampel, berdasarkan metode pengambilan sampel Military Standard 105E. Data diperoleh melalui observasi, studi literatur, diskusi kelompok (Focus Group Discussion), eksperimen, dan dokumentasi. Hasil penelitian menunjukkan bahwa peningkatan komposisi afval berpengaruh signifikan terhadap peningkatan jumlah cacat visual berupa bintik hitam. Analisis regresi linear menunjukkan nilai koefisien determinasi (R^2) tertinggi sebesar 0,959 pada komposisi 50%, yang mengindikasikan hubungan yang sangat kuat antara variabel. Batas maksimum penggunaan afval yang masih dapat ditoleransi untuk menjaga kualitas produk berada pada komposisi di bawah 30% sesuai standar mutu perusahaan. Selain itu, penerapan Statistical Process Control (SPC) dan Seven Tools of Quality Control terbukti efektif dalam memantau variasi proses produksi serta mendukung pengendalian mutu secara sistematis.

ABSTRACT

This study aims to analyze the effect of recycled material (afval) composition on the quality of PVC (Polyvinyl Chloride) bottle packaging produced using an extrusion blow molding machine. The research was conducted at a bottle packaging manufacturing company PT.X in Bogor Regency, West Java, from January to March 2025. A quantitative approach was employed using linear regression analysis to examine the relationship between the independent variable (afval composition) and the dependent variable (number of black spots on the packaging). A total of 300 bottle samples were tested, consisting of six variations of material composition (0%, 10%, 20%, 30%, 40%, and 50%), with 50 samples each, based on the Military Standard 105E sampling method. Data were collected through observation, literature review, Focus Group Discussion (FGD), experimentation, and documentation. The results indicate that an increase in afval composition significantly affects the increase in visual defects in the form of black spots. Linear regression analysis showed the highest coefficient of determination (R^2) value of 0.959 at a composition of 50%, indicating a very strong correlation between variables. The maximum recommended afval composition to maintain product quality within acceptable limits is below 30%, in accordance with company quality standards. Furthermore, the implementation of Statistical Process Control (SPC) and the Seven Tools of Quality Control proved effective in monitoring process variation and supporting systematic quality control.

*Corresponding author
E-mail addresses: devitaaads@gmail.com

1. INTRODUCTION

The plastic packaging industry continues to innovate, particularly in sustainability efforts, one of which is the use of recycled materials (afval) to reduce production costs and environmental impact. The utilization of recycled polymers has been widely recognized as part of efficiency and waste reduction strategies; however, it may also introduce quality degradation risks due to contamination and thermal degradation during reprocessing (Ratnadewi, Y., 2019; Grant, T. et al., 2015). One of the most common issues is the emergence of visual defects such as black spots, which are often associated with material impurities and processing residues (Putri, F. S., 2022).

PT. X, a bottle packaging manufacturing company utilizing extrusion blow molding (EBM) technology, has experienced a relatively high reject rate in its production process. Based on internal production data from October to December 2024, the average reject rate reached 6.8%, exceeding the company's tolerance limit of 5%, with an increasing trend primarily attributed to black spot defects caused by afval contamination and residual crust deposits in the machine system. Similar findings have been reported in polymer processing studies, where recycled material content significantly influences defect formation and product inconsistency (Kana, T. P. et al., 2021; Waskito, N. W., n.d.). This condition highlights the urgency of implementing data-driven quality control to optimize afval usage without compromising product quality.

Process control in manufacturing can be effectively conducted using Statistical Process Control (SPC) and Statistical Quality Control (SQC), which are capable of detecting process variations and maintaining product stability (Siregar, A. S., 2019; Mitra, A., 2016). In addition, acceptance sampling and quality analysis tools such as Pareto diagrams and seven tools have been widely applied to identify dominant defects and improve production processes (Defiatri, D. & Damayanti, R. W., 2023; Faritsy, A. Z., 2019; Salawu, E. Y. et al., 2018). However, previous studies generally focus on either the economic benefits of recycled material usage or defect analysis separately, without integrating quantitative optimization of afval composition, defect correlation modeling, and real-time process control evaluation in a single framework.

Therefore, this study aims to determine the optimal threshold for afval utilization through linear regression modeling of defect occurrence, while simultaneously evaluating the effectiveness of SPC and SQC methods in controlling process variation. The novelty of this research lies in the integration of material composition analysis, statistical modeling, and quality control tools to establish a data-driven decision basis for sustainable and quality-consistent production in PVC bottle manufacturing.

2. METHOD

This type of research is quantitative with an experimental approach. The research was conducted at PT. X during the period January to March 2025. Data were obtained from the PVC bottle packaging production process using an extrusion blow molding (EBM) machine, which experienced variations in the composition of afval material use.

The independent variable in this study is the composition of afval material in percent (%), while the dependent variable is the number of visual defects in the form of black spots that appear on the product. Samples were taken as many as 300 units, which were divided into 6 groups based on variations in afval composition, namely 0%, 10%, 20%, 30%, 40%, and 50%, each with 50 samples.

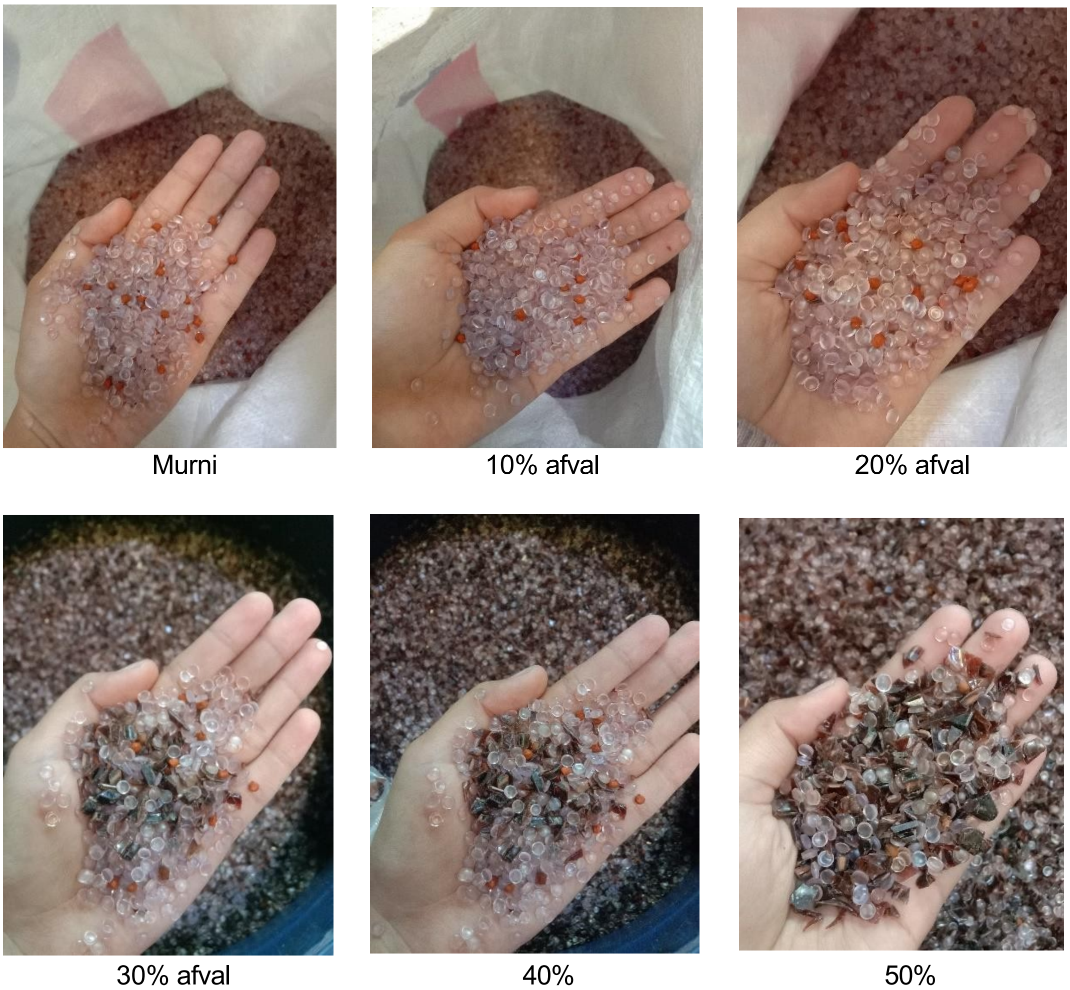


Figure 1. Variation of afval material composition

To ensure strong internal validity, key process parameters were strictly controlled and maintained constant throughout the experiment. These included barrels temperature (170–190°C), blow pressure (6–8 bar), screw rotation speed, and cycle time (±12 seconds per cycle). No changes were made to machine settings or operating conditions during the study, ensuring that the observed effects were solely due to variations in afval composition.

Data collection was carried out through direct observation of production results for each experiment condition. Data analysis was conducted using linear regression to evaluate the relationship between afval composition and the number of black spots, and Statistical Process Control (SPC) to monitor the stability of the production process. The analysis was performed using Microsoft Excel, which supports regression calculations and SPC visualization. In addition, a comparative analysis between product quality and material efficiency was conducted to determine the optimal afval composition from both quality and operational perspectives.

To ensure the reliability of the statistical model, several tests were conducted, including the coefficient of determination (R^2) to measure model fit, t-tests to evaluate the significance of regression coefficients (p-value < 0.05), and classical assumption tests such as normality, linearity, and homoscedasticity. In addition, ANOVA testing was conducted to evaluate the overall significance of the regression model. These tests were used to confirm that the regression model met the necessary assumptions and produced valid and reliable results. Sample validation used the Military Standard 105E standard to ensure that the number of samples was sufficient to represent the production population. The research procedure followed a structured workflow consisting of: (1) experimental design and determination of afval composition levels, (2) controlled production and data collection, (3) statistical analysis using regression and SPC methods, and (4) evaluation and interpretation of results to determine the optimal afval composition and process performance.

3. RESULT AND DISCUSSION

Result

Tabel 1. Test Results of Afval Composition Variations

Afval	Black spot defects	Sample
0%	1	50
10%	2	50
20%	5	50
30%	9	50
40%	15	50
50%	19	50
Total	**51**	**300**

The results of the study showed a significant relationship between the increase in the percentage of afval use and the number of visual defects in the form of black spots on PVC bottle packaging. From a total of 300 samples analyzed, a trend was obtained that the higher the afval composition, the more black spots appeared on the final product.

At a composition of 0% afval, the average number of black spots was 0.02 defect per sample (1 defect per 50 samples). As the composition increased to 10%, 20%, and 30%, the defect rates rose to 0.04, 0.10, and 0.18 defects per sample, respectively. At higher compositions of 40% and 50%, the defect rates increased more sharply to 0.30 and 0.38 defects per sample, indicating a nonlinear escalation in quality degradation at higher afval levels.

Discussion

Based on the data obtained, it was then processed statistically by linear regression using Excel software, using a combined trendline with the following analysis results:

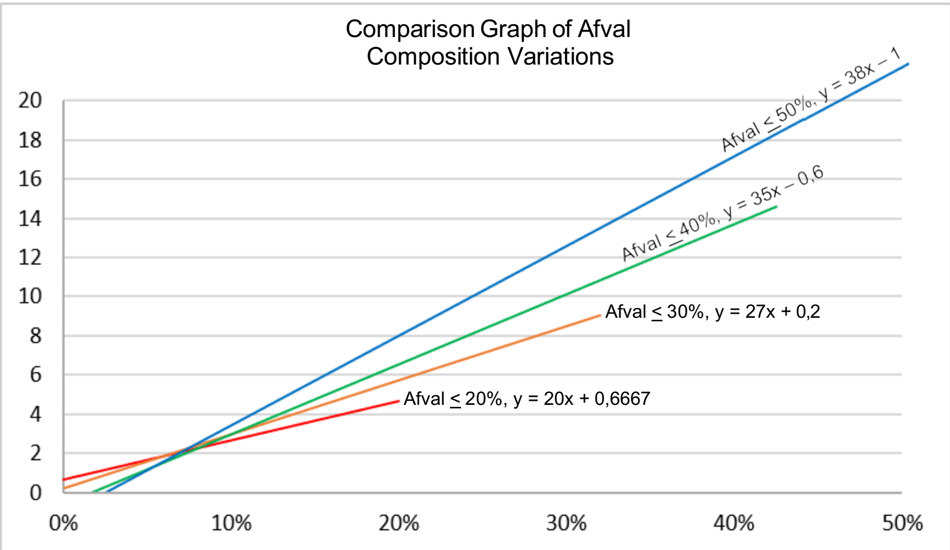


Figure 2. Trend graph of changes in composition of afval versus reject black spots

Statistical analysis using linear regression in in Figure 1 shows the regression equation: $y = 0.38x + 1$, with a coefficient of determination $R^2 = 0.959$, indicating that 95.9% of the variation in defect occurrence can be explained by the afval composition. To validate the model, hypothesis testing was conducted using ANOVA and t-tests. The regression model showed a p-value < 0.001, confirming that the relationship between afval composition and defect rate is statistically significant.

The ANOVA results also indicated that the model is highly significant (F-calculated > F-critical), supporting the reliability of the regression model.

In addition to regression analysis, Statistical Process Control (SPC) was applied to evaluate process stability. Using X-bar and P-charts, the control parameters were determined as follows: the Central Line (CL) represents the average defect proportion, while the Upper Control Limit (UCL) and Lower Control Limit (LCL) were calculated based on $\pm 3\sigma$ control limits. For compositions ≤30%, all data points remained within control limits (e.g., CL ≈ 0.11, UCL ≈ 0.25, LCL ≈ 0), indicating a stable and controlled process. However, at 40% and 50% compositions, several points exceeded the UCL, confirming process instability and a higher risk of producing nonconforming products.

A cost–quality trade-off analysis was also conducted to determine the optimal afval composition. The use of afval reduces raw material costs by approximately 8–15% depending on composition; however, the reject rate increases significantly beyond 30%, leading to higher rework and waste costs. At 30% composition, the process achieves a balance between cost efficiency and acceptable quality levels, while at 40% and above, the increase in reject costs outweighs the material savings.

Thus, the recommended maximum limit for afval usage is 30%, as it maintains process stability, ensures product quality within acceptable standards, and provides optimal economic benefits. The integration of regression analysis and SPC tools, including X-bar and P-charts, has proven effective in identifying process deviations and supporting data-driven decision-making in production control.

4. CONCLUSION

Based on the results of this study, which aimed to analyze the effect of recycled afval material composition on the quality of PVC bottle packaging produced using an extrusion blow molding (EBM) machine, it can be concluded that:

1. The study successfully demonstrates that the composition of afval has a significant effect on product quality, particularly on the increase of visual defects in the form of black spot. A higher percentage of afval consistently leads to a higher defect rate.
2. Linear regression analysis confirms a strong positive relationship between afval composition and defect occurrence, represented by the equation $y = 0.38x + 1$ with a coefficient of determination $R^2 = 0.959$, indicating that most of the variation in defects is explained by changes in afval composition.
3. Based on Statistical Process Control (SPC) analysis, the production process remains stable and within control limits at afval compositions up to 30%, while higher compositions show increased process instability and defect occurrence.
4. Therefore, the optimal maximum limit for afval usage is identified at ≤30%, as it provides the best balance between product quality, process stability, and material efficiency.

In practical terms, these findings provide a data-driven basis for manufacturing companies to optimize the use of recycled materials without compromising product quality. From a scientific perspective, this study contributes by integrating material composition analysis, regression modeling, and SPC methods into a unified framework for evaluating process performance and quality control in plastic packaging production.

5. ACKNOWLEDGE

The author would like to thank PT. X (name disguised) for providing permission and support during the research data collection process. Gratitude is also expressed to the supervisor and all members of the Creative Media State Polytechnic for their direction and guidance in completing this research.

6. REFERENCES

Defiatri, D., & Damayanti, R. W. (2023). Acceptance sampling MIL-STD 105E for quality control: A case study. *E3S Web of Conferences*, *465*, 02043.

https://doi.org/10.1051/e3sconf/202346502043

Faritsy, A. Z. (2019). Analisis pengendalian kualitas produk tutup botol tipe flip top menggunakan seven tools dan 5W+1H (What, When, Who, Where, Why, How). *Jurnal Ilmiah Teknik Industri Prima (JURITI PRIMA)*, *3*(1). https://jurnal.pnj.ac.id/index.php/juriti/article/view/2282

Grant, T., Barichello, V., & Fitzpatrick, L. (2015). Accounting the impacts of waste product in package design. *Procedia CIRP*, *29*, 568–572. https://doi.org/10.1016/j.procir.2015.02.089

Kana, T. P., Rahmayanti, H. D., & Didik, H. M. (2021). Study of defect on 180 ml HDPE bottles yogurt products with SMC B11 extrusion blow machine at PT X. *Kreator*, *8*(1), 21–28. https://doi.org/10.46961/kreator.v8i1.164

Mitra, A. (2016). *Fundamentals of quality control and improvement* (4th ed.). John Wiley & Sons. https://www.wiley.com/enus/Fundamentals+of+Quality+Control+and+Improvement%2C+4th+Edition-p-9781118705141

Putri, F. S. (2022). Mengurangi cacat bintik hitam pada produk botol plastik M500 berbahan HDPE dengan metode PDCA di CV Jordan. *Politeknik ATK*. https://repository.atk.ac.id/id/eprint/422

Ratnadewi, Y. (2019). Upaya peningkatan value afval di PT. X. *Jurnal Titra*, *7*(2), 297–302. https://openlibrarypublications.telkomuniversity.ac.id/index.php/titra/article/view/9492

Salawu, E. Y., Ajayi, O. O., Inegbenebor, A. O., Afolalu, S. A., & Ongbali, S. O. (2018). Pareto analysis of product quality failures and cost effects in bottling machines—a lean thinking solution for alcohol industry. *International Journal of Mechanical Engineering and Technology*,*9*(11).https://iaeme.com/MasterAdmin/Journal_uploads/IJMET/VOLUME_9_ISSUE_11/IJMET_09_11_189.pdf

Sinaga, P. (2012). Material plastik. Disampaikan pada Pelatihan Quality Control Alat-Alat IPA. *Jurusan Pendidikan Fisika UPI dan PT. Sugitex Indotama*.

Siregar, A. S. (2019). Analisis pengendalian kualitas produk pellet dengan metode statistical quality control (SQC) dan statistical process control (SPC) di PT. Gold Coin Indonesia Kim II Mabar. *Universitas Medan Area*. https://repositori.uma.ac.id/handle/123456789/12685

Utami, A. F. (n.d.). Penerapan peta kendali statistik dalam mengontrol perubahan mutu crude palm oil pada proses distribusi. *Indonesian Council of Premier Statistical Science*, *3* (2), 79–86. https://journal.statind.or.id/index.php/icpss/article/view/98

Waskito, N. W. (n.d.). Optimasi produksi botol 400 ml pada proses extrusion blow moulding. https://repository.polman-bandung.ac.id/files/digital/18324.pdf