Development and characterization of miltefosine-loaded polymeric micelles for cancer treatment

This research paper aims to develop a formulation of miltefosine-loaded polymeric micelles of the copolymer Pluronic-F127 to decrease the hemolytic potential of miltefosine. Design of experiments (DoE) methodology is implemented in order to evaluate the effect of the independent variables on the responses.

The factors (independent variables) examined are: X_1 = hydration temperature (°C), X_2 = stirring speed (rpm) and X_3 = stirring time (min). All the factors are continuous. The response (dependent variable) examined is: Y_1 = polydispersity index. The applied DoE method is 2^3 full factorial design.

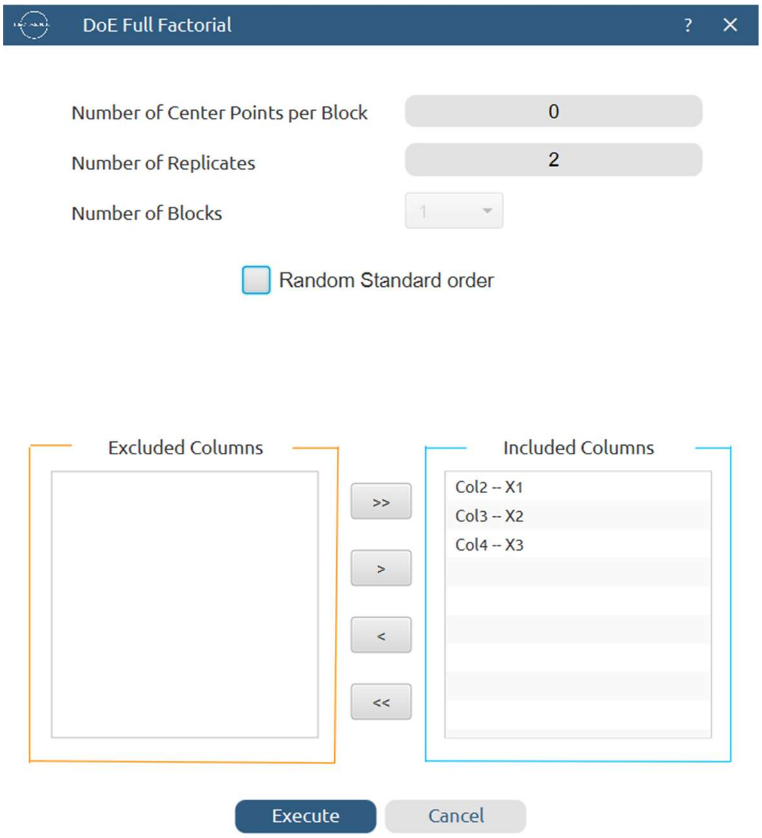
Isalos version used: 2.0.6

Scientific article: https://www.sciencedirect.com/science/article/pii/S0928493117320921

Step 1: Full Factorial Design

In the first tab named "Action" define the factors in the column headers and fill each column with the low and high levels of the corresponding factors. This tab can be renamed "Full Factorial". Afterwards, apply the full factorial method: *DOE → Factorial → Full Factorial*

	Col1	Col2 (I)	Col3 (I)	Col4 (I)
User Header	User Row ID	X1	X2	X3
1		30	550	30
2		50	750	60



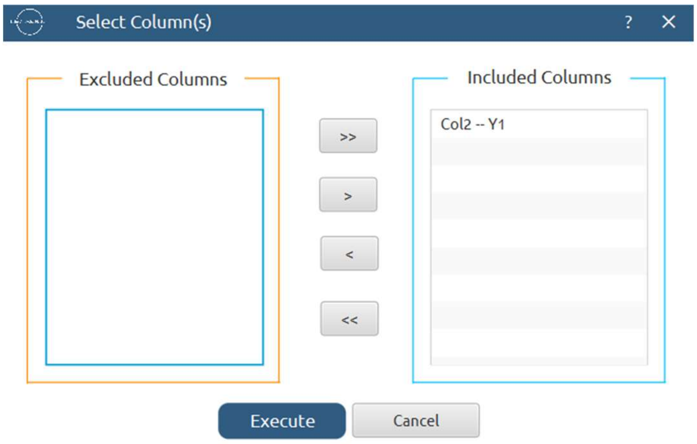
Results (right spreadsheet):

	Col1	Col2 (I)	Col3 (S)	Col4 (S)	Col5 (S)	Col6 (D)	Col7 (D)	Col8 (D)
User Header	User Row ID	Standard Order	Block Number	Replicate Number	Point Type	X1	X2	X3
1		1	Block: 1	Replicate: 1	Design Point	30.0	550.0	30.0
2		2	Block: 1	Replicate: 1	Design Point	50.0	550.0	30.0
3		3	Block: 1	Replicate: 1	Design Point	30.0	750.0	30.0
4		4	Block: 1	Replicate: 1	Design Point	50.0	750.0	30.0
5		5	Block: 1	Replicate: 1	Design Point	30.0	550.0	60.0
6		6	Block: 1	Replicate: 1	Design Point	50.0	550.0	60.0
7		7	Block: 1	Replicate: 1	Design Point	30.0	750.0	60.0
8		8	Block: 1	Replicate: 1	Design Point	50.0	750.0	60.0
9		9	Block: 1	Replicate: 2	Design Point	30.0	550.0	30.0
10		10	Block: 1	Replicate: 2	Design Point	50.0	550.0	30.0
11		11	Block: 1	Replicate: 2	Design Point	30.0	750.0	30.0
12		12	Block: 1	Replicate: 2	Design Point	50.0	750.0	30.0
13		13	Block: 1	Replicate: 2	Design Point	30.0	550.0	60.0
14		14	Block: 1	Replicate: 2	Design Point	50.0	550.0	60.0
15		15	Block: 1	Replicate: 2	Design Point	30.0	750.0	60.0
16		16	Block: 1	Replicate: 2	Design Point	50.0	750.0	60.0

Step 2: Definition of response variables

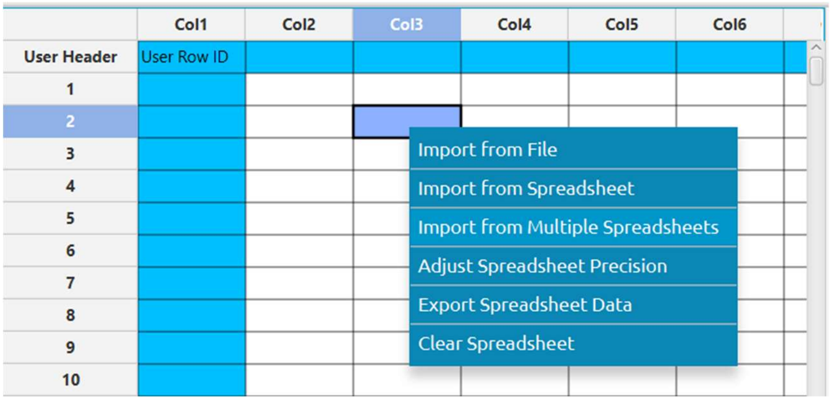
Create a new tab named “Responses” and define the response in the column headers. Fill a column with the values of the response variable that were observed and make sure the values follow the order of the experiments as given by the full factorial method. Then, select the column to be transferred to the right spreadsheet: *Data Transformation → Data Manipulation → Select Column(s)*

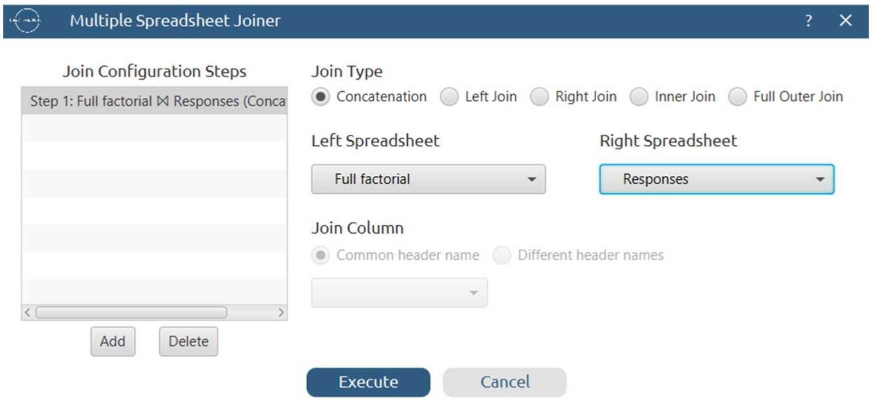
	Col1	Col2 (D)
User Header	User Row ID	Y1
1		8.8
2		4.4
3		5.2
4		5
5		4.5
6		4
7		7.2
8		6.6
9		9
10		4.5
11		4.9
12		5.2
13		4.2
14		4.1
15		6.4
16		6.3

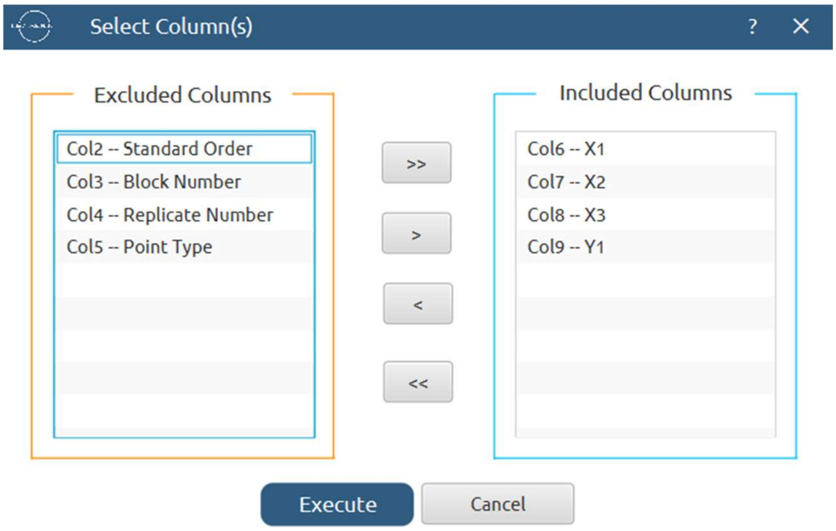


Step 3: Data isolation

Create a new tab named "Data" and import the results from the "Full Factorial" and "Responses" spreadsheets by right clicking on the left spreadsheet. Then, select only the factors and response columns to be transferred to the right spreadsheet: *Data Transformation → Data Manipulation → Select Column(s)*





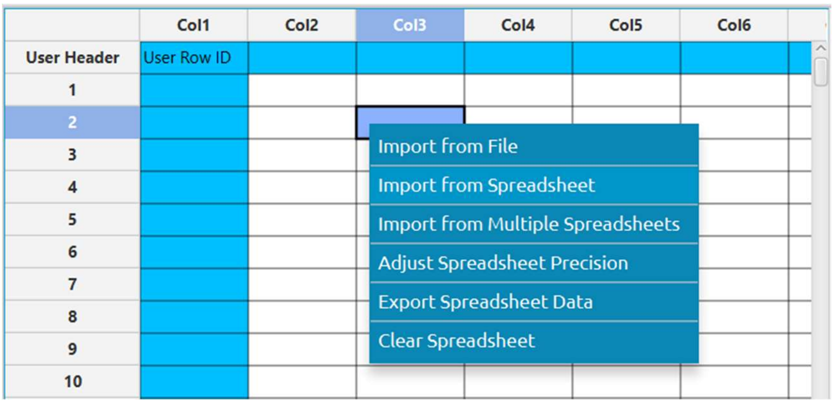


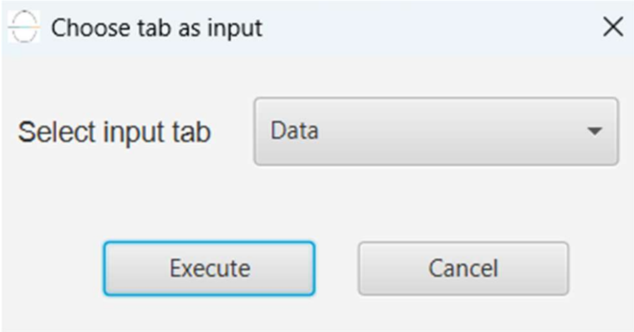
Results:

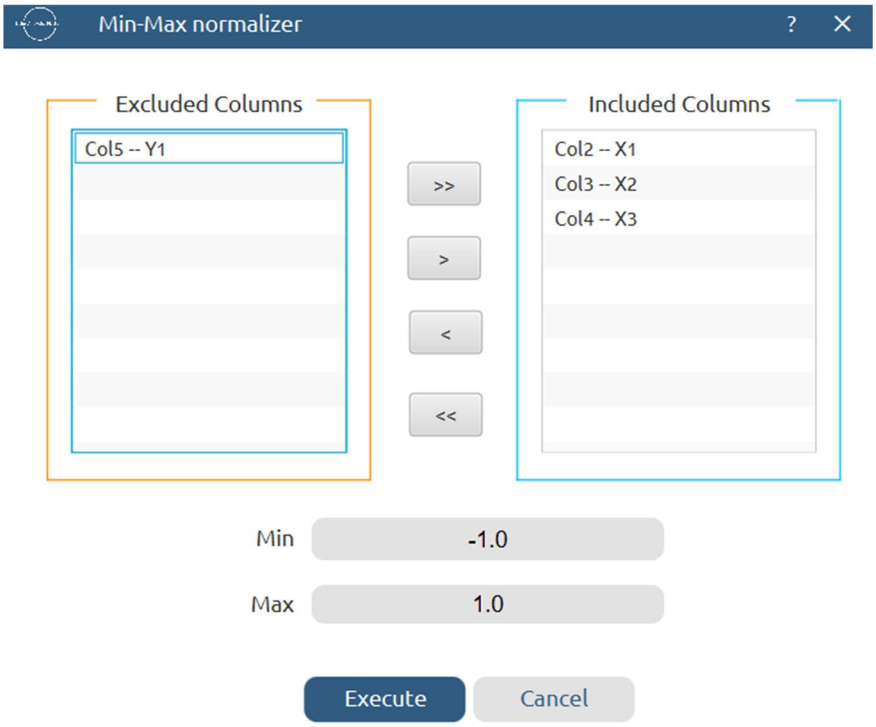
	Col1	Col2 (D)	Col3 (D)	Col4 (D)	Col5 (D)
User Header	User Row ID	X1	X2	X3	Y1
1		30.0	550.0	30.0	8.8
2		50.0	550.0	30.0	4.4
3		30.0	750.0	30.0	5.2
4		50.0	750.0	30.0	5
5		30.0	550.0	60.0	4.5
6		50.0	550.0	60.0	4
7		30.0	750.0	60.0	7.2
8		50.0	750.0	60.0	6.6
9		30.0	550.0	30.0	9
10		50.0	550.0	30.0	4.5
11		30.0	750.0	30.0	4.9
12		50.0	750.0	30.0	5.2
13		30.0	550.0	60.0	4.2
14		50.0	550.0	60.0	4.1
15		30.0	750.0	60.0	6.4
16		50.0	750.0	60.0	6.3

Step 4: Normalization

Create a new tab named “Normalized data” and import the results from the “Data” spreadsheet. Afterwards, normalize the factor columns to take values in the range [-1, 1]: *Data Transformation → Normalizers → Min-Max*




Choose tab as input
Select input tab
Data
Execute
Cancel


Min-Max normalizer
Excluded Columns
Col5 -- Y1
Included Columns
Col2 -- X1
Col3 -- X2
Col4 -- X3
Min
-1.0
Max
1.0
Execute
Cancel

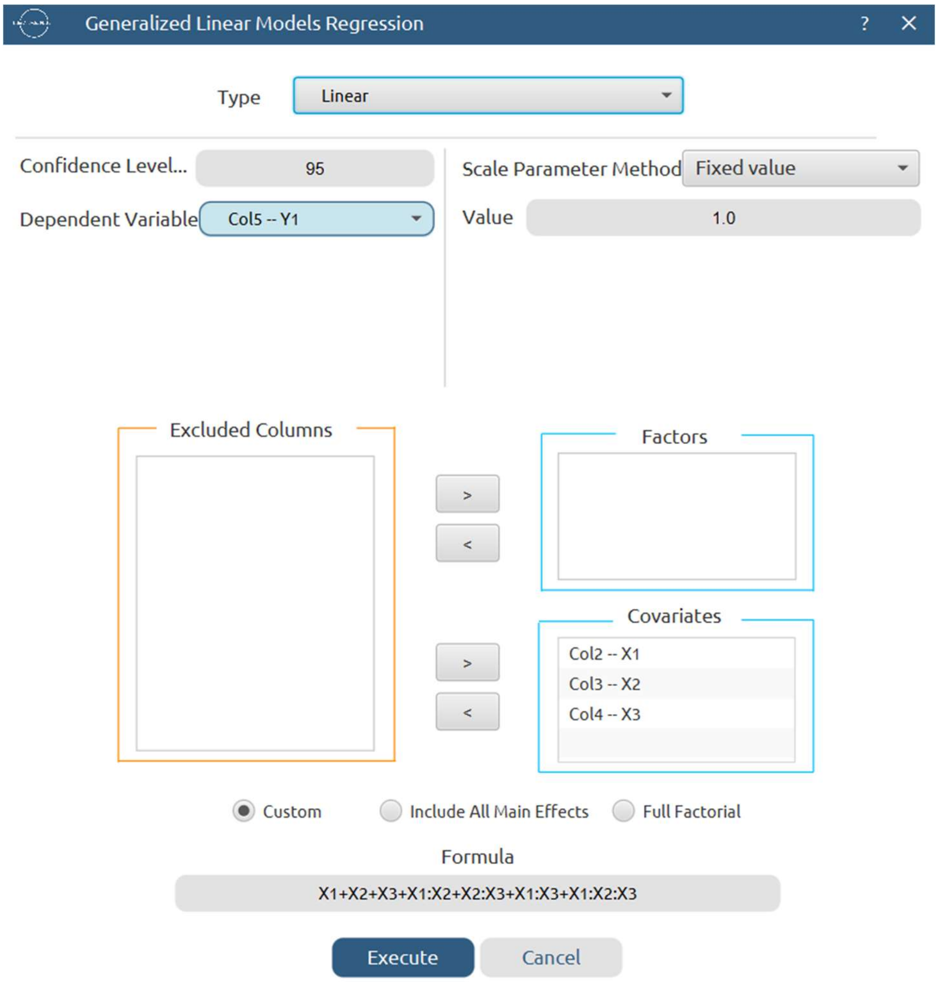
Results:

	Col1	Col2 (D)	Col3 (D)	Col4 (D)	Col5 (D)
User Header	User Row ID	X1	X2	X3	Y1
1		-1.0	-1.0	-1.0	8.8
2		1.0	-1.0	-1.0	4.4
3		-1.0	1.0	-1.0	5.2
4		1.0	1.0	-1.0	5.0
5		-1.0	-1.0	1.0	4.5
6		1.0	-1.0	1.0	4.0
7		-1.0	1.0	1.0	7.2
8		1.0	1.0	1.0	6.6
9		-1.0	-1.0	-1.0	9.0
10		1.0	-1.0	-1.0	4.5
11		-1.0	1.0	-1.0	4.9
12		1.0	1.0	-1.0	5.2
13		-1.0	-1.0	1.0	4.2
14		1.0	-1.0	1.0	4.1
15		-1.0	1.0	1.0	6.4
16		1.0	1.0	1.0	6.3

Step 5: Regression

The goal here is to produce a regression equation that includes main effects, two-factor interactions and quadratic effects for Y_1: $Y = b_0 + b_1X_1 + b_2X_2 + b_{12}X_1X_2 + b_{11}{X_1}^2 + b_{22}{X_2}^2$

Create a new tab named "Regression – Y1" and import the results from the spreadsheet "Normalized data". Afterwards, fit a generalized linear model to the data: *Analytics → Regression → Statistical fitting → Generalized Linear Models*



Results:

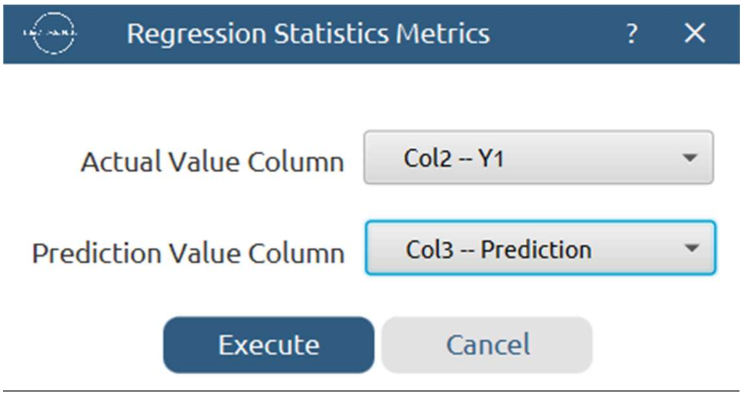
Y1	Prediction
8.8	8.9000000
4.4	4.4500000
5.2	5.0500000
5	5.1000000
4.5	4.3500000
4	4.0500000
7.2	6.8000000
6.6	6.4500000
9	8.9000000
4.5	4.4500000
4.9	5.0500000
5.2	5.1000000
4.2	4.3500000
4.1	4.0500000
6.4	6.8000000
6.3	6.4500000

Goodness of Fit	
	Value
Deviance	0.5050000
Scaled Deviance	0.5050000
Pearson Chi-Square	0.5050000
Scaled Pearson Chi-Square	0.5050000
Log Likelihood	-14.9555165
Akaike's Information Criterion (AIC)	45.9110331
Finite Sample Corrected AIC (AICC)	66.4824616
Bayesian Information Criterion (BIC)	52.0917428
Consistent AIC (CAIC)	60.0917428

Parameter Estimates							
Variable	Coefficient	Std. Error	Lower CI	Upper CI	Test Statistic	df	p-value
intercept	91.5937500	21.4366800	49.5786292	133.6088708	18.2564625	1	0.0000193
X1	-1.6743750	0.5199159	-2.6933914	-0.6553586	10.3714465	1	0.0012798
X2	-0.1186250	0.0325960	-0.1825120	-0.0547380	13.2441324	1	0.0002734
X3	-1.5622917	0.4519249	-2.4480482	-0.6765351	11.9506548	1	0.0005463
X1*X3	0.0277708	0.0109608	0.0062881	0.0492536	6.4193967	1	0.0112881
X1*X2	0.0022625	0.0007906	0.0007130	0.0038120	8.1902500	1	0.0042116
X2*X3	0.0021875	0.0006872	0.0008406	0.0035344	10.1332721	1	0.0014562
X1*X2*X3	-0.0000379	0.0000167	-0.0000706	-0.0000053	5.1756250	1	0.0229059

Step 6: Regression Metrics

Create a tab named “Metrics – Y1” and import the results from the spreadsheet “Regression – Y1”. Then, produce the regression metrics for the Y_1 regression equation: *Statistics → Model Metrics → Regression Metrics*

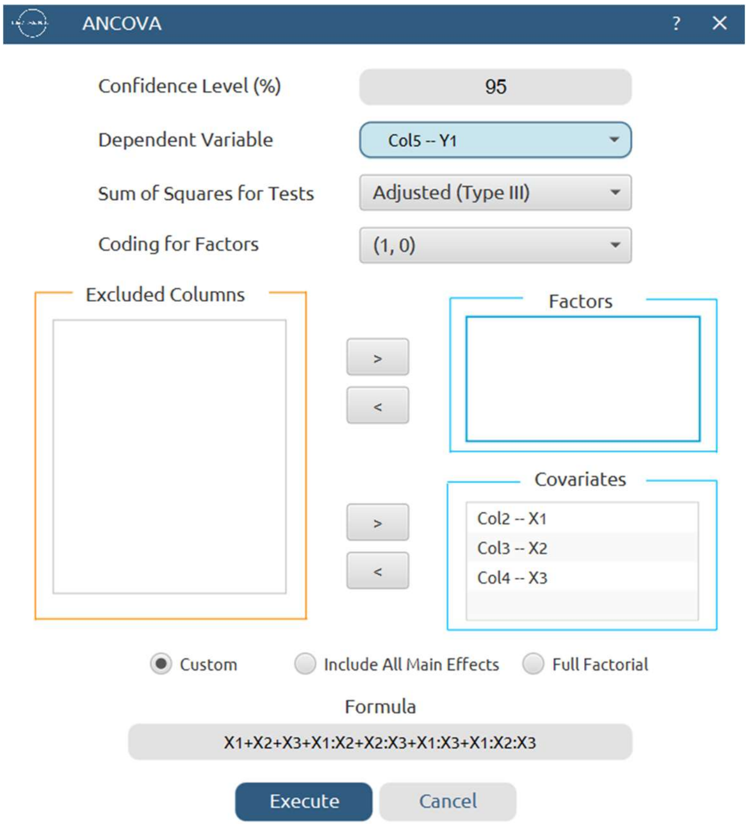


Results:

	Col1	Col2 (D)	Col3 (D)	Col4 (D)	Col5 (D)
User Header	User Row ID	Mean Squared Error	Root Mean Squared Error	Mean Absolute Error	R Squared
1		0.0315625	0.1776584	0.1437500	0.9868006

Step 7: Analysis of Covariance

Create a new tab named “ANCOVA – Y1” and import the results from the spreadsheet “Normalized data”. Afterwards perform analysis of covariance for Y_1: *Statistics → Analysis of (Co)Variance → ANCOVA*



Results:

	Col1	Col2 (S)	Col3 (I)	Col4 (D)	Col5 (D)	Col6 (D)	Col7 (D)
User Header	User Row ID	Source	DF	Adj SS	Adj MS	F-Value	P-Value
1		X1	1	6.3756250	6.3756250	101.0000000	0.0000082
2		X2	1	0.6806250	0.6806250	10.7821782	0.0111275
3		X3	1	0.8556250	0.8556250	13.5544554	0.0062045
4		X1*X2	1	4.9506250	4.9506250	78.4257426	0.0000209
5		X2*X3	1	16.200625	16.200625	256.6435644	2E-7
6		X1*X3	1	3.515625	3.515625	55.6930693	0.0000718
7		X1*X2*X3	1	5.1756250	5.1756250	81.9900990	0.0000177
8		Error	8	0.5050000	0.0631250		
9		Total	15	38.2593750			

References

(1) Valenzuela-Oses, J. K.; García, M. C.; Feitosa, V. A.; Pachioni-Vasconcelos, J. A.; Gomes-Filho, S. M.; Lourenço, F. R.; Cerize, N. N. P.; Bassères, D. S.; Rangel-Yagui, C. O. Development and Characterization of Miltefosine-Loaded Polymeric Micelles for Cancer Treatment. *Materials Science and Engineering: C* **2017**, *81*, 327–333. https://doi.org/10.1016/j.msec.2017.07.040.