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Evaluating the Performance of LPG 3 KG Filling Machines: An ANOVA Approach to Machine Brand Efficiency (Study case: SPBE Wilayah Sumatera Utara-SAR Medan PT Pertamina Patra Niaga C&T)

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ABSTRACT

This study aims to investigate the differences in the average loading order quantities during the LPG 3 Kg filling process, as influenced by the type of filling machine brand. Specifically, the research focuses on three brands of filling machines: KOSAN-215H, DAESUNG-2189, and ELIXIR-217Q, which are utilized at the LPG Filling Stations (SPBE) in the Sumatera Utara-SAR Medan PT Pertamina Patra Niaga C&T. The statistical method employed for analysis is One-Way Univariate Analysis of Variance (ANOVA). A total of 27 observations were collected for each machine brand. The results of the analysis show that the calculated F-Statistic (3.171240679) exceeds the F-Critical (3.11379226), with a P-value of 0.0474111978, which is < 0.05 significance threshold. Therefore, the null hypothesis (H0) is rejected, and the alternative hypothesis (H1) is accepted, indicating that there is a statistically significant difference in the average loading order quantities among the three filling machines. These findings suggest that the loading order quantities differ significantly across the different brands of 3 KG LPG filling machines.

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INTRODUCTION

PT Pertamina Patra Niaga C&T (Commercial & Trading) is a subsidiary of PT Pertamina (Persero), focusing on distribution and energy sectors in Indonesia. As part of Pertamina, the company is responsible for ensuring a sufficient and secure energy supply through efficient management, particularly in the provision of fuel and gas.

SPBE (Stasiun Pengisian Bulk Elpiji) are facilities managed by PT Pertamina (Persero), used for filling liquefied petroleum gas (LPG) into bulk or tube, which are then distributed by LPG agents to meet the needs of end users. SPBE plays a critical role in maintaining a steady

supply of LPG fuel throughout Indonesia. To achieve this, adequate infrastructure is essential to support the company's daily operations. The LPG filling process occurs in a filling hall, where multiple filling machines operate continuously over specified periods. There is a suspicion that differences in machine performance may be influenced by the brand of the vendor, which could impact the loading order quantity in the filling process. Therefore, it is necessary to conduct testing to determine the effect of the filling machine brand on the loading order quantity during the LPG 3 KG filling process (Study case: SPBE Wilayah Sumatera Utara-SAR Medan PT Pertamina Patra Niaga C&T). Analysis of Variance (ANOVA) is a statistical method first developed and introduced by Sir Ronald A. Fisher [1]. It is commonly used for hypothesis testing to draw conclusions about differences in population means by comparing the variances across more than two groups.[2]

Thus, this research aims to provide conclusions that can serve as a reference for decision-making in selecting the most optimal machine brand for operational efficiency, contributing to the smooth distribution and fulfillment of fuel needs for the people of Indonesia, particularly in the Sumatra Utara region.

METODE

The methodology employed in this quantitative study is One-Way Univariate Analysis of Variance (ANOVA), which is used to test for differences in the means of more than two groups of the independent variable X. The independent variable in this study is the brand of the LPG filling machine, with three treatment groups: KOSAN-215H (A1)[3], DAESUNG-2189 (A2)[4], and ELIXIR-217Q (A3)[5]. The dependent variable measured is the loading order quantity recorded during the LPG 3 KG filling process.

The data for this analysis were obtained from 27 observations for each machine brand over a one-month period. Hypothesis testing was conducted at a significance level of $\alpha = 0.05$. The ANOVA results were analyzed by comparing the calculated F-value with the critical F-value to determine whether there is a statistically significant difference between the three filling machine brands.

Research Step

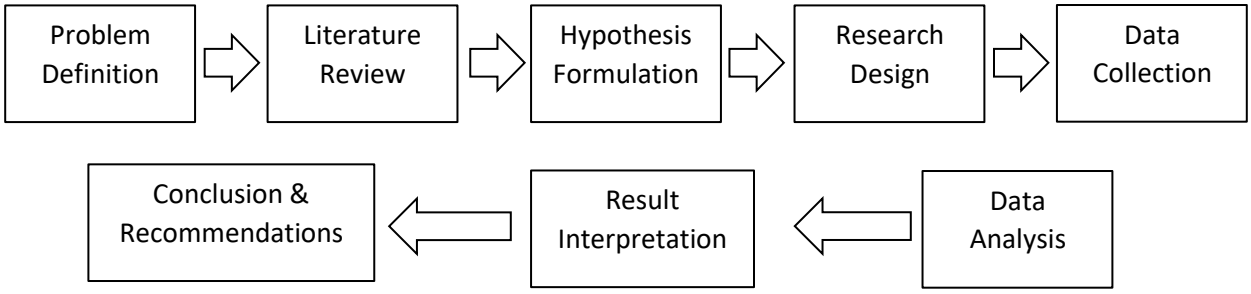


Figure 1. Research Step

This study aims to test the differences in means between several groups using the One-Way Univariate ANOVA statistical method. The first step in the research is problem definition, where the focus is on the differences in the loading order quantity of LPG filling machines based on their brand. After the problem is defined, a literature review is conducted to understand the relevant theories and statistical methods used in similar studies.

Next, the hypothesis formulation step is undertaken, where two hypotheses are developed: the null hypothesis (H0), which states that there is no significant difference between the groups, and the alternative hypothesis (H1), which posits that there is a significant difference. The researcher then designs the study by selecting the appropriate research methodology, specifically One-Way ANOVA, which is used to compare more than two groups. Afterward, data collection takes place, with observations made on each type of filling machine.

The study collects a sample of 27 data points for each machine type over the course of one month. Once the data is collected, the next step is data analysis, where ANOVA is used to test if there are significant differences between the analyzed groups.

Following the analysis, the next step is result interpretation, which involves comparing the calculated F-Statistic to F-Critical to determine whether significant differences exist between the groups. If significant differences are found, the researcher proceeds to conclusion and recommendations based on the findings. The aim of this study is to provide better insights into selecting the optimal filling machine to improve the efficiency and accuracy of the filling process, offering recommendations based on the results obtained.

RESULT AND DISCUSSION

In this study, the author utilized 27 sample data points for each of the three different machine brands, with data collected over a one-month period. Prior to conducting the analysis, the data were subjected to normality and homogeneity tests to ensure their suitability for further statistical testing. The data sets are as follows:

Table 1. Data Sample

Filling Date	Loading Order Quantity in PCS		
Dec-24	KOSAN -215H	DAESUNG - 2189	ELIXIR - 217Q
12/1/2024	14,560.00	15,120.00	16,800.00
12/2/2024	16,240.00	16,240.00	16,240.00
12/3/2024	16,800.00	15,680.00	16,240.00
12/4/2024	15,120.00	16,240.00	16,240.00
12/5/2024	16,240.00	15,120.00	16,800.00
12/6/2024	14,000.00	16,240.00	16,240.00
12/7/2024	15,120.00	15,680.00	18,480.00
12/9/2024	14,560.00	16,240.00	17,920.00
12/10/2024	15,120.00	15,120.00	16,240.00
12/11/2024	15,120.00	17,360.00	15,120.00
12/12/2024	16,240.00	15,120.00	17,920.00
12/13/2024	13,440.00	15,120.00	17,360.00
12/14/2024	16,240.00	15,680.00	18,480.00
12/16/2024	16,240.00	16,800.00	16,240.00
12/17/2024	17,360.00	16,800.00	17,360.00
12/18/2024	14,000.00	16,240.00	16,800.00
12/19/2024	14,560.00	15,120.00	15,680.00
12/20/2024	14,000.00	15,680.00	15,120.00
12/21/2024	15,120.00	15,680.00	18,480.00
12/23/2024	15,680.00	16,240.00	17,920.00
12/24/2024	2,800.00	6,720.00	4,480.00
12/25/2024	18,480.00	16,800.00	16,800.00
12/26/2024	13,440.00	15,680.00	17,920.00
12/27/2024	14,000.00	15,680.00	16,800.00
12/28/2024	14,560.00	15,680.00	17,360.00
12/30/2024	15,120.00	15,120.00	16,240.00
12/31/2024	15,120.00	15,120.00	16,240.00
Total	**399,280.00**	**418,320.00**	**443,520.00**

Formulating the Hypotheses

The initial step in this study involved formulating the hypotheses, which are stated as follows:

- H0: There is no significant difference in the loading order quantity for LPG 3 KG filling when using machines of different brands.
- H1: There is a significant difference in the loading order quantity for LPG 3 KG filling when using machines of different brands.

The next step involves formulating the mathematical hypotheses as follows:

- H0: $\mu 1=\mu 2=\mu 3$
- H1: $\mu 1\neq\mu 2\neq\mu 3$

H0 asserts that there is no difference in the means of the factors. However, if a difference is found, it will be considered under H1. After establishing the mathematical hypotheses, the next step is to determine the significance level (alpha). Alpha represents the allowable probability of a Type I error in statistical testing. In this study, an alpha value of 0.05 was used..

Here's a more precise version:
The decision rule applied in drawing conclusions is as follows:
IF F-statistic > F-Critical Then Reject H0
IF F-statistic ≤ F-Critical Then Accept H0 where reject H1
To simplify the calculation of the F-statistic, the following auxiliary table was used:

Table 2. Auxiliary Table

Dec-24	KOSAN -215H	DAESUNG - 2189	ELIXIR - 217Q	$X1^2$	$X2^2$	$X3^2$
12/1/2024	14,560.00	15,120.00	16,800.00	211,993,600.00	228,614,400.00	282,240,000.00
12/2/2024	16,240.00	16,240.00	16,240.00	263,737,600.00	263,737,600.00	263,737,600.00
12/3/2024	16,800.00	15,680.00	16,240.00	282,240,000.00	245,862,400.00	263,737,600.00
12/4/2024	15,120.00	16,240.00	16,240.00	228,614,400.00	263,737,600.00	263,737,600.00
12/5/2024	16,240.00	15,120.00	16,800.00	263,737,600.00	228,614,400.00	282,240,000.00
12/6/2024	14,000.00	16,240.00	16,240.00	196,000,000.00	263,737,600.00	263,737,600.00
12/8/2024	15,120.00	15,680.00	18,480.00	228,614,400.00	245,862,400.00	341,510,400.00
12/9/2024	14,560.00	16,240.00	17,920.00	211,993,600.00	263,737,600.00	321,126,400.00
12/10/2024	15,120.00	15,120.00	16,240.00	228,614,400.00	228,614,400.00	263,737,600.00
12/11/2024	15,120.00	17,360.00	15,120.00	228,614,400.00	301,369,600.00	228,614,400.00
12/12/2024	16,240.00	15,120.00	17,920.00	263,737,600.00	228,614,400.00	321,126,400.00
12/13/2024	13,440.00	15,120.00	17,360.00	180,633,600.00	228,614,400.00	301,369,600.00
12/15/2024	16,240.00	15,680.00	18,480.00	263,737,600.00	245,862,400.00	341,510,400.00
12/16/2024	16,240.00	16,800.00	16,240.00	263,737,600.00	282,240,000.00	263,737,600.00
12/17/2024	17,360.00	16,800.00	17,360.00	301,369,600.00	282,240,000.00	301,369,600.00
12/18/2024	14,000.00	16,240.00	16,800.00	196,000,000.00	263,737,600.00	282,240,000.00
12/19/2024	14,560.00	15,120.00	15,680.00	211,993,600.00	228,614,400.00	245,862,400.00
12/20/2024	14,000.00	15,680.00	15,120.00	196,000,000.00	245,862,400.00	228,614,400.00
12/22/2024	15,120.00	15,680.00	18,480.00	228,614,400.00	245,862,400.00	341,510,400.00
12/23/2024	15,680.00	16,240.00	17,920.00	245,862,400.00	263,737,600.00	321,126,400.00
12/24/2024	2,800.00	6,720.00	4,480.00	7,840,000.00	45,158,400.00	20,070,400.00
12/25/2024	18,480.00	16,800.00	16,800.00	341,510,400.00	282,240,000.00	282,240,000.00
12/26/2024	13,440.00	15,680.00	17,920.00	180,633,600.00	245,862,400.00	321,126,400.00
12/27/2024	14,000.00	15,680.00	16,800.00	196,000,000.00	245,862,400.00	282,240,000.00
12/29/2024	14,560.00	15,680.00	17,360.00	211,993,600.00	245,862,400.00	301,369,600.00
12/30/2024	15,120.00	15,120.00	16,240.00	228,614,400.00	228,614,400.00	263,737,600.00
12/31/2024	15,120.00	15,120.00	16,240.00	228,614,400.00	228,614,400.00	263,737,600.00
	ΣX_1	ΣX_2	ΣX_3	$\Sigma X1^2$	$\Sigma X2^2$	$\Sigma X3^2$
Total	**399,280.00**	**418,320.00**	**443,520.00**	**6,091,052,800.00**	**6,571,488,000.00**	**7,457,408,000.00**

Performing the Statistical Test:
Using the Auxiliary Table above, the sums for each group (X1, X2, and X3) were computed as follows:

$\Sigma X_{Total} = \Sigma X_1 + \Sigma X_2 + \Sigma X_3$
$\Sigma X_{Total} =$ 399,280.00 + 418,320.00 + 443,520.00
$\Sigma X_{Total} =$ 1,261,120.00

The sum of squares for each of the totals can be explained as follows:
$(\Sigma X_{Total})^2 = (\Sigma X_1)^2 + (\Sigma X_2)^2 + (\Sigma X_3)^2$
$(\Sigma X_{Total})^2 =$ 6,091,052,800.00 + 6,571,488,000.00 + 7,457,408,000.00
$(\Sigma X_{Total})^2 =$ 20,119,948,800.00

Next, the sum of squares (JK_T) for the total variances (T) is determined using the following:

formula:$JK_T = \Sigma x_{T^2} - \frac{(\Sigma x_{Total})^2}{n_{Total}}$

The total number of observations (n) for each factor is as follows:

n_1, n_2, n_3= 27 with n_{total} = 81

Further the sum of squares (JK_T):

$JK_T = 1{,}261{,}120.00^{\,2} - \frac{20{,}119{,}948{,}800.00^{\,2}}{81}$

$JK_T = 20{,}119{,}948{,}800.00 - \frac{1{,}590{,}423{,}654{,}400.00}{81}$

$JK_T = 20{,}119{,}948{,}800.00 - 1{,}905{,}747{,}200$

$JK_T = 485{,}088{,}869.14$

Next, to calculate the Sum of Squares Between Groups (JKK), the following formula is used:

$$JKK = \frac{(\Sigma x_1)^2}{n_1} + \frac{(\Sigma x_2)^2}{n_2} + \frac{(\Sigma x_3)^2}{n_3} - \frac{(\Sigma x_{Total})^2}{n_{Total}}$$

$$JKK = \frac{(\ 399{,}280.00\ )^2}{27} + \frac{(\ 418{,}320.00\ )^2}{27} + \frac{(\ 443{,}520.00\ )^2}{27} - \frac{(\ 1{,}261{,}120.00\ )^2}{81}$$

$JKK = 5{,}904{,}611{,}792.59 + 6{,}481{,}171{,}200.00 + 7{,}285{,}555{,}200.00 - 19{,}634{,}859{,}930.86$

$JKK = 36{,}478{,}261.73$

Once the values for the Total Sum of Squares (JK_T) and the Sum of Squares Between Groups (JKK) are obtained, the Sum of Squares Within Groups (JKE) can be calculated using the following formula:

$JKE = JK_T - JKK$

$JKE = 485{,}088{,}869.14 - 36{,}478{,}261.73$

$JKE = 448{,}610{,}607.41$

Determining the Degrees of Freedom (DF):

In the ANOVA method, there are two types of degrees of freedom (DF) involved, which differ from the single degree of freedom used in t-tests[6]. The notations for these degrees of freedom are as follows:

Where K represents the number of groups or factors within the independent variable X.

DF_1=K-1
DF_1=3-1
DF_1=2

DF_2=K(n-1)
DF_2=3(27-1)
DF_2=78

Next, the variance values can be determined, where MSE is the mean square error (average of the within-group sum of squares), and MSK is the mean square between groups (average of the between-group sum of squares). These can be expressed as follows:

MSE=$\frac{JKE}{K(n-1)}$ dan MSK=$\frac{JKK}{K-1}$

MSE=$\frac{JKE}{K(n-1)}$
MSE=$\frac{448610607.4}{3(27-1)}$
MSE=$\frac{448610607.4}{78}$
MSE=5751418.044

MSK=$\frac{JKK}{K-1}$
MSK=$\frac{36478261.73}{3-1}$
MSK=$\frac{36478261.73}{2}$
MSK=18239130.86

After completing all the calculations above, the calculated F-Statistic is determined using the following formula:

F-Statistic= $\frac{MSK}{MSE}$
F-Statistic = $\frac{18239130.86}{5751418.044}$
F-Statistic = 3.171240679

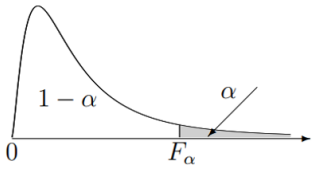
Further, the F-Critical value can be determined by combining the calculations above with the critical value. Thus, for α = 0.05, with DF1 (numerator) = 2 and DF2 (denominator) = 78, the F-Critical value is as follows:

F-Critical = $F\alpha(DF_1,DF_2)$
F-Critical = (0.05)(2;78)

Table 3. F-Distribution

Table A7. F-distribution

F_α; critical values such that $\boldsymbol{P}\{F > F_\alpha\} = \alpha$



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df_2	df_1, Numerator degrees of freedom with α = 0.05											
	1	2	3	4	5	6	7	8	9	10	11	12
69	3.97980721	3.12[illegible]4398	2.73749231	2.50460914	2.34754991	2.23317145	2.14547481	2.07570603	2.01863561	1.97092921	1.93035102	1.89534049
70	3.97777939	3.12[illegible]7560	2.73554145	2.50265646	2.34558633	2.23119242	2.14347804	2.07369040	2.01660069	1.96887495	1.92827761	1.89324825
71	3.97581015	3.12[illegible]6424	2.73364716	2.50076042	2.34367968	2.22927075	2.14153910	2.07173310	2.01462461	1.96688002	1.92626402	1.89121631
72	3.97389699	3.12[illegible]0745	2.73180701	2.49891858	2.34182753	2.22740397	2.13965551	2.06983164	2.01270484	1.96494190	1.92430770	1.88924210
73	3.97203754	3.12[illegible]0293	2.73001871	2.49712866	2.34002757	2.22558978	2.13782494	2.06798366	2.01083902	1.96305818	1.92240625	1.88732319
74	3.97022958	3.12[illegible]4851	2.72828011	2.49538848	2.33827763	2.22382597	2.13604518	2.06618692	2.00902490	1.96122662	1.92055738	1.88545730
75	3.96847099	3.11[illegible]4213	2.72658916	2.49369600	2.33657565	2.22211049	2.13431415	2.06443934	2.00726036	1.95944506	1.91875895	1.88364226
76	3.96675978	3.11[illegible]8184	2.72494392	2.49204930	2.33491969	2.22044136	2.13262986	2.06273892	2.00554340	1.95771149	1.91700891	1.88187601
77	3.96509407	3.11536580	2.72334257	2.49044653	2.33330790	2.21881674	2.13099046	2.06108378	2.00387212	1.95602400	1.91530534	1.88015661
78	3.96347205	**3.11379226**	2.72178338	2.48888596	2.33173854	2.21723487	2.12939416	2.05947212	2.00224471	1.95438078	1.91364641	1.87848221
79	3.96189203	3.11225957	2.72026470	2.48736595	2.33020996	2.21569408	2.12783930	2.05790227	2.00065948	1.95278009	1.91203039	1.87685109
80	3.96035242	3.11076647	2.71878498	2.48588494	2.32872059	2.21419280	2.12632428	2.05637261	1.99911481	1.95122032	1.91045564	1.87526157
81	3.95885167	3.10931055	2.71734273	2.48444144	2.32726894	2.21272952	2.12484759	2.05488162	1.99760915	1.94969992	1.90892059	1.87371209

Based on F-Distribution table with Fα = 0.05; DF_1 (numerator) = 2; DF_2 (denominator) = 78 we obtain that F-Critical = 3.11379226.

Therefore, we are nearing the conclusion of the test, with the calculated F-Statistic is 3.171240679 and the F-Critical value of 3.11379226. According to the decision rule, since F-Statistic > F-Critical then null hypothesis (H0) is rejected, leading to the conclusion that **H1: There is a significant difference in the loading order quantity for LPG 3 KG filling when using machines of different brands.**

When compared to the computational test, the results align with the manual calculations, as demonstrated below:

Table 4. Anova Computation Result

Anova: Single Factor

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
KOSAN -215H	27	399280	14788.14815	7170807.977
DAESUNG - 2189	27	418320	15493.33333	3473723.077
ELIXIR - 217Q	27	443520	16426.66667	6609723.077

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	36478261.73	2	18239130.86	3.171240679	0.047411198	3.11379226
Within Groups	448610607.4	78	5751418.044			

Visual Presentation:

In the visual presentation using a scatter plot, we can observe the distribution of each factor, the mean quantity of the dependent variable, and the level of variability. The data can be presented as follows:

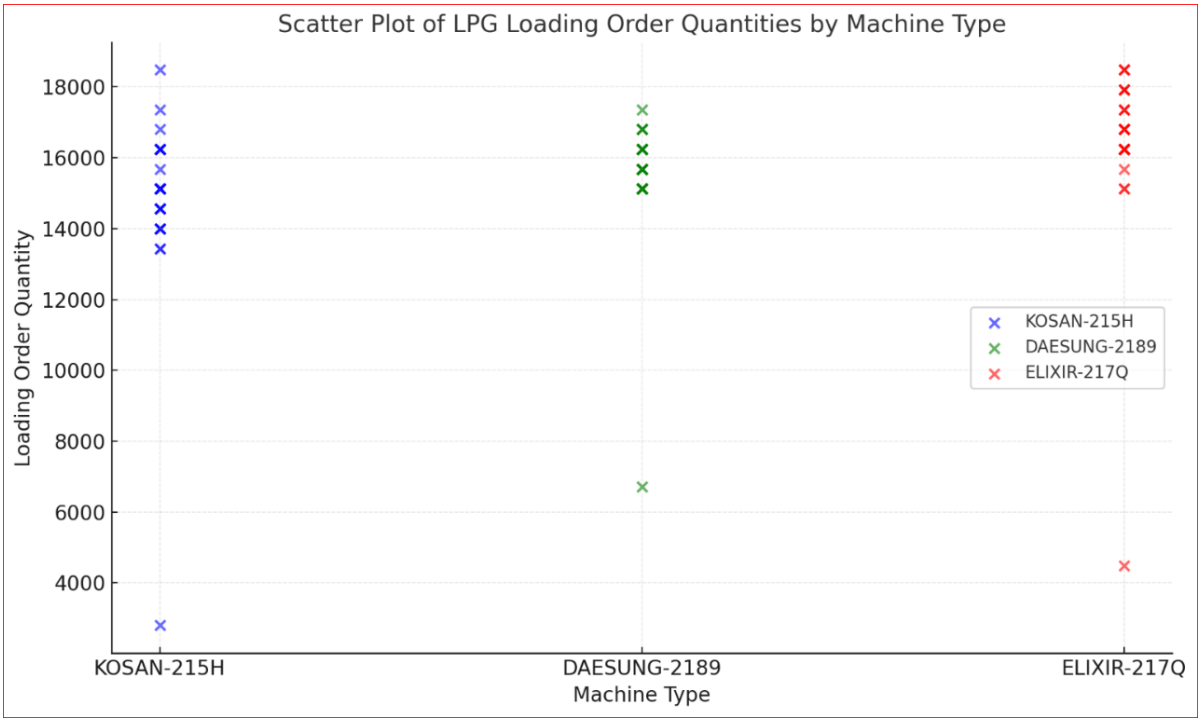

Figure 2. Scatter Plot Visual

X-axis:
The horizontal axis represents the type of filling machine, where:
1 denotes KOSAN-215H,
2 denotes DAESUNG-2189,
3 denotes ELIXIR-217Q.

Y-axis:
The vertical axis represents the loading order quantity of LPG 3 KG (measured in pieces). These values are the observed quantities for each type of filling machine. In the data distribution for KOSAN-215H, there is significant variability, with values ranging from 2,800 to 18,480. A few data points, such as 2,800, represent low outliers. For DAESUNG-2189, the data is more concentrated compared to KOSAN, though some variability still exists. The loading order quantities fall within the range of approximately 6,720 to 17,360. For ELIXIR-217Q, the data tends to be skewed towards higher values, with the range spanning from 4,480 to 18,480, showing generally higher quantities compared to both KOSAN and DAESUNG

CONCLUSION

The calculated F-Statistic (3.171240679) exceeds the F-Critical value (3.11379226), with a P-value of 0.0474111978 (below 0.05). This result leads to the rejection of the null hypothesis (H0), indicating a statistically significant difference in the mean loading order quantities across the three machines. ELIXIR-217Q demonstrates higher efficiency in achieving larger loading order quantities, consistently showing a higher average compared to the other machines. It exhibits a trend towards higher quantities, with values approaching the upper limit of the range,

and has a consistently higher mean loading order compared to both KOSAN-215H and DAESUNG-2189. DAESUNG-2189, while exhibiting more stability around the central values, does not perform as efficiently as ELIXIR-217Q. On the other hand, KOSAN-215H shows substantial variability, which may reflect inconsistent performance, with a wider data distribution and notable fluctuations in machine output.

REFERENCE

[1] Tae Kyun Kim, "Understanding one-way anova using conceptual figures.," *Korean J. Anesthesiol.*, vol. 70, no. 1, pp. 22–26, 2017, [Online]. Available: https://doi.org/10.4097/kjae.2017.70.1.22

[2] Amiruddin, "Analisis variansi (Anava) dalam penelitian pendidikan," *Univers. Grace J.*, vol. 1, no. 1, pp. 161–172, 2023.

[3] makeen, "Universal filling machine," makeenenergy. Accessed: Jan. 10, 2025. [Online]. Available: https://www.makeenenergy.com/products-solutions/lpg-solutions/filing-equipment/bd-ufm-mh_universal-filling-machine-ufm

[4] DSM, "About company Introduction," Daesung Mechatron CO.,LTD. Accessed: Jan. 12, 2025. [Online]. Available: http://mtsds.com/index.html

[5] Elpiji_Group, "ELIXIR EK 670 C2 Stationary Electronic Filling Machine for Domestic & Industrial Cylinders," Elpiji (M) Sdn Bhd. Accessed: Jan. 02, 2025. [Online]. Available: http://elpiji-group.com/project/elixir-ek-670-c2-stationary-electronic-filling-machine-for-domestic-industrial-cylinders/

[6] R. Adolph, *済無No Title No Title No Title*. 2016.

[7] H. Anysz, Ł. Rosicki, and P. Narloch, "Compressive Strengths of Cube vs. Cored Specimens of Cement Stabilized Rammed Earth Compared with ANOVA," *Appl. Sci.*, vol. 14, no. 13, 2024, doi: 10.3390/app14135746.

[8] W. Zhang and Y. Qi, "ANOVA-nSTAT: ANOVA methodology and computational tools in the paradigm of new statistics," *Comput. Ecol. Softw.*, vol. 2024, no. 1, pp. 48–67, 2020, [Online]. Available: www.iaees.org

[9] J. Zhang and Y. Guo, "Examining the Impact of Blended Learning on Test Scores: A Statistical Analysis Using an ANOVA Model," *SHS Web Conf.*, vol. 190, p. 01019, 2024, doi: 10.1051/shsconf/202419001019.

[10] B. Ukert, M. Lawley, and H. C. Kum, "Geographic disparities in telemedicine mental health use by applying three way ANOVA on Medicaid claims population data," *BMC Health Serv. Res.*, vol. 24, no. 1, pp. 1–9, 2024, doi: 10.1186/s12913-024-10898-0.

[11] L. Muflikhah, A. Iskandar, N. Yudistira, I. U. Nadlori, and B. N. Dewanto, "High performance of Dengue shock syndrome detection using extreme gradient boosting with ANOVA feature selection," *J. Biotech Res.*, vol. 16, no. 2011, pp. 22–31, 2024.

[12] N. Kekana, M. B. Shongwe, K. Mpofu, and R. Muvunzi, "Investigation into Process Parameter Optimization of Selective Laser Melting for Producing AlSi12 Parts Using ANOVA," *Appl. Sci.*, vol. 14, no. 15, 2024, doi: 10.3390/app14156519.

[13] N. M. Likando and M. S. Chipandwe, "Statistical investigation of climate and landfill age impacts on Kupferberg landfill leachate composition: one-way ANOVA analysis," *Discov.*

Water, vol. 4, no. 1, 2024, doi: 10.1007/s43832-024-00102-z.

[14] F. O. Kolawole, A. T. Ayeni, S. K. Kolawole, O. S. Kolade, and A. F. Owa, "Statistical Models for Predicting Wear and Friction Coefficient of Valve Tappet Using ANOVA," *Tribol. Ind.*, vol. 46, no. 2, pp. 210–216, 2024, doi: 10.24874/ti.1517.07.23.09.

[15] F. O. Kolawole and S. K. Kolawole, "Statistical model for predicting friction coefficient and wear of duplex CrN/DLC and nano-multilayer DLC-W coatings using ANOVA," *Discov. Mater.*, vol. 4, no. 1, 2024, doi: 10.1007/s43939-024-00099-1.

[16] M. F. Ijaz, B. T. Nashri, and M. T. Qamash, "Sustainability through Optimal Compositional and Thermomechanical Design for the Al-7XXX Alloys: An ANOVA Case Study," *Sustain.*, vol. 16, no. 4, 2024, doi: 10.3390/su16041515.