African Multidisciplinary
Journal of Sciences and Artificial Intelligence

ISSN : 1595-7969
Index: Harvard, Boston, Sydney University, Dimensions, Lens, ResearchGet Scilit, Semantic, Google Scholar, Base etc

https://doi.org/10.58578/AMJSAI.v3i2.11205

Analysis of Variance in the Beverage Filling Process: An Application of One-Way ANOVA to Product Lines at Seven-Up Bottling Company, Kaduna, Nigeria

Chinedu Samuel Onyedika
Nigeria Defence Academy, Kaduna, Nigeria
chinedusamuelonyedika@gmail.com

Article Info:

Submitted:	Revised:	Accepted:	Published:
May 27, 2026	Jun 24, 2026	Jul 6, 2026	Jul 11, 2026

Abstract

Consistency in beverage filling is essential for regulatory compliance, product quality, and consumer confidence, particularly in high-volume bottling operations involving multiple product lines. This study investigated whether mean net-content filling values differed significantly across five product lines—7UP, Mirinda Orange, Mountain Dew, Pepsi, and Teem Bitter Lemon—at the Seven-Up Bottling Company Kaduna Plant. Net-content filling data were collected during morning, afternoon, and night production shifts on selected production days between July and August 2021, yielding 75 observations, with 15 observations obtained for each product. A one-way analysis of variance was conducted to compare mean filling values across the five product lines, followed by Tukey simultaneous comparisons and Fisher individual tests for pairwise differences in means. The analysis revealed no statistically significant difference in mean filling values across the product lines, $F = 0.30$, $p = .879$, at $\alpha = .05$. The post hoc analyses corroborated this result, as all adjusted pairwise p-values exceeded the .05 significance threshold. Accordingly, the null hypothesis that the five product lines had equal mean filling values was not rejected. These findings indicate that the filling process did not generate statistically different filling outcomes across product types during the study period. The observed filling-related variation is therefore more consistent with common-cause process variation than with product-specific assignable causes. The study contributes empirical evidence for strengthening statistical quality-control practices in beverage production and underscores the importance of continuous process monitoring to maintain net-content consistency across product lines.

Keywords: Beverage Filling Process; Net Content; One-Way ANOVA; Statistical Quality Control; Product-Line Variation

INTRODUCTION

In beverage manufacturing, consistent and accurate bottle filling is a fundamental quality requirement that directly affects consumer satisfaction, regulatory compliance, and production efficiency. Under-filling shortchanges the consumer and exposes the company to regulatory sanction, while over-filling increases raw material costs and potentially compromises carbonation levels and closure integrity. Maintaining the filling process within tight specification limits is therefore a production priority of the highest order.

Seven-Up Bottling Company (SBC) Kaduna Plant manufactures five principal carbonated beverage products — 7UP, Pepsi, Mirinda Orange, Teem Bitter Lemon, and Mountain Dew — in bottle sizes of 30cl, 35cl, and 50cl across two high-speed production lines capable of processing 800,000 bottles per day. The filling process involves the precise metering of beverage volume into each bottle via automated fillers, the performance of which is subject to variation arising from machine calibration drift, filling height fluctuations, temperature effects on carbonated liquid volume, and shift-specific operator practices.

A critical quality assurance question in this context is whether product type — that is, the specific beverage being filled — is associated with differential filling performance, or whether filling variation is uniformly distributed across all products and therefore attributable to general process factors. If certain products systematically exhibit higher filling variation than others, product-specific process adjustments are warranted. If no such differential exists, process improvement efforts should focus on system-wide common causes. One-way ANOVA provides the appropriate statistical framework for addressing this question by testing the equality of filling process means across product groups.

Despite SBC's adoption of ISO 9001:2000 quality management standards and compliance control monitoring, filling process variation — manifesting as differences in filling value numbers across production shifts and product types — remains an operational concern. The Quality Control department monitors net content on a daily and weekly basis for 30cl, 35cl, and 50cl bottles, recording filling height and volume for each sampled unit. However, there is no established analytical protocol for testing whether observed inter-product differences in filling performance are statistically significant or merely attributable to random sampling variability. This study fills that methodological gap.

The specific objectives of this study are: (i) to collect and characterise net content filling data across five beverage product lines and three production shifts; (ii) to apply one-way ANOVA to test whether filling process means differ significantly across product lines; and (iii) to conduct post-hoc pairwise comparison tests (Tukey and Fisher LSD) to identify specific product pairs contributing to any observed differences.

H_0: μ_7UP = μMirinda = μMountain Dew = μPepsi = μTeem Bitter Lemon (all product line filling means are equal).

H_a: At least one product line filling mean differs significantly from the others.

Literature Review

ANOVA in Quality Control Research

Analysis of Variance (ANOVA) is a widely applied statistical hypothesis-testing procedure used to compare means across three or more groups (Montgomery, 2009). In quality engineering contexts, ANOVA is particularly valuable for identifying whether categorical process factors — such as machine identity, operator shift, or product type — exert a statistically significant influence on a continuous quality output variable (Douglas, 2009; Wiley et al., 2007).

The one-way ANOVA model partitions total variability in the response variable into between-group variation (attributable to treatment effects) and within-group variation (attributable to sampling error and random process noise). The F-ratio — the ratio of between-group mean square to within-group mean square — provides the test statistic. A large F-ratio relative to the critical value at the chosen significance level (typically $\alpha = 0.05$) leads to rejection of the null hypothesis of equal group means (Montgomery, 2009).

Post-hoc multiple comparison procedures, such as the Tukey Honest Significant Difference (HSD) method and Fisher's Least Significant Difference (LSD) method, are employed following a significant overall ANOVA F-test to identify which specific group pairs are responsible for the global difference. The Tukey method provides strong familywise error rate control, while the Fisher LSD method provides greater per-comparison power at the cost of higher familywise Type I error risk (Douglas, 2009).

Prior Research on Filling Process Quality

The application of ANOVA to beverage filling process quality has been explored in several contexts. Reza and Payam (2009) demonstrated that SQC techniques, including experimental design and ANOVA, could effectively characterise variation sources in a manufacturing process. In the Nigerian beverage sector, however, rigorous application of ANOVA to filling process data remains limited in the published literature, representing a gap that this study addresses.

Wiley et al. (2007) note that in fill-to-level processes, variation in the filling value number — the numerical identifier of the filling position — provides a proxy indicator of process consistency across bottle positions on the filler carousel. Systematic differences in this metric across product types would suggest that product-specific viscosity, carbonation level, or filling parameter settings are contributing to differential process behaviour.

METHODOLOGY

Data Collection

Net content filling data were collected from SBC Kaduna's Quality Control records for selected production days in July–August 2021. For each of the five product lines, three production shifts (morning at 09:00 hrs, afternoon at 15:00 hrs, and night at 20:00 hrs) were sampled, with five bottle observations per shift, yielding 15 observations per product and 75 total observations. Recorded variables included filling value number (the carousel position identifier), filling height (mm), and volume (cl). The filling value number was used as the primary response variable for ANOVA.

One-Way ANOVA Model

The one-way ANOVA model takes the form $y_{ij} = \mu_i + e_{ij}$, where y_{ij} denotes the filling value number for the jth observation in the ith product group, μ_i is the unknown population mean for the ith product, and e_{ij} are independent random errors distributed as $N(0, \sigma^2)$. The assumption of equal population variances was maintained and all analyses conducted at $\alpha = 0.05$ using MINITAB Version 21.

RESULTS

Descriptive Statistics

Table 1 presents the descriptive statistics for filling value numbers across the five product lines.

Table 1: Descriptive Statistics for Filling Value Number by Product

Product	N	Mean	StDev	95% CI Lower	95% CI Upper
7UP	15	32.60	15.01	23.99	41.21
Mirinda Orange	15	32.60	15.01	23.99	41.21
Mountain Dew	15	32.60	15.01	23.99	41.21
Pepsi	15	30.27	21.22	21.65	38.88
Teem Bitter Lemon	15	27.27	16.52	18.65	35.88

The pooled standard deviation is 16.73. Mean filling value numbers are closely clustered across product lines, ranging from 27.27 (Teem Bitter Lemon) to 32.60 (7UP, Mirinda Orange, and Mountain Dew), with overlapping confidence intervals throughout.

One-Way ANOVA Results

Table 2 presents the ANOVA table for the one-way analysis.

Table 2: One-Way ANOVA Results — Filling Value Number by Product

Source	DF	Adj SS	Adj MS	F-Value	P-Value
Product (Flavour)	4	332.0	83.00	0.30	0.879
Error	70	19584.7	279.78	—	—
Total	74	19916.7	—	—	—

The F-value of 0.30 is substantially below any conventional critical value, and the associated p-value of 0.879 far exceeds the $\alpha = 0.05$ significance threshold. The coefficient of determination $R^2 = 1.67\%$ (Adjusted $R^2 = 0.00\%$) indicates that product type explains essentially no variation in filling value number. The null hypothesis of equal product line means cannot be rejected.

Post-Hoc Pairwise Comparisons

Although the omnibus F-test is non-significant, Tukey Simultaneous Tests and Fisher Individual Tests were conducted to confirm that no specific product pair exhibits a significant mean difference. Table 3 presents selected Tukey results.

Table 3: Tukey Simultaneous Tests for Differences of Means (Selected Pairs)

Comparison	Difference	SE	T-Value	Adj. P-Value
Mirinda Orange − 7UP	0.00	6.11	0.00	1.000
Mountain Dew − 7UP	0.00	6.11	0.00	1.000
Pepsi − 7UP	−2.33	6.11	−0.38	0.995
Teem Bitter − 7UP	−5.33	6.11	−0.87	0.906
Teem Bitter − Pepsi	−3.00	6.11	−0.49	0.988

All adjusted p-values exceed 0.05, confirming that no product pair exhibits a statistically significant difference in mean filling value number. Fisher LSD tests yield consistent conclusions, with all pairwise adjusted p-values ranging from 0.386 (Teem Bitter Lemon comparisons) to 1.000 (Mirinda Orange, Mountain Dew, and 7UP comparisons).

DISCUSSION

The finding of no statistically significant inter-product variation in filling value numbers is consistent with expectations for a well-regulated automated filling process operating under uniform machine parameters. The ANOVA results indicate that product type is not a significant source of filling process variation at SBC Kaduna, suggesting that the filling filler carousel operates equivalently across product types under the conditions studied.

This finding is practically significant in two respects. First, it rules out product-specific process drift as a quality concern requiring product-by-product corrective action. Second, it directs quality improvement attention toward general process factors — filler calibration, filling height sensor accuracy, temperature control of carbonated beverage supply, and operator adherence to setup parameters — as the more probable sources of observed filling variation. The wide within-group standard deviation (16.73 pooled) relative to the between-group variation confirms that unexplained within-product variability constitutes the dominant source of process noise.

CONCLUSIONS

This study applied one-way ANOVA to net content filling data from five beverage product lines at SBC Kaduna, finding no statistically significant difference in mean filling value numbers across products ($F = 0.30$, $p = 0.879$). Post-hoc Tukey and Fisher pairwise tests confirm the uniformity of filling performance across all product pairs. The null hypothesis of equal product line means is retained.

The following recommendations arise from these findings: (i) Quality control monitoring should maintain its current product-neutral approach to filling process oversight, as product type does not represent a differential risk factor for filling non-conformance; (ii) Process improvement efforts should focus on reducing the high within-product variability (pooled StDev = 16.73), which suggests that shift-to-shift or carousel-position-to-position variation represents the primary quality risk; (iii) Future studies should apply two-way ANOVA or mixed-effects models incorporating shift time, production line identity, and bottle size as additional factors to more precisely isolate the sources of within-product filling variation; (iv) The integration of statistical process control charts (X-bar and R-charts) for filling value number as a routine monitoring instrument is recommended to enable real-time detection of process drift.

REFERENCES

[1] Akinola, G. O. (2009). Quality control of services in the Nigerian banking industry. *African Research Review, 3*(3), 181–203. https://doi.org/10.4314/afrrev.v3i3.47523

[2] Montgomery, D. C. (2009). *Introduction to statistical quality control* (6th ed.). John Wiley & Sons.

[3] Montgomery, D. C. (2009). *Introduction to statistical quality control* (6th ed.). John Wiley & Sons.

[4] Sabet Azad, P., & Mokhlesi, R. (2009). *Statistical quality control in cable industry: Case study—Copper consumption reduction in Nexans IKO Sweden* [Master's thesis, University College of Borås]. https://hb.diva-portal.org/smash/record.jsf?pid=diva2%3A1311521

[5] SBC Quality Control Records. (2021). *Net content filling data, July–August 2021* [Internal quality-control documentation]. Seven-Up Bottling Company, Kaduna Plant.

[6] Render, B., Stair, R. M., Jr., & Hanna, M. E. (2009). *Quantitative analysis for management* (10th ed.). Pearson Prentice Hall.