Summary of Statistics

Wednesday, July 23, 2025

E. coli - Sonication

Normality Test Results

Table 1: Normality Test Results (using Shapiro-Wilk tests, as well as visual interpretation from the Boxplot and individual Q-Q plots)

Sonication Time	Sample Size (N)	SW Statistic	p-value	Normality Conclusion
30 seconds	9	0.8858	0.1805	Do not reject normality
1 minute	27	0.8463	0.0010	Reject normality
2 minutes	19	0.9736	0.8449	Do not reject normality
5 minutes	18	0.7818	0.0008	Reject normality
10 minutes	38	0.7408	0.0000	Reject normality
30 minutes	17	0.9501	0.4577	Do not reject normality
60 minutes	9	0.7493	0.0053	Reject normality
120 minutes	6	0.9694	0.8881	Do not reject normality

Levene's Test for Homogeneity of Variances

- **Test statistic:** 6.3459
- **p-value:** 0.0000
- **Conclusion:** Reject null hypothesis — variances are significantly different across groups.

Additional Notes on Data and Assumptions

Sample Sizes: Unequal sample sizes across groups (imbalanced dataset).

Normality Assumption: Partially met — only 4 out of 8 groups pass statistical and visual normality tests.

Equal Variance Assumption: Not met — Levene's test indicates unequal variances.

Independence of Observations: Assumed to be met.

Implications for Statistical Analysis

- Given the violation of normality in some groups and unequal variances, **use robust methods** such as Welch's ANOVA or non-parametric tests like Kruskal-Wallis.
- Classical ANOVA assuming equal variances and normality is not appropriate.

Kruskal-Wallis and Dunn's post-hoc test

Table 2: Kruskal-Wallis Test Summary

Variable	n	Statistic	df	p-value	Method
value	143	91.63	7	5.73×10^{-17}	Kruskal-Wallis

Table 3: Dunn's Post-hoc Test with Holm Correction - Main Results

Group 1	Group 2	n_1	n_2	Test Statistic	Adj. p-value	Significance
30_sec	30_min	9	17	3.26	0.0269	*
1_min	10_min	27	38	-4.60	1.05×10^{-4}	***
1_min	30_min	27	17	3.20	0.0318	*
2_min	10_min	19	38	-6.93	1.14×10^{-10}	****
5_min	10_min	18	38	-6.74	4.16×10^{-10}	****
10_min	30_min	38	17	7.36	5.03×10^{-12}	****

Legend: * $p \leq 0.05$, ** $p \leq 0.01$, *** $p \leq 0.001$, **** $p \leq 0.0001$, ns = not significant

Table 4: Complete Dunn's Post-hoc Test with Holm Correction

Group 1	Group 2	n_1	n_2	Statistic	p-value	Adj. p	Signif
30_sec	1_min	9	27	0.92	0.3590	1.0000	ns
30_sec	2_min	9	19	2.82	0.0048	0.1002	ns
30_sec	5_min	9	18	2.75	0.0059	0.1189	ns
30_sec	10_min	9	38	-2.17	0.0299	0.3584	ns
30_sec	30_min	9	17	3.26	0.0011	0.0269	*
30_sec	60_min	9	9	0.29	0.7736	1.0000	ns
30_sec	120_min	9	6	0.49	0.6239	1.0000	ns
1_min	2_min	27	19	2.63	0.0084	0.1600	ns
1_min	5_min	27	18	2.53	0.0114	0.2009	ns
1_min	10_min	27	38	-4.60	4.19e-06	0.0001	***
1_min	30_min	27	17	3.20	0.0014	0.0318	*
1_min	60_min	27	9	-0.57	0.5721	1.0000	ns
1_min	120_min	27	6	-0.21	0.8339	1.0000	ns
2_min	5_min	19	18	-0.06	0.9538	1.0000	ns
2_min	10_min	19	38	-6.93	4.21e-12	1.14e-10	****
2_min	30_min	19	17	0.60	0.5465	1.0000	ns
2_min	60_min	19	9	-2.49	0.0129	0.2060	ns
2_min	120_min	19	6	-1.89	0.0592	0.6510	ns
5_min	10_min	18	38	-6.74	1.60e-11	4.16e-10	****
5_min	30_min	18	17	0.65	0.5147	1.0000	ns
5_min	60_min	18	9	-2.42	0.0156	0.2322	ns
5_min	120_min	18	6	-1.83	0.0667	0.6666	ns

Group 1	**Group 2**	$\mathbf{n_1}$	$\mathbf{n_2}$	**Statistic**	**p-value**	**Adj. p**	**Signif**
10_min	30_min	38	17	7.36	1.80e-13	5.03e-12	****
10_min	60_min	38	9	2.54	0.0112	0.2009	ns
10_min	120_min	38	6	2.42	0.0155	0.2322	ns
30_min	60_min	17	9	-2.93	0.0034	0.0746	ns
30_min	120_min	17	6	-2.28	0.0223	0.2903	ns
60_min	120_min	9	6	0.23	0.8157	1.0000	ns

E. coli - Vortexing and Hand Shaking

Normality Test Results

Table 5: Normality Test Results (using Shapiro-Wilk tests, as well as visual interpretation from the Boxplot and individual Q-Q plots)

Treatment	Sample Size (N)	SW Statistic	p-value
Vortexing 5 seconds	18	0.7546	0.0004
Vortexing 15 seconds	16	0.7774	0.0014
Vortexing 30 seconds	21	0.7246	0.0001
Vortexing 60 seconds	27	0.7265	0.0000
Hand Shaking	46	0.5897	0.0000

Levene's Test for Homogeneity of Variances

- **Test statistic:** 12.2790
- **p-value:** 0.0000
- **Conclusion:** Reject null hypothesis — variances are significantly different across groups.

Additional Notes on Data and Assumptions

Sample Sizes: Unequal sample sizes across treatment groups (imbalanced dataset).

Normality Assumption: Not met — all groups significantly deviate from normality based on statistical and visual tests.

Equal Variance Assumption: Not met — Levene's test indicates unequal variances.

Independence of Observations: Assumed to be met.

Implications for Statistical Analysis

- Due to violations in both normality and variance homogeneity — and given the unequal sample sizes — classical parametric tests (such as ANOVA) are not appropriate.
- The use of **non-parametric methods** (e.g., Kruskal-Wallis with Dunn's post-hoc test) or **robust parametric alternatives** (e.g., Welch's ANOVA) is recommended.

Kruskal-Wallis and Dunn's Post-hoc Test

Table 6: Kruskal-Wallis Test Summary

Variable	n	Statistic	df	p-value	Method
value	128	18.35	4	0.00105	Kruskal-Wallis

Table 7: Dunn's Post-hoc Test with Holm Correction — Significant Results

Group 1	**Group 2**	$\mathbf{n_1}$	$\mathbf{n_2}$	**Test Statistic**	**Adj. p-value**	**Significance**
5_sec	hs	18	46	-3.28	0.0103	*
15_sec	hs	16	46	-3.00	0.0243	*

Legend: * $p \leq 0.05$, ** $p \leq 0.01$, *** $p \leq 0.001$, **** $p \leq 0.0001$, ns = not significant

Table 8: Complete Dunn's Post-hoc Test with Holm Correction

Group 1	**Group 2**	$\mathbf{n_1}$	$\mathbf{n_2}$	**Test Stat.**	**p-value**	**Adj. p**	**Signif**
5_sec	15_sec	18	16	-0.12	0.9039	1.0000	ns
5_sec	30_sec	18	21	-0.71	0.4795	1.0000	ns
5_sec	60_sec	18	27	-2.32	0.0202	0.1412	ns
5_sec	hs	18	46	-3.28	0.0010	0.0103	*
15_sec	30_sec	16	21	-0.56	0.5759	1.0000	ns
15_sec	60_sec	16	27	-2.11	0.0349	0.2096	ns
15_sec	hs	16	46	-3.00	0.0027	0.0243	*
30_sec	60_sec	21	27	-1.65	0.0991	0.4956	ns
30_sec	hs	21	46	-2.60	0.0093	0.0742	ns
60_sec	hs	27	46	-0.85	0.3970	1.0000	ns

B. subtilis - MGS-1 + Incubation

Normality Test Results

Table 9: Normality Test Results, using Shapiro-Wilk tests to analyse MGS-1 Incubation treatments (very small datasets)

Treatment	Sample Size	SW Statistic	p-value	Normality Conclusion
Vortex 5 sec	3	0.7629	0.0287	Non-normal (assumed)
Vortex 15 sec	3	0.9067	0.4072	Non-normal (assumed)
Vortex 30 sec	3	0.9987	0.9311	Non-normal (assumed)
Vortex 60 sec	3	0.9659	0.6451	Non-normal (assumed)
Vortex 300 sec	2	NaN	NaN	Cannot assess (assumed non-normal)
Hand Shaking	3	0.9774	0.7118	Non-normal (assumed)

Levene's Test for Homogeneity of Variances

- **Test statistic:** 32.0843
- **p-value:** 0.0000
- **Conclusion:** The variances are significantly different across groups (reject the null hypothesis of equal variances).

Additional Notes on Data and Assumptions

Sample Sizes: Mostly equal sample sizes across treatment groups (balanced dataset).

Normality Assumption: Not met — normality is not assumed due to each group's extremely small sample size.

Equal Variance Assumption: Not met — Levene's test indicates unequal variances.

Independence of Observations: Met.

Kruskal-Wallis and Dunn's Post-hoc Test

Table 10: Kruskal-Wallis Test Results for MGS-1 Incubation (by Treatment Group)

Variable	n	Statistic	df	p-value	Method
value	17	11.7124	5	0.0389	Kruskal-Wallis

Table 11: Significant Pairwise Comparisons (Dunn's Post-Hoc, MGS-1 Incubation)

Group 1	Group 2	Statistic	Adjusted p-value	Signif.
15_sec	hs	3.0721	0.0319	*

Table 12: Dunn's Post-Hoc Pairwise Comparisons (Holm-adjusted p-values, MGS-1 Incubation)

Variable	Group 1	Group 2	n1	n2	Statistic	p-value	p.adj	Signif.
value	5_sec	15_sec	3	3	-1.3744	0.1693	1.0000	ns
value	5_sec	30_sec	3	3	0.0000	1.0000	1.0000	ns
value	5_sec	60_sec	3	3	0.0808	0.9356	1.0000	ns
value	5_sec	300_sec	3	2	1.3016	0.1931	1.0000	ns
value	5_sec	hs	3	3	1.6977	0.0896	1.0000	ns
value	15_sec	30_sec	3	3	1.3744	0.1693	1.0000	ns
value	15_sec	60_sec	3	3	1.4552	0.1456	1.0000	ns
value	15_sec	300_sec	3	2	2.5309	0.0114	0.1593	ns
value	15_sec	hs	3	3	3.0721	0.0021	0.0319	*
value	30_sec	60_sec	3	3	0.0808	0.9356	1.0000	ns
value	30_sec	300_sec	3	2	1.3016	0.1931	1.0000	ns
value	30_sec	hs	3	3	1.6977	0.0896	1.0000	ns
value	60_sec	300_sec	3	2	1.2293	0.2190	1.0000	ns
value	60_sec	hs	3	3	1.6169	0.1059	1.0000	ns
value	300_sec	hs	2	3	0.2169	0.8283	1.0000	ns

B. subtilis - MMS-2 + Incubation

Normality Test Results

Table 13: Normality Test Results, using Shapiro-Wilk test to analyse MMS-2 Incubation treatments (very small datasets)

Treatment	Sample Size	SW Statistic	p-value	Normality Conclusion
Vortex 5 sec	2	NaN	NaN	Cannot assess (assumed non-normal)
Vortex 15 sec	3	0.8909	0.3572	Non-normal (assumed)
Vortex 30 sec	3	0.7562	0.0137	Non-normal (assumed)
Vortex 60 sec	3	0.7521	0.0046	Non-normal (assumed)
Vortex 120 sec	3	0.9902	0.8111	Non-normal (assumed)
Vortex 300 sec	3	0.8446	0.2261	Non-normal (assumed)
Hand Shaking	3	0.8404	0.2151	Non-normal (assumed)

Levene's Test for Homogeneity of Variances

- **Test statistic:** 0.8062
- **p-value:** 0.5828
- **Conclusion:** Variances are not significantly different across groups (fail to reject the null hypothesis of equal variances).

Additional Notes on Data and Assumptions

Sample Sizes: Mostly equal sample sizes across treatment groups (balanced dataset).

Normality Assumption: Not met — normality is not assumed due to each group's extremely small sample size.

Equal Variance Assumption: Met — Levene's test indicates equal variances.

Independence of Observations: Met.

Kruskal-Wallis and Dunn's Post-hoc Test

Table 14: Kruskal-Wallis Test Results for MMS-2 Incubation (by Treatment Group)

Variable	n	Statistic	df	p-value	Method
value	20	13.21	6	0.0398	Kruskal-Wallis

Table 15: No Significant Pairwise Comparisons after Holm Adjustment (MMS-2 Incubation)

Group 1	Group 2	Statistic	Adjusted p-value	Significance
No pairwise comparisons significant after p-value adjustment at 0.05				

Table 16: Dunn's Post-Hoc Pairwise Comparisons (Holm-adjusted p-values, MMS-2 Incubation)

Variable	Group 1	Group 2	n1	n2	Statistic	p-value	p.adj	Signif.
value	5_sec	15_sec	2	3	0.741	0.459	1.000	ns
value	5_sec	30_sec	2	3	0.432	0.666	1.000	ns
value	5_sec	60_sec	2	3	0.617	0.537	1.000	ns
value	5_sec	120_sec	2	3	-0.802	0.422	1.000	ns
value	5_sec	300_sec	2	3	-1.358	0.175	1.000	ns
value	5_sec	hs	2	3	-1.481	0.139	1.000	ns
value	15_sec	30_sec	3	3	-0.345	0.730	1.000	ns
value	15_sec	60_sec	3	3	-0.138	0.890	1.000	ns
value	15_sec	120_sec	3	3	-1.725	0.085	1.000	ns
value	15_sec	300_sec	3	3	-2.346	0.019	0.379	ns
value	15_sec	hs	3	3	-2.484	0.013	0.273	ns
value	30_sec	60_sec	3	3	0.207	0.836	1.000	ns
value	30_sec	120_sec	3	3	-1.380	0.168	1.000	ns
value	30_sec	300_sec	3	3	-2.001	0.045	0.726	ns
value	30_sec	hs	3	3	-2.139	0.032	0.551	ns
value	60_sec	120_sec	3	3	-1.587	0.112	1.000	ns
value	60_sec	300_sec	3	3	-2.208	0.027	0.490	ns
value	60_sec	hs	3	3	-2.346	0.019	0.379	ns
value	120_sec	300_sec	3	3	-0.621	0.535	1.000	ns
value	120_sec	hs	3	3	-0.759	0.448	1.000	ns
value	300_sec	hs	3	3	-0.138	0.890	1.000	ns

B. subtilis - MMS-2 + Desiccation

Normality Test Results

Table 17: Normality Test Results, using Shapiro-Wilk test to analyse MMS-2 Desiccation treatments (very small datasets)

Treatment	Sample Size	SW Statistic	p-value	Normality Conclusion
Vortex 5 sec	3	0.9888	0.7977	Non-normal (assumed)
Vortex 15 sec	3	0.8363	0.2045	Non-normal (assumed)
Vortex 30 sec	3	0.9997	0.9652	Non-normal (assumed)
Vortex 60 sec	3	0.8490	0.2377	Non-normal (assumed)
Vortex 120 sec	2	NaN	NaN	Cannot assess (assumed non-normal)
Vortex 300 sec	3	0.8473	0.2333	Non-normal (assumed)
Hand Shaking	3	0.9952	0.8677	Non-normal (assumed)

Levene's Test for Homogeneity of Variances

- **Test statistic:** 1.6863
- **p-value:** 0.2019
- **Conclusion:** Variances are not significantly different across groups (fail to reject the null hypothesis of equal variances).

Additional Notes on Data and Assumptions

Sample Sizes: Mostly equal sample sizes across treatment groups (balanced dataset).

Normality Assumption: Not met — normality is not assumed due to each group's extremely small sample size.

Equal Variance Assumption: Met — Levene's test indicates equal variances.

Independence of Observations: Met.

Kruskal-Wallis and Dunn's Post-hoc Test

Table 18: Kruskal-Wallis Test Results for MMS-2 Desiccation (by Treatment Group)

Variable	n	Statistic	df	p-value	Method
value	20	12.6571	6	0.0488	Kruskal-Wallis

Table 19: No Significant Pairwise Comparisons after Holm Adjustment (MMS-2 Desiccation)

Group 1	Group 2	Statistic	Adjusted p-value	Significance
No pairs significant after p-value adjustment at 0.05				

Table 20: Dunn's Post-Hoc Pairwise Comparisons (Holm-adjusted p-values, MMS-2 Desiccation)

Variable	Group 1	Group 2	n1	n2	Statistic	p-value	p.adj	Signif.
value	5_sec	15_sec	3	3	-1.863	0.062	1.000	ns
value	5_sec	30_sec	3	3	-1.587	0.112	1.000	ns
value	5_sec	60_sec	3	3	-1.518	0.129	1.000	ns
value	5_sec	120_sec	3	2	-2.345	0.019	0.361	ns
value	5_sec	300_sec	3	3	-2.829	0.005	0.098	ns
value	5_sec	hs	3	3	-0.345	0.730	1.000	ns
value	15_sec	30_sec	3	3	0.276	0.783	1.000	ns
value	15_sec	60_sec	3	3	0.345	0.730	1.000	ns
value	15_sec	120_sec	3	2	-0.679	0.497	1.000	ns
value	15_sec	300_sec	3	3	-0.966	0.334	1.000	ns
value	15_sec	hs	3	3	1.518	0.129	1.000	ns
value	30_sec	60_sec	3	3	0.069	0.945	1.000	ns
value	30_sec	120_sec	3	2	-0.926	0.355	1.000	ns
value	30_sec	300_sec	3	3	-1.242	0.214	1.000	ns
value	30_sec	hs	3	3	1.242	0.214	1.000	ns
value	60_sec	120_sec	3	2	-0.988	0.323	1.000	ns
value	60_sec	300_sec	3	3	-1.311	0.190	1.000	ns
value	60_sec	hs	3	3	1.173	0.241	1.000	ns
value	120_sec	300_sec	2	3	-0.185	0.853	1.000	ns
value	120_sec	hs	2	3	2.037	0.042	0.750	ns
value	300_sec	hs	3	3	2.484	0.013	0.260	ns

Implications for Statistical Analysis of the Three Setups

- Given the violation of normality in all groups and unequal variances in some datasets (in the case of MGS-1 + Incubation), **use robust methods** such as ART-ANOVA (assumes equal variances) or SRH (Scheirer-Ray-Hare) Test (can handle unequal variances).
- Classical ANOVA assuming equal variances and normality is not appropriate.

Scheirer-Ray-Hare Test and Dunn's post-hoc test: MGS-1 and MMS-2

Table 21: Scheirer-Ray-Hare Test Results

Source	Df	Sum of Squares	H	p-value
Factor A (Treatments)	5	28.63	0.289	0.998
Factor B (Regolith Type)	1	1914.08	19.30	1.12e-05
Interaction (Factor A : B)	5	908.76	9.16	0.103
Residuals	22	392.50	—	—

Table 22: Dunn's Post-Hoc Test Result for Factor B (Regolith Type)

Variable	Group 1	Group 2	N1	N2	Statistic	p-value	Signif.
value	MGS-1	MMS-2	17	17	4.426	9.60e-06	****

Legend: * $p \leq 0.05$, ** $p \leq 0.01$, *** $p \leq 0.001$, **** $p \leq 0.0001$, ns = not significant

ART-ANOVA and Estimated Marginal Means test: Incubation and Desiccation

Table 23: ANOVA Table for ART-ANOVA on Treatment (i.e., Techniques) and Condition (i.e., Drying Process) with Interaction

Term	Df	Df.res	Sum Sq	Sum Sq.res	F value	p-value
treatment	6	26	1291.10	2750.50	2.03	0.0970
condition	1	26	938.45	3157.17	7.73	0.0100*
treatment:condition	6	26	1099.16	2497.00	1.91	0.1180

Table 24: Post-hoc Contrast using Estimated Marginal Means: Desiccation vs. Incubation

Contrast	**Estimate**	**Std. Error**	**df**	**t ratio**	**p-value**
Desiccation - Incubation	-9.79	3.52	26	-2.78	0.010

Legend: * $p \leq 0.05$, ** $p \leq 0.01$, *** $p \leq 0.001$, **** $p \leq 0.0001$, ns = not significant

B. subtilis - Motility+Extraction Results - MGS-1 Incubation

Normality Test Results

Table 25: Normality Test Results for MGS-1 Incubation Treatments obtained via the Shapiro-Wilk test and via direct visual interpretation using Q-Q plots and the original boxplot.

Treatment	Sample size	SW Statistic	p-value	Normality Conclusion
Vortex 5 seconds	12	0.7957	0.0084	Not normally distributed
Vortex 15 seconds	12	1.0000	1.0000	Not normally distributed
Vortex 30 seconds	12	1.0000	1.0000	Not normally distributed
Vortex 60 seconds	16	1.0000	1.0000	Not normally distributed
Vortex 300 seconds	15	0.9114	0.1424	Normally distributed
Hand Shaking	18	0.9426	0.3206	Normally distributed

Levene's Test for Homogeneity of Variances

- **Test statistic:** 19.9353
- **p-value:** 0.0000
- **Conclusion:** The variances are significantly different (reject H_0)

Additional Notes on Data and Assumptions

- **Sample Sizes:** Imbalanced dataset.
- **Normality Assumption:** Normality was assessed both statistically and visually. While some groups showed p-values from the Shapiro-Wilk test suggesting normality, visual inspection of Q-Q plots and boxplots indicated non-normality in most vortex treatments except for V-300sec and Hand Shaking.
- **Equal Variance Assumption:** Levene's test indicated that variances are significantly different among the treatment groups, therefore the assumption of homogeneity of variances is violated.
- **Independence of Measurements:** Met.

Kruskal-Wallis and Dunn's Post-hoc Test

Table 26: Kruskal-Wallis Test Result for MGS-1 Incubation

Variable	n	Statistic	df	p-value	Method
value	85	62.6312	5	3.47e-12	Kruskal-Wallis

Table 27: Significant Pairwise Comparisons from Dunn's Test (Holm Adjusted) for MGS-1 Incubation

Variable	Group 1	Group 2	n1	n2	Statistic	p-value	Adjusted p-value	Significance
value	5_sec	15_sec	12	12	3.2797	0.0010	0.0083	**
value	5_sec	30_sec	12	12	3.2797	0.0010	0.0083	**
value	5_sec	60_sec	12	16	3.5062	0.0005	0.0041	**
value	15_sec	300_sec	12	15	-4.5582	5.16e-06	5.68e-05	****
value	15_sec	hs	12	18	-4.9986	5.77e-07	8.08e-06	****
value	30_sec	300_sec	12	15	-4.5582	5.16e-06	5.68e-05	****
value	30_sec	hs	12	18	-4.9986	5.77e-07	8.08e-06	****
value	60_sec	300_sec	16	15	-4.9120	9.01e-07	1.08e-05	****
value	60_sec	hs	16	18	-5.4218	5.90e-08	8.85e-07	****

Legend: * $p \leq 0.05$, ** $p \leq 0.01$, *** $p \leq 0.001$, **** $p \leq 0.0001$, ns = not significant

Table 28: Complete Dunn's Post-hoc Test Results with Holm Adjustment for MGS-1 Incubation

Variable	Group 1	Group 2	n1	n2	Statistic	p-value	Adjusted p-value	Significance
value	5_sec	15_sec	12	12	3.2797	0.0010	0.0083	**
value	5_sec	30_sec	12	12	3.2797	0.0010	0.0083	**
value	5_sec	60_sec	12	16	3.5062	0.0005	0.0041	**
value	5_sec	300_sec	12	15	-1.1010	0.2709	1	ns
value	5_sec	hs	12	18	-1.4059	0.1598	0.9586	ns
value	15_sec	30_sec	12	12	0	1	1	ns
value	15_sec	60_sec	12	16	0	1	1	ns
value	15_sec	300_sec	12	15	-4.5582	5.16e-06	5.68e-05	****
value	15_sec	hs	12	18	-4.9986	5.77e-07	8.08e-06	****
value	30_sec	60_sec	12	16	0	1	1	ns
value	30_sec	300_sec	12	15	-4.5582	5.16e-06	5.68e-05	****
value	30_sec	hs	12	18	-4.9986	5.77e-07	8.08e-06	****
value	60_sec	300_sec	16	15	-4.9120	9.01e-07	1.08e-05	****
value	60_sec	hs	16	18	-5.4218	5.90e-08	8.85e-07	****
value	300_sec	hs	15	18	-0.2789	0.7803	1	ns

Legend: * $p \leq 0.05$, ** $p \leq 0.01$, *** $p \leq 0.001$, **** $p \leq 0.0001$, ns = not significant

B. subtilis - Motility+Extraction Results - MMS-2 Incubation

Normality Test Results

Table 29: Normality Test Results for MMS-2 Incubation Treatments obtained via the Shapiro-Wilk test and via direct visual interpretation using Q-Q plots and the original boxplot.

Treatment	Sample size	SW Statistic	p-value	Normality Conclusion
Vortex 5 seconds	9	0.7442	0.0046	Not normally distributed
Vortex 15 seconds	12	0.9597	0.7796	Normally distributed
Vortex 30 seconds	13	0.9567	0.7022	Normally distributed
Vortex 60 seconds	13	0.9391	0.4453	Not normally distributed
Vortex 120 seconds	13	0.9611	0.7708	Not normally distributed
Vortex 300 seconds	15	0.8880	0.0626	Normally distributed
Hand Shaking	15	0.8679	0.0314	Not normally distributed

Levene's Test for Homogeneity of Variances

- **Test statistic:** 4.3271
- **p-value:** 0.0008
- **Conclusion:** The variances are significantly different (reject H_0)

Additional Notes on Data and Assumptions

- **Sample Sizes:** Marginally imbalanced dataset.
- **Normality Assumption:** Normality assessment combined both statistical testing (Shapiro-Wilk test) and visual inspection (Q-Q plots and boxplots). While some groups passed the normality test, visual inspection helped identify departures from normality in certain groups (such as vortex treatments at 5, 60, 120 seconds, and hand shaking).
- **Equal Variance Assumption:** Levene's test results indicate that the assumption of homogeneity of variances across treatment groups is violated (unequal variances).
- **Independence of Measurements:** Met.

Kruskal-Wallis and Dunn's Post-hoc Test

Table 30: Kruskal-Wallis Test Result for MMS-2 Incubation Groups

Variable	n	Statistic	df	p-value	Method
value	90	33.3685	6	8.91e-06	Kruskal-Wallis

Table 31: Significant Dunn's Post-hoc Comparisons for MMS-2 Incubation (Holm Adjusted)

Variable	Group 1	Group 2	n1	n2	Statistic	p-value	Adjusted p-value	Significance
value	15_sec	120_sec	12	13	-3.9743	7.06e-05	0.0013	**
value	15_sec	300_sec	12	15	-4.5859	4.52e-06	9.49e-05	****
value	60_sec	120_sec	13	13	-3.4232	0.0006	0.0111	*
value	60_sec	300_sec	13	15	-4.0318	5.54e-05	0.0011	**

Legend: * $p \leq 0.05$, ** $p \leq 0.01$, *** $p \leq 0.001$, **** $p \leq 0.0001$, ns = not significant

Table 32: Complete Dunn's Post-hoc Test Results for MMS-2 Incubation (Holm Adjusted)

Variable	Group 1	Group 2	n1	n2	Statistic	p-value	Adjusted p-value	Significance
value	5_sec	15_sec	9	12	2.6331	0.0085	0.1438	ns
value	5_sec	30_sec	9	13	0.6994	0.4843	1	ns
value	5_sec	60_sec	9	13	2.1050	0.0353	0.4235	ns
value	5_sec	120_sec	9	13	-0.9914	0.3215	1	ns
value	5_sec	300_sec	9	15	-1.4586	0.1447	1	ns
value	5_sec	hs	9	15	0.6355	0.5251	1	ns
value	15_sec	30_sec	12	13	-2.1428	0.0321	0.4176	ns
value	15_sec	60_sec	12	13	-0.6203	0.5351	1	ns
value	15_sec	120_sec	12	13	-3.9743	0.0001	0.0013	**
value	15_sec	300_sec	12	15	-4.5859	4.52e-06	9.49e-05	****
value	15_sec	hs	12	15	-2.3061	0.0211	0.2955	ns
value	30_sec	60_sec	13	13	1.5539	0.1202	0.9616	ns
value	30_sec	120_sec	13	13	-1.8692	0.0616	0.6775	ns
value	30_sec	300_sec	13	15	-2.4233	0.0154	0.2461	ns
value	30_sec	hs	13	15	-0.0932	0.9257	1	ns
value	60_sec	120_sec	13	13	-3.4232	0.0006	0.0111	*
value	60_sec	300_sec	13	15	-4.0318	5.54e-05	0.0011	**
value	60_sec	hs	13	15	-1.7017	0.0888	0.7993	ns
value	120_sec	300_sec	13	15	-0.4885	0.6252	1	ns
value	120_sec	hs	13	15	1.8416	0.0655	0.6775	ns
value	300_sec	hs	15	15	2.4180	0.0156	0.2461	ns

Legend: * $p \leq 0.05$, ** $p \leq 0.01$, *** $p \leq 0.001$, **** $p \leq 0.0001$, ns = not significant

B. subtilis - Motility+Extraction Results - MMS-2 Desiccation

Normality Test Results

Table 33: Normality Test Results for MMS-2 Desiccation Treatments obtained via the Shapiro-Wilk test and via direct visual interpretation using Q-Q plots and the original boxplot.

Treatment	Sample size	SW Statistic	p-value	Normality Conclusion
Vortex 5 seconds	13	0.6067	0.0001	Not normally distributed
Vortex 15 seconds	12	0.4874	0.0000	Not normally distributed
Vortex 30 seconds	14	0.7673	0.0020	Not normally distributed
Vortex 60 seconds	14	0.8004	0.0051	Not normally distributed
Vortex 120 seconds	13	1.0000	1.0000	Not normally distributed
Vortex 300 seconds	15	0.8726	0.0368	Not normally distributed
Hand Shaking	14	0.9509	0.5744	Normally distributed

Levene's Test for Homogeneity of Variances

- **Test statistic:** 19.1255
- **p-value:** 0.0000
- **Conclusion:** The variances are significantly different (reject H_0)

Additional Notes on Data and Assumptions

- **Sample Sizes:** Mostly balanced dataset.
- **Normality Assumption:** Normality was assessed using both Shapiro-Wilk tests and visual inspection of Q-Q plots and boxplots. The analysis revealed deviations from normality in most treatment groups.
- **Equal Variance Assumption:** Levene's test for homogeneity of variances indicated significant differences among group variances. Therefore, the assumption of equal variances is violated.
- **Independence of Measurements:** Met.

Kruskal-Wallis and Dunn's Post-hoc Test

Table 34: Kruskal-Wallis Test Result for MMS-2 Desiccation Groups

Variable	n	Statistic	df	p-value	Method
value	95	31.2757	6	2.25e-05	Kruskal-Wallis

Table 35: Significant Pairwise Comparisons from Dunn's Test for MMS-2 Desiccation (Holm Adjusted)

Variable	Group 1	Group 2	n1	n2	Statistic	p-value	Adjusted p-value	Significance
value	5_sec	300_sec	13	15	3.3289	0.0009	0.0157	*
value	15_sec	300_sec	12	15	3.5174	0.0004	0.0083	**
value	15_sec	hs	12	14	3.0129	0.0026	0.0440	*
value	120_sec	300_sec	13	15	4.3720	1.23e-05	0.0003	***
value	120_sec	hs	13	14	3.8417	0.0001	0.0024	**

Legend: * $p \leq 0.05$, ** $p \leq 0.01$, *** $p \leq 0.001$, **** $p \leq 0.0001$, ns = not significant

Table 36: Complete Dunn's Post-hoc Test Results for MMS-2 Desiccation (Holm Adjusted)

Variable	Group 1	Group 2	n1	n2	Statistic	p-value	Adjusted p-value	Significance
value	5_sec	15_sec	13	12	-0.2520	0.8010	1	ns
value	5_sec	30_sec	13	14	1.4381	0.1504	1	ns
value	5_sec	60_sec	13	14	0.9504	0.3419	1	ns
value	5_sec	120_sec	13	13	-1.0078	0.3136	1	ns
value	5_sec	300_sec	13	15	3.3289	0.0009	0.0157	*
value	5_sec	hs	13	14	2.8154	0.0049	0.0779	ns
value	15_sec	30_sec	12	14	1.6644	0.0960	0.9603	ns
value	15_sec	60_sec	12	14	1.1869	0.2353	1	ns
value	15_sec	120_sec	12	13	-0.7354	0.4621	1	ns
value	15_sec	300_sec	12	15	3.5174	0.0004	0.0083	**
value	15_sec	hs	12	14	3.0129	0.0026	0.0440	*
value	30_sec	60_sec	14	14	-0.4969	0.6192	1	ns
value	30_sec	120_sec	14	13	-2.4643	0.0137	0.2059	ns
value	30_sec	300_sec	14	15	1.9040	0.0569	0.6830	ns
value	30_sec	hs	14	14	1.4036	0.1604	1	ns
value	60_sec	120_sec	14	13	-1.9767	0.0481	0.6250	ns
value	60_sec	300_sec	14	15	2.4094	0.0160	0.2237	ns
value	60_sec	hs	14	14	1.9005	0.0574	0.6830	ns
value	120_sec	300_sec	13	15	4.3720	1.23e-05	0.0003	***
value	120_sec	hs	13	14	3.8417	0.0001	0.0024	**
value	300_sec	hs	15	14	-0.4764	0.6338	1	ns

Legend: * $p \leq 0.05$, ** $p \leq 0.01$, *** $p \leq 0.001$, **** $p \leq 0.0001$, ns = not significant

Implications for Statistical Analysis of the Three Setups

- Given the violation of normality in most groups and unequal variances in all datasets, **use robust methods** such as ART-ANOVA (assumes equal variances) or SRH (Scheirer-Ray-Hare) Test (can handle unequal variances).
- Classical ANOVA assuming equal variances and normality is not appropriate.

Scheirer-Ray-Hare Test and Dunn's post-hoc test: MGS-1 and MMS-2

Table 37: Scheirer-Ray-Hare Test Results

Factor	Df	Sum Sq	H	p-value
Treatment	5	109953.32	50.99	8.69e-10
Regolith Type	1	81559.04	37.82	7.75e-10
Interaction	5	25672.19	11.91	0.0361
Residuals	150	131665.49	NA	NA

Table 38: Significant Pairwise Dunn's Test Comparisons Between Treatment Groups with Holm Adjustment

Variable	Group 1	Group 2	n1	n2	Statistic	p-value	Adjusted p-value	Significance
value	HS	V15	33	24	4.2198	2.45e-05	2.93e-04	***
value	HS	V30	33	25	3.0542	2.26e-03	1.81e-02	*
value	HS	V60	33	29	4.4259	9.60e-06	1.25e-04	***
value	V15	V300	24	30	-5.0312	4.87e-07	6.82e-06	****
value	V15	V5	24	21	-3.1530	1.62e-03	1.45e-02	*
value	V30	V300	25	30	-3.8982	9.69e-05	1.07e-03	**
value	V300	V60	30	29	5.2699	1.37e-07	2.05e-06	****
value	V5	V60	21	29	3.2688	1.08e-03	1.08e-02	*

Legend: * $p \leq 0.05$, ** $p \leq 0.01$, *** $p \leq 0.001$, **** $p \leq 0.0001$, ns = not significant

Table 39: Complete Pairwise Dunn's Test Comparisons Between Treatment Groups with Holm Adjustment

Variable	Group 1	Group 2	n1	n2	Statistic	p-value	Adjusted p-value	Significance
value	HS	V15	33	24	4.2198	2.4457e-05	2.9349e-04	***
value	HS	V30	33	25	3.0542	2.2567e-03	1.8054e-02	*
value	HS	V300	33	30	-0.9745	3.2982e-01	1.0000	ns
value	HS	V5	33	21	0.6803	4.9633e-01	1.0000	ns
value	HS	V60	33	29	4.4259	9.6031e-06	1.2484e-04	***
value	V15	V30	24	25	-1.1276	2.5950e-01	1.0000	ns
value	V15	V300	24	30	-5.0312	4.8732e-07	6.8225e-06	****
value	V15	V5	24	21	-3.1530	1.6159e-03	1.4544e-02	*
value	V15	V60	24	29	-0.0200	9.8408e-01	1.0000	ns
value	V30	V300	25	30	-3.8982	9.6920e-05	1.0661e-03	**
value	V30	V5	25	21	-2.0943	3.6237e-02	2.5366e-01	ns
value	V30	V60	25	29	1.1605	2.4584e-01	1.0000	ns
value	V300	V5	30	21	1.5314	1.2567e-01	7.5401e-01	ns
value	V300	V60	30	29	5.2699	1.3652e-07	2.0478e-06	****
value	V5	V60	21	29	3.2688	1.0799e-03	1.0799e-02	*

Legend: * $p \leq 0.05$, ** $p \leq 0.01$, *** $p \leq 0.001$, **** $p \leq 0.0001$, ns = not significant

Table 40: Pairwise Dunn's Test Comparison Between MGS-1 and MMS-2 Groups

Variable	Group 1	Group 2	n1	n2	Statistic	Adjusted p-value	Significance
value	MGS-1	MMS-2	85	77	-6.0865	1.15e-09	****

Legend: * $p \leq 0.05$, ** $p \leq 0.01$, *** $p \leq 0.001$, **** $p \leq 0.0001$, ns = not significant

Scheirer-Ray-Hare Test and Dunn's post-hoc test: Incubation and Desiccation

Table 41: Scheirer-Ray-Hare Test Results

Factor	Df	Sum Sq	H	p-value
Treatment	6	72472.90	25.92	0.00023
Condition	1	7059.22	2.52	0.1121
Interaction	6	89127.92	31.87	1.72e-05
Residuals	171	344823.97	NA	NA

Table 42: Complete Pairwise Dunn's Test Comparisons Between Treatment Groups (Holm Adjusted p-values)

Variable	Group 1	Group 2	n1	n2	Statistic	p-value	Adjusted p-value	Significance
value	V5	V15	22	24	0.739	0.4601	1	ns
value	V5	V30	22	27	1.312	0.1895	1	ns
value	V5	V60	22	27	1.879	0.0602	0.8432	ns
value	V5	V120	22	26	-1.355	0.1755	1	ns
value	V5	V300	22	30	1.850	0.0643	0.8432	ns
value	V5	HS	22	29	2.990	0.0028	0.0502	ns
value	V15	V30	24	27	0.566	0.5713	1	ns
value	V15	V60	24	27	1.147	0.2516	1	ns
value	V15	V120	24	26	-2.157	0.0310	0.4655	ns
value	V15	V300	24	30	1.100	0.2712	1	ns
value	V15	HS	24	29	2.273	0.0230	0.3683	ns
value	V30	V60	27	27	0.598	0.5496	1	ns
value	V30	V120	27	26	-2.800	0.0051	0.0869	ns
value	V30	V300	27	30	0.537	0.5911	1	ns
value	V30	HS	27	29	1.752	0.0798	0.9580	ns
value	V60	V120	27	26	-3.392	0.0007	0.0133	*
value	V60	V300	27	30	-0.077	0.9389	1	ns
value	V60	HS	27	29	1.143	0.2531	1	ns
value	V120	V300	26	30	3.403	0.0007	0.0133	*
value	V120	HS	26	29	4.583	4.59e-06	9.63e-05	****
value	V300	HS	30	29	1.252	0.2107	1	ns

Legend: * $p \leq 0.05$, ** $p \leq 0.01$, *** $p \leq 0.001$, **** $p \leq 0.0001$, ns = not significant

Table 43: Significant Pairwise Dunn's Test Comparisons Between Treatment Groups (Holm Adjusted)

Variable	Group 1	Group 2	n1	n2	Statistic	p-value	Adjusted p-value	Significance
value	V60	V120	27	26	-3.3925	0.0006927	0.0133331	*
value	V120	V300	26	30	3.4029	0.0006667	0.0133331	*
value	V120	HS	26	29	4.5829	4.5859e-06	9.6303e-05	****

Legend: * $p \leq 0.05$, ** $p \leq 0.01$, *** $p \leq 0.001$, **** $p \leq 0.0001$, ns = not significant