

**UNIVERSITI TUNKU ABDUL RAHMAN**

**Faculty of Science**

**Bachelor of Science (HONS) Statistical Computing**

**and Operations Research**

**UDPS 2143 Design and Analysis of Experiments**

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**1.0 INTRODUCTION**

Water absorbency is the ability of textile materials to absorb and hold the solution within its structure. Different types of fabric will have different water absorbency. Furthermore, the other factors such as the concentration of solution and the layers of fabric would also affect the water absorbency.

1.1 Motivation of the project

There is lack of information about the effect of the factors affecting the performance of the usage of cloth. Thus, an experiment was ran in order to study the effect of fabric type, water concentration and layers of fabric on the water absorbency.

1.2 Objectives of the experiment

To determine the effect of water concentration on the weight of solution absorbed by the fabric.

To determine the type of fabric that absorb the largest amount of solution weight.

To determine the layers of fabric that absorb the largest amount of solution weight.

**2.0 METHODOLOGY**

2.1 Experimental Design

This experiment is designed under the 3-factor factorial design. A full factorial design of experiment was used to study all the combinations of factors at each level. Two replications are conducted for each combination of factors. This experiment is designed to study the effect of each factor on the response which is the amount of weight absorbed by the fabric.

2.2 Choices of Factors and Levels

In order to conduct this experiment, three factors are chosen to be studied which are types of solutions, types of clothes, and number of fabric layers. There are two levels in the factor types of solution, which are salt water and tap water. For the types of clothes, we carried out the experiment by using three types of cloth that are polyester, microfiber and cotton. Each cloth was cut into a dimension of 10cm x 10cm and 3 gram of mass. The third factor is the number fabric layers, there are 3 levels under this factor (1 layer, 4 layers and 8 layers).

2.3 Selection of Response Variables

The response variable in this experiment is the weight of solution absorbed by the fabrics. The weight of solution absorbed is determined by weighing the fabric after it was soaked into the solution. The weight of soaked fabric was then subtracted by 3 gram, which is the mass of the dried fabric.

2.4 Number of Replication

A trial experiment has been carried out to obtain the average and standard deviation of weights of solution that has been absorbed by different types of clothes. By referring to the sample size determination by JMP with alpha level at 0.05 and power at 0.9 (Appendix I), the suggested sample size was 41, therefore 2 replicates for each treatment have been used for the real experiment with 36 samples.

2.5 Randomization

According to Appendix II, the experiment sequences were randomized using JMP software.

2.6 Experimental Procedure

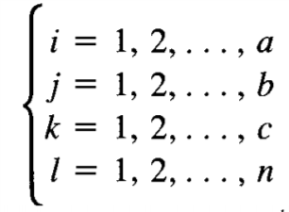
Three type of fabric (microfiber, cotton, polyester) were cut into dimension of 10cm x 10cm which having mass of 3 gram each. The cloth was then sewed into 4 layers and 8 layers. After performing randomization in JMP, different types and layers of clothes are immersed into different types of solution (tap water & salt water) in sequence of randomisation created by JMP for 30 seconds. The cloth was then applied pressure by using a spoon in order to squeeze out the air inside the cloth. After immersed for 30 seconds, then the cloth was placed on a filter and wait until it stopped dripping. Then the weight of the cloth was measure in gram and recorded accordingly. The weight of the soaked cloth was subtracted by 3 gram, which is the initial mass of the cloth to obtain the solution weight absorbed by the cloth.

**3.0 RESULTS AND DISCUSSION**

From the table of summary of fit in Appendix III below, 0.9327 R squared indicating 93% of the variation in weight of solution absorbed can be explained by using the 3 factors which are the types of solution, types of fabric, and layers of fabric.

3.1 Statistical Model

**yijk = µ + ﺡi + βj + ỿk + (ﺡβ)ij + (ﺡỿ)ik + (βỿ)jk + (ﺡβỿ)ijk + €ijkl**



where ﺡi , βj , ỿk , (ﺡβ)ij , (ﺡỿ)ik , (βỿ)jk and (ﺡβỿ)ijk refer to the effect of types of solution,

effect of types of cloth, effect of layers of cloth and interaction effect respectively.

3.2 Analysis of Variance

Based on the table of Analysis of Variance in Appendix IV, the output of ANOVA analysis depicts whether there is a statistically significant difference between the group means. Since the p-value of this model is smaller than α=0.05, thus the null hypothesis is rejected. Therefore, there is sufficient evidence to conclude that there is statistically significant difference in the mean of weight of solution absorbed between three factors with difference factor levels. Multiple Comparisons Test is conducted in order to find out the specific different groups.

3.2.1 Effect Test

H0: All ﺡi = 0

H1: Not all ﺡi =0. (i=1,2)

ﺡi : Effect of type of solution on the amount of solution weight absorbed, 1: tap water ; 2: salt water.

Based on Appendix V the p-value is smaller than α=0.05, thus H0 is rejected. There is sufficient evidence to conclude that there is statistically significant difference in type of solutions.

H0: All **βj** = 0

H1: Not all **βj**=0. (j=1,2,3)

ﺡi : Effect of type of fabric on the amount of solution weight absorbed, 1: microfiber ; 2: cotton; 3: polyester.

Based on Appendix V the p-value of is smaller than α=0.05, thus H0 is rejected. There is sufficient evidence to conclude that there is statistically significant difference in type of fabric.

H0: All **ỿk** = 0

H1: Not all **ỿk** =0. (k=1,2,3)

ﺡi : Effect of layer of fabric on the amount of solution weight absorbed, 1: 1 layer; 2: 4 layers; 3: 8 layers.

Based on Appendix V the p-value is smaller than α=0.05, thus H0 is rejected. There is sufficient evidence to conclude that there is statistically significant difference in layer of fabrics.

H0: All **(ﺡβ)ij** = 0

H1: Not all **(ﺡβ)ij** =0. (i=1,2; j=1,2,3)

**(ﺡβ)ij** : Interaction effect between type of solution and type of fabric on the amount of solution weight absorbed.

Based on Appendix V the p-value is smaller than α=0.05, thus H0 is rejected. There is sufficient evidence to conclude that different interaction between type of solution and type of fabric will have different effect on the amount of solution weight absorbed.

H0: All **(ﺡỿ)ik** = 0

H1: Not all **(ﺡỿ)ik** =0. (i=1,2,; k=1,2,3)

**(ﺡỿ)ik** : Interaction effect between type of solution and layer of fabric on the amount of solution weight absorbed.

Based on Appendix V the p-value is smaller than α=0.05, thus H0 is rejected. There is sufficient evidence to conclude that different interaction between type of solution and layer of fabric will have different effect on the amount of solution weight absorbed.

H0: All **(βỿ)jk** = 0

H1: Not all **(βỿ)jk** =0. (j=1,2,3; k=1,2,3)

**(βỿ)jk**: Interaction effect between type of fabric and layers of fabric on the amount of solution weight absorbed.

Based on Appendix V the p-value is smaller than α=0.05, thus H0 is rejected. There is sufficient evidence to conclude that different interaction between type of fabric and layer of fabric will have different effect on the amount of solution weight absorbed.

3.2.2 Interaction Plot

Based on the interaction profiles in Appendix VI, since the lines in each plot are not parallel to each other, there is an interaction relationship between type of solution and layer of cloth, between type of solution and type of cloth and between layers of cloth and type of cloths. Interaction plot show that the fabric has higher amount of solution weight absorbed when soaked in salt water compare to tap water. Moreover, eight layers of microfiber has the highest amount of solution weight absorbed when it is soaked in tap water or salt water. Thus, eight layers of microfiber has the best water absorbency to tap and salt water. In contrast, one layer of cotton has the lowest solution weight absorbed when it soaked to tap water or salt water. One layer of cotton has the poorest performance in term of water absorbency.

3.3 Diagnostic of Assumptions

3.3.1 Residual Plot

In the residual plot of this experiment (Appendix VII) there’s no special pattern can be found and all points are distributed randomly. Hence, the constant variance assumption is not violated. Besides, it’s clearly showed that the cloth that made by Microfiber are totally different compared to the other two types of cloth (Cotton and Polyester) as it’s separated into a group.

3.3.2 One-way analysis of residual weight of water absorbed with different factors

H0: All σi are equal; (i=1, 2, 3)

H1: At least one pair of σi ≠ σj exists. (i=1, 2, 3)

According to Appendix VIII, at α = 0.05, all the p-values for the statistical tests (O’Brien, Brown-Forsythe, Levene, Bartlett and F Test 2-sided) are greater than 0.05, thus H0 should not be rejected. There is insufficient evidence to conclude that the variances of different type of solutions (low concentration and high concentration) are not equal. Therefore, the constant variance assumption is not violated.

Furthermore, based on Appendix IX the p-value of all statistical tests is greater than 0.05, so do not reject H0 and it can be concluded that there is no violation of variance assumption for different layers of clothes (1 layers, 4 layers and 8 layers).

From the Appendix X, the p-value of all statistical tests is also greater than 0.05, so it’s insufficient evidence to conclude that the variances of different type of clothes (Cotton, Polyester and Microfiber) are not equal.

3.4 Run Plot (Independency)

Based on the residual by row plot (Appendix XI), no special pattern was observed, all points are distributed randomly. Therefore, independency assumption is not violated.

3.5 Test on normality

Based on the histogram in Appendix XII, a bell-shape curve can be observed; it indicated that assumption of normality is fulfilled. Besides, from the normal quantile plot all points are close to the straight line and majority of the point fall around the centre so it also indicated assumption of normality is fulfilled. Lastly, from the Goodness-of-Fit test the p-value of Shapiro-Wilk W test is 0.8034 which is much larger than α= 0.05. So do not reject H0, because there is insufficient evidence to conclude that there is a violation for the normality assumption.

**4.0 Other Relevant Statistical Testing**

4.1 Multiple Comparisons

4.1.1 Pairwise Differences for Types of Solution

Let µi = mean of different type of solutions (where i =1, 2)

1: Tap water, 2: Salt water

H0: µi = µj, H1: µi ≠ µj

Based on Appendix XIII, at α= 0.05, the p-value is smaller than 0.05, hence we reject H0. There is sufficient evidence to conclude that the tap water and salt water have significant difference on the weight of solutions absorbed.

4.1.2 Pairwise Differences for Layers of Cloth

Let µi = mean of different layers of cloth (where i =1, 2, 3)

1: 1 layer, 2=4 layers, 3=8 layers

H0: µi = µj, H1: µi ≠ µj

Based on Appendix XIV, it shows that the combination (1 layer & 4 layers) has a p-value smaller than 0.05. On the other hand, the p-value for (1 layer & 8 layers) and (4 layers & 8 layers) are larger than 0.05. Thus, there is sufficient evidence to conclude that there is statistically significant difference on the weight of solutions absorbed between (1 layer & 4 layers). However, we do not have sufficient evidence to conclude that the combinations (1 layer & 8 layers) and (4 layers & 8 layers) have different absorbency.

4.1.3 Pairwise Differences for Types of Cloth

Let µi = mean of different types of cloth (where i =1, 2, 3)

1=cotton, 2=microfiber, 3=polyester

H0: µi = µj, H1: µi ≠ µj

Based on Appendix XV, it shows that the p-value for (cotton & microfiber) and (microfiber & polyester) is smaller than 0.05. While the p-value for (cotton & polyester) is larger than 0.05. Therefore, there is sufficient evidence to conclude that microfiber is different with cotton and polyester on the weight of solutions absorbed.

4.1.4 Pairwise Differences for Types of Solution vs Layers of Cloth

H0: There is no significant difference for the pairwise on absorbency.

H1: There is significant difference for the pairwise on absorbency.

By referring to Appendix XVI, it shows only four pairs are significantly different (on absorbency), which are (tap water with 1 layer cloth & salt water with 4 layers cloth), (tap water with 4 layers cloth & salt water with 4 layers cloth), (tap water with 8 layers cloth & salt water with 4 layers cloth), and (salt water with 1 layer cloth & salt water with 4 layers cloth). Other pairs are having the p-values greater than 0.05, which indicates that there is no significant difference between them.

4.1.5 Pairwise Differences for Types of Solution vs Types of Cloth

H0: There is no significant difference for the pairwise on absorbency.

H1: There is significant difference for the pairwise on absorbency.

Appendix XVII shows that all combinations compared with the combination containing microfiber have the p-values smaller than 0.05, which indicates that they are significantly different with the microfiber pairs (on absorbency). The effect of types of cloth seems bigger than the effect of types of solution in this pairwise comparison.

4.1.6 Pairwise Differences for Layers of Cloth vs Types of Cloth

H0: There is no significant difference for the pairwise on absorbency.

H1: There is significant difference for the pairwise on absorbency.

Appendix XVIII shows the pairwise differences between different layers of cloth (1 layer & 4 layers & 8 layers) and types of cloth (cotton & microfiber & polyester). Most of the pairwise are significantly different. There are only 14 pairs not significantly different with each other.

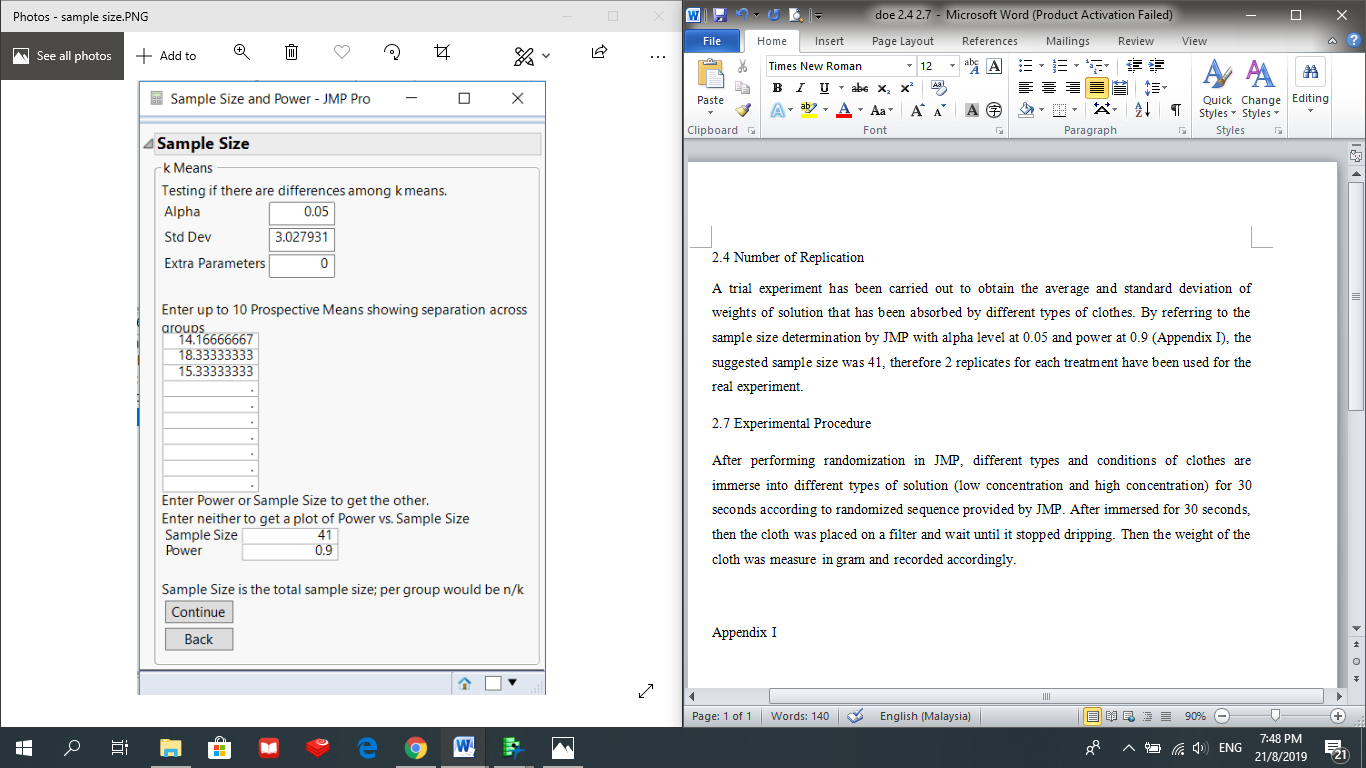
**5.0 Conclusion**

We have carried out an experiment to study effect of the factors on the performance of fabric in water absorbency. The chosen factors are type of fabric, type of solution and layer of fabric. JMP software was used to conduct analysis on the obtained result. First analysis that had been done is the analysis of variance. The output from JMP shows that this model was significant, indicating the factor of fabric type, solution type and fabric layers are significant in this experiment. From the effect test, the 3 main effect are significant, the interaction between layers of cloth and type of cloth has the most significance followed by interaction between type of solution and layer of cloth while interaction between type of solution and type of cloth has the least significance among others. From the result of model adequacy checking, the model does not violate the three assumptions which are constant variance, normality and independency.

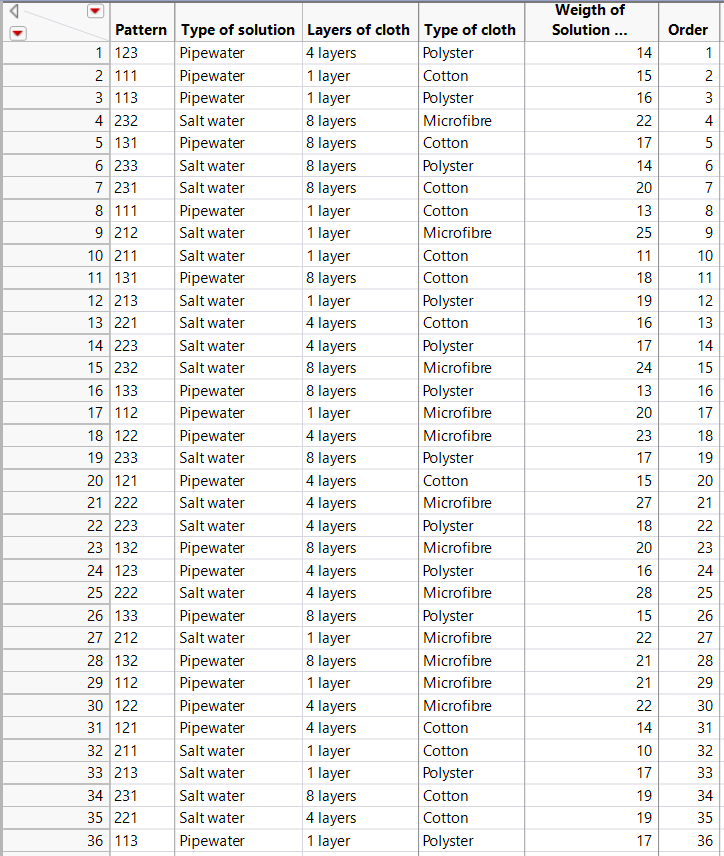
Concisely, based on the finding, Interaction plots show that the fabric has higher amount of solution weight absorbed when soaked in salt water compare to tap water. Moreover, eight layers of microfiber has the highest amount of solution weight absorbed when it is soaked in tap water or salt water. Thus, eight layers of microfiber has the best water absorbency to tap and salt water. In contrast, one layer of cotton has the lowest solution weight absorbed when it soaked to tap water or salt water. One layer of cotton has the poorest performance in term of water absorbency.

This experiment can be improved by using larger sample size with more replicates in order to increase the accuracy of the results.

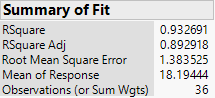
**Appendix I**



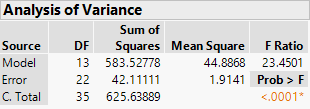
**Appendix II**



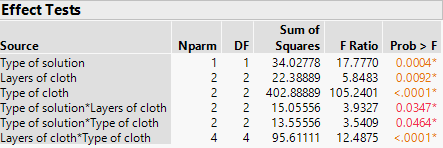
**Appendix III**



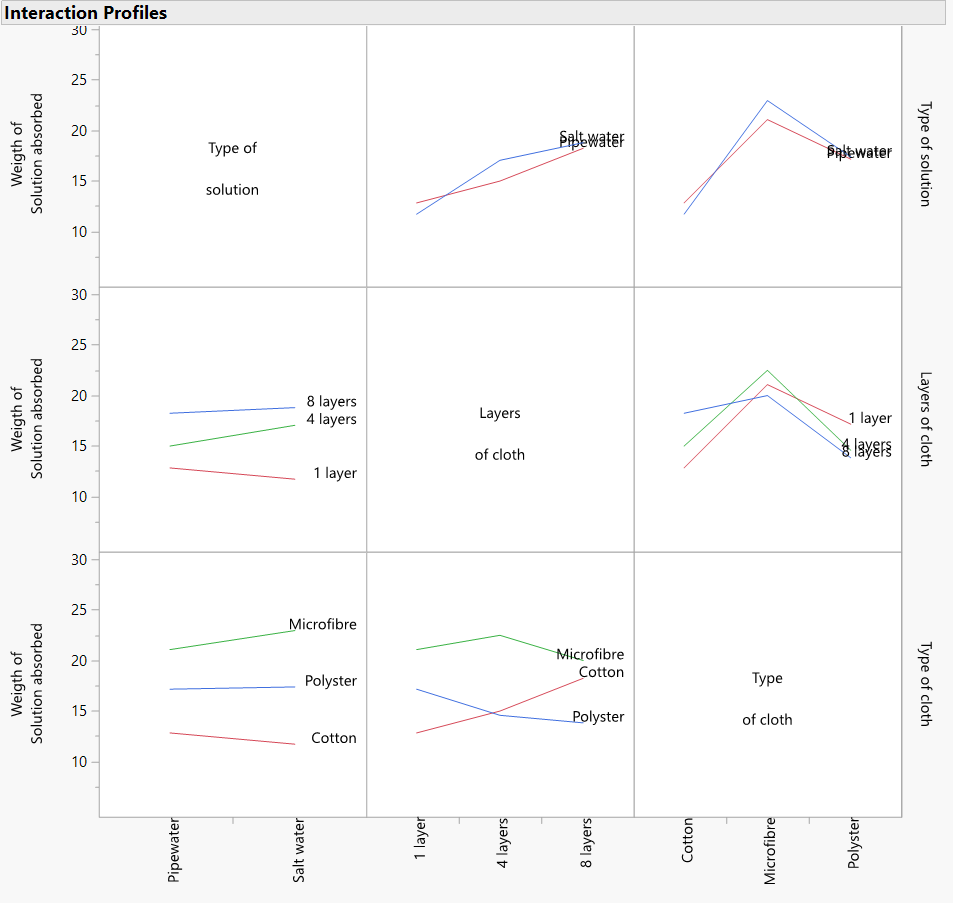
**Appendix IV**



**Appendix V**

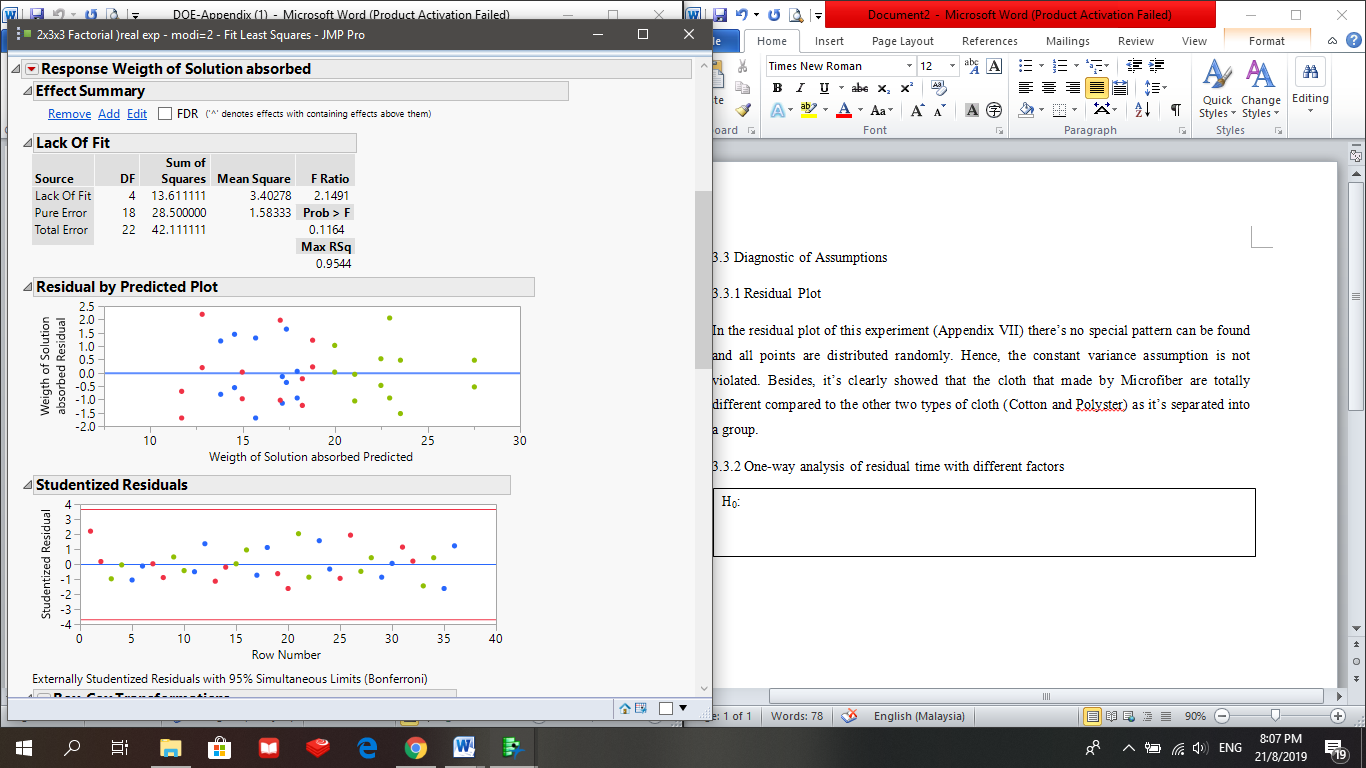


**Appendix VI**

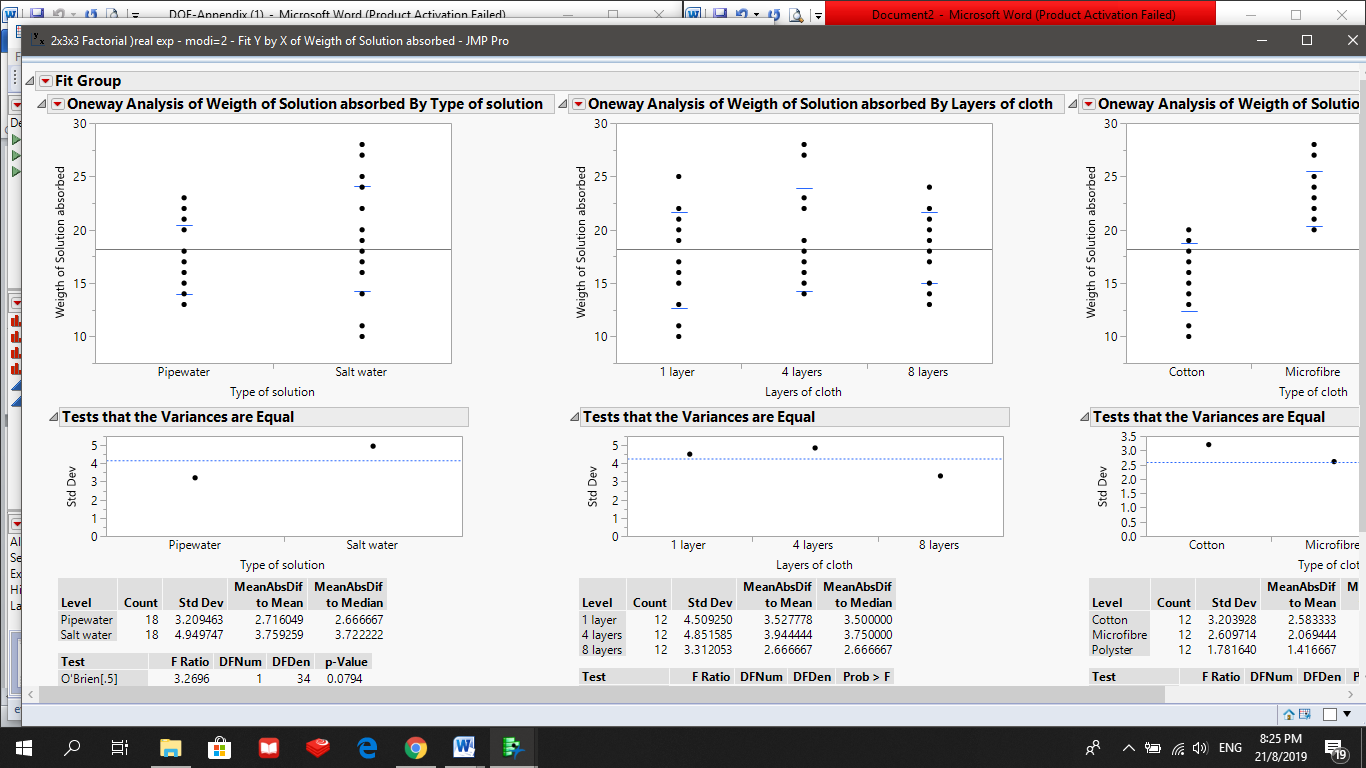


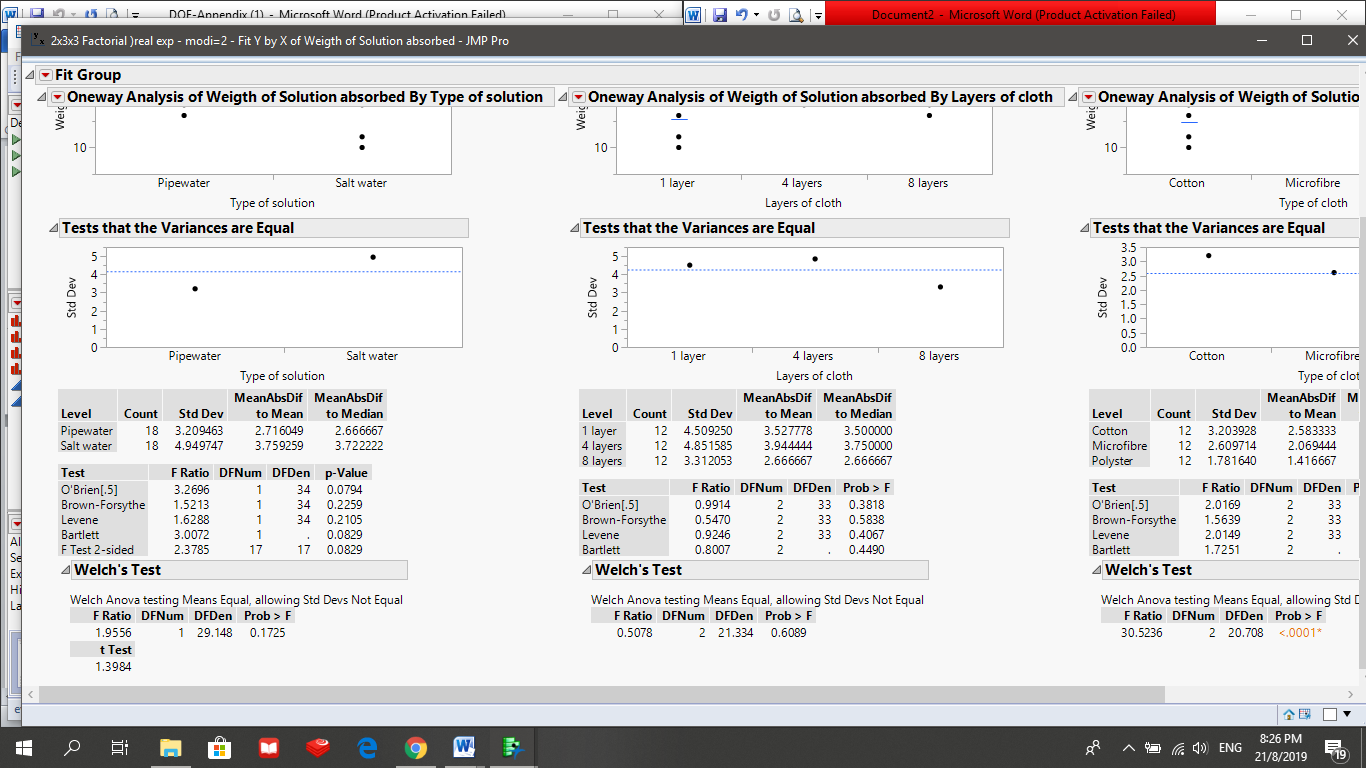
**Appendix VII**

Red: Cotton, Black: Polyester, Green: Microfiber

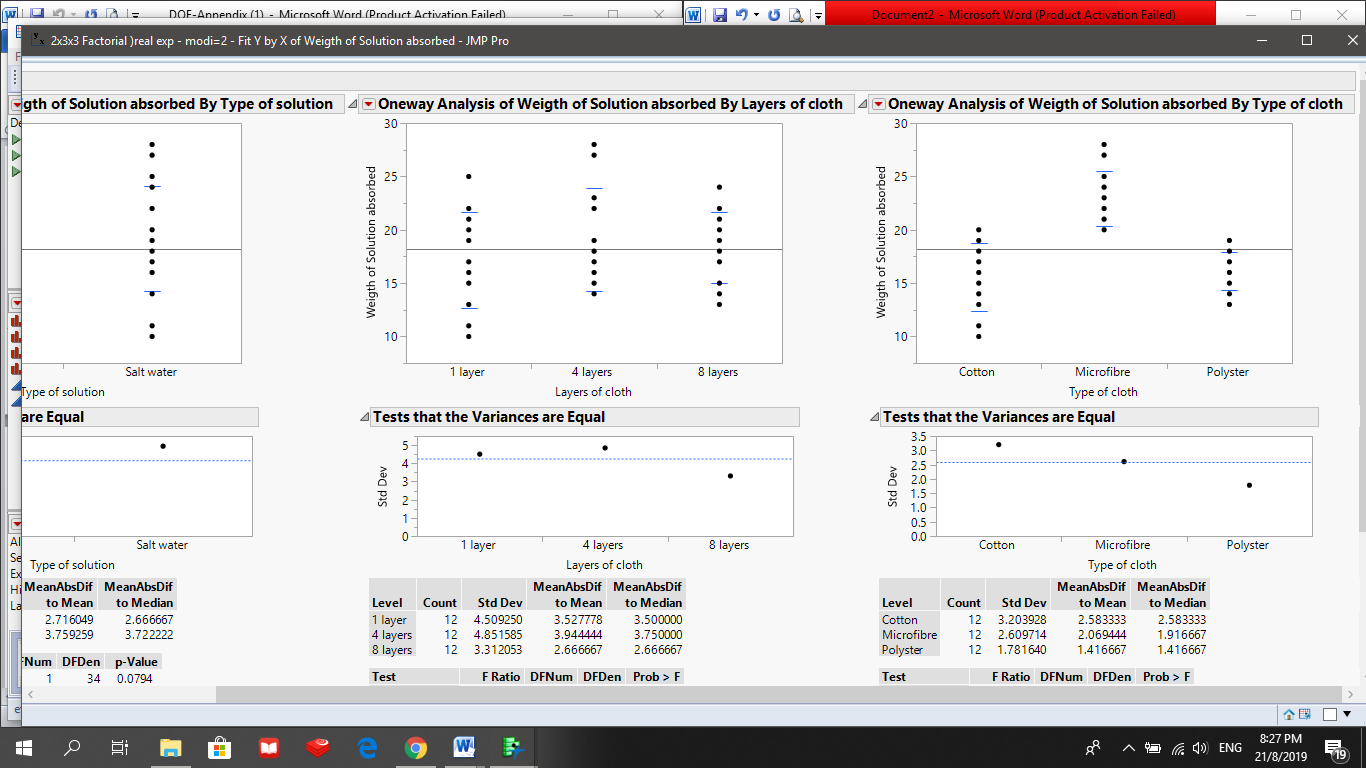


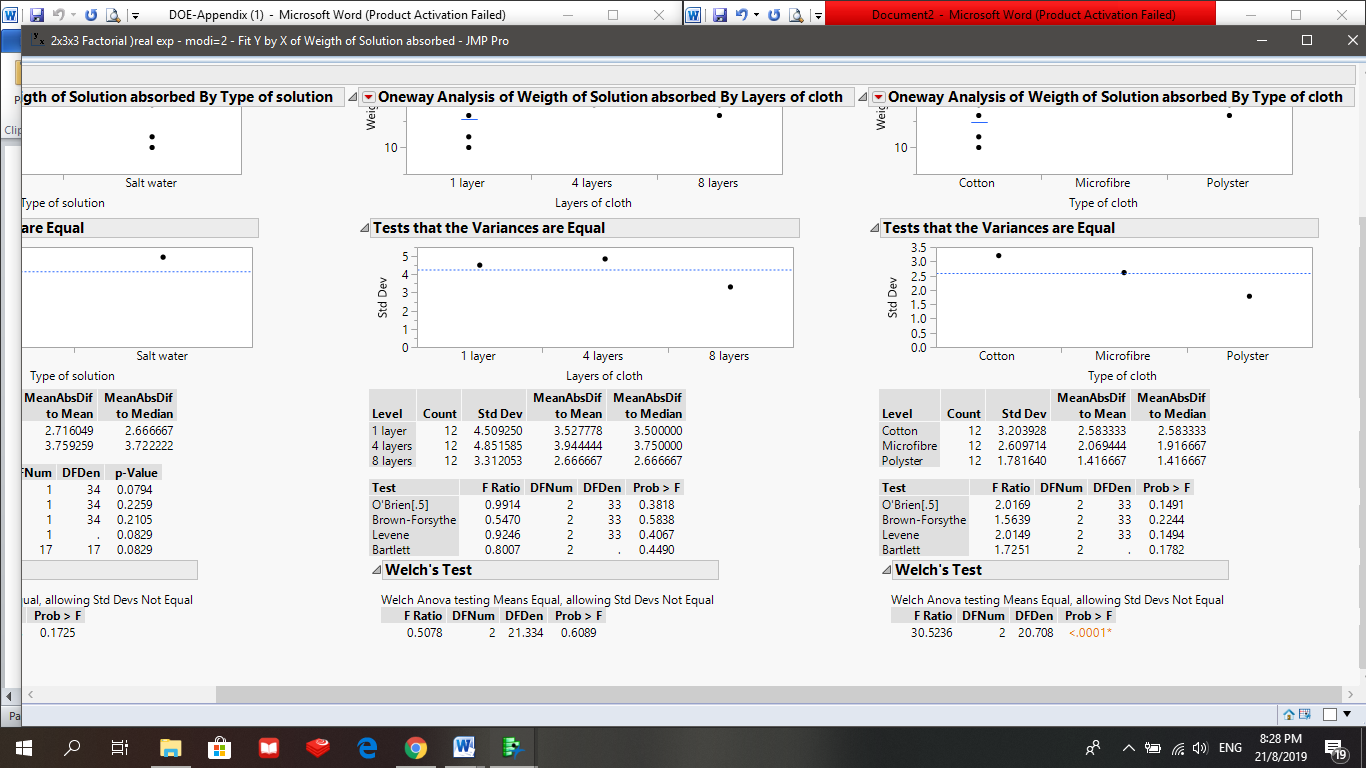
**Appendix VIII**



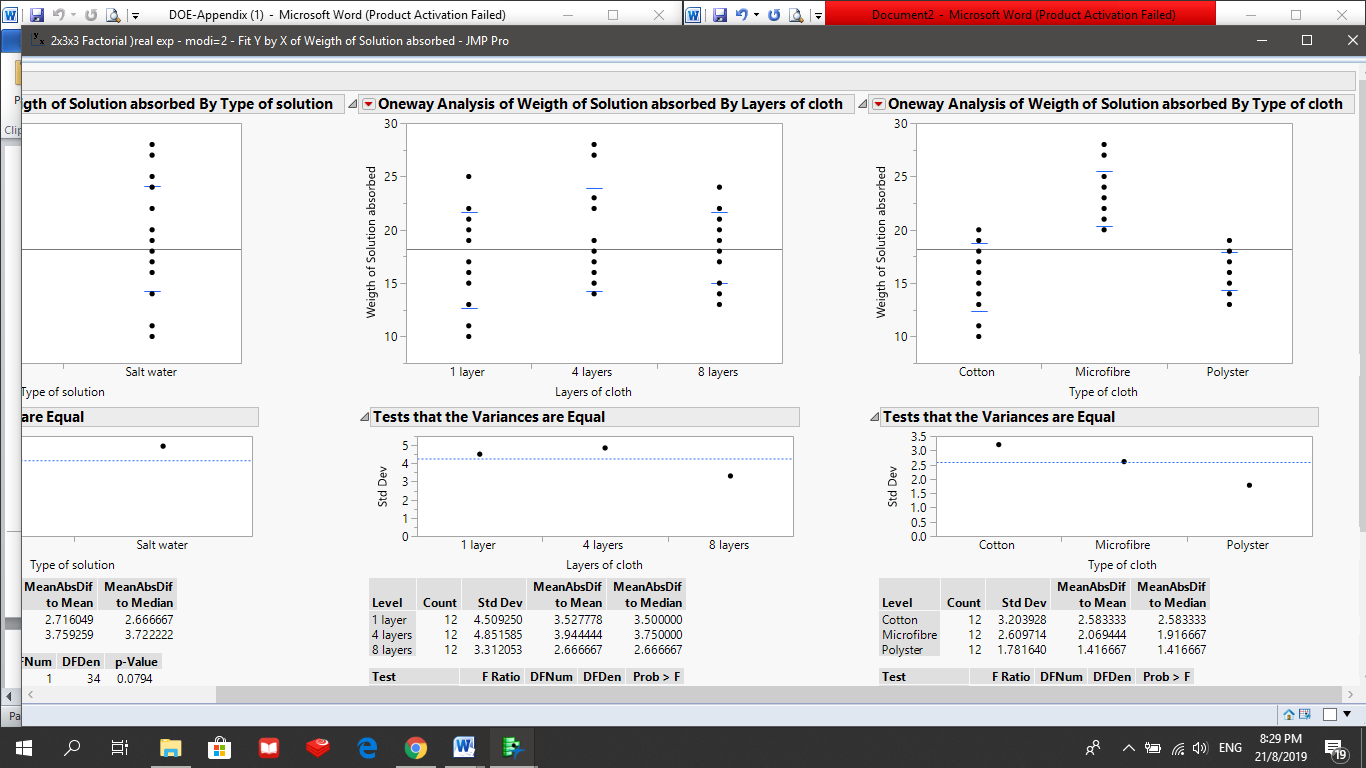


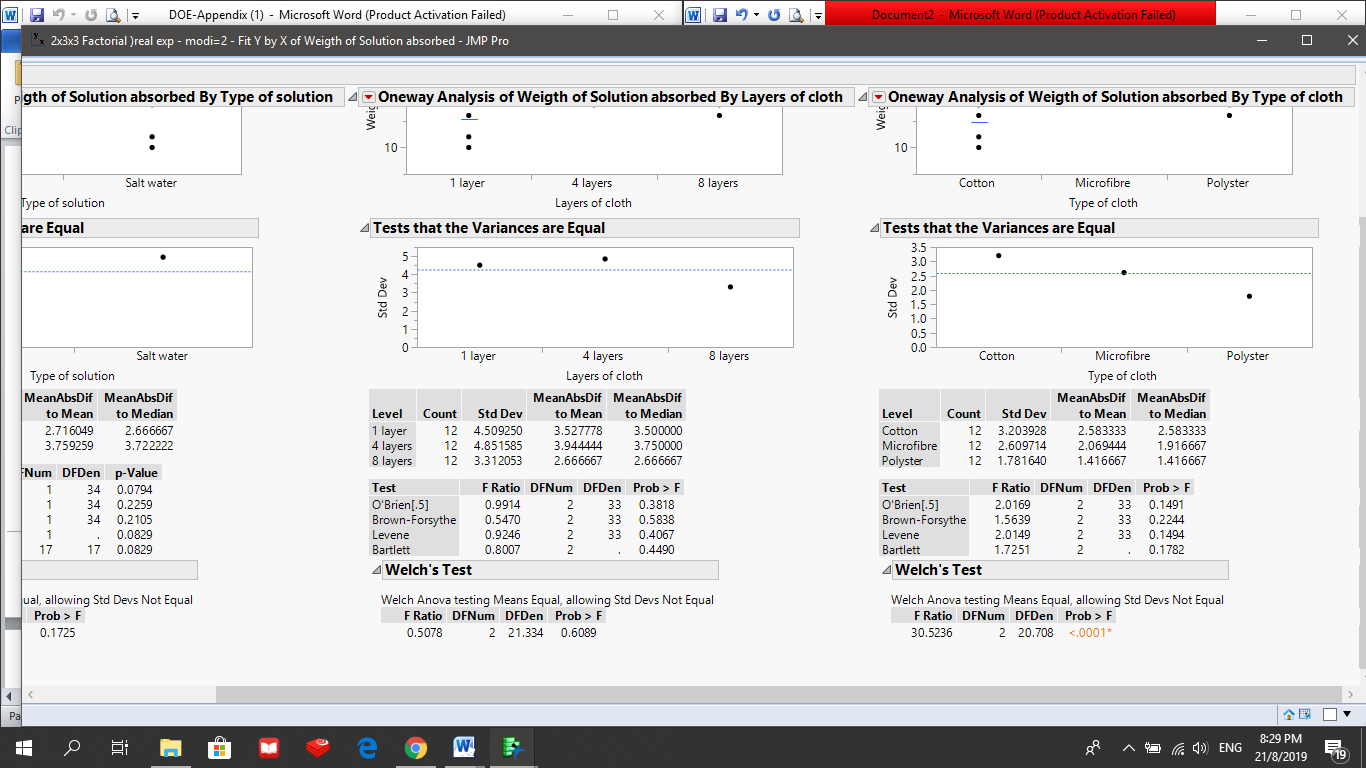
**Appendix IX**



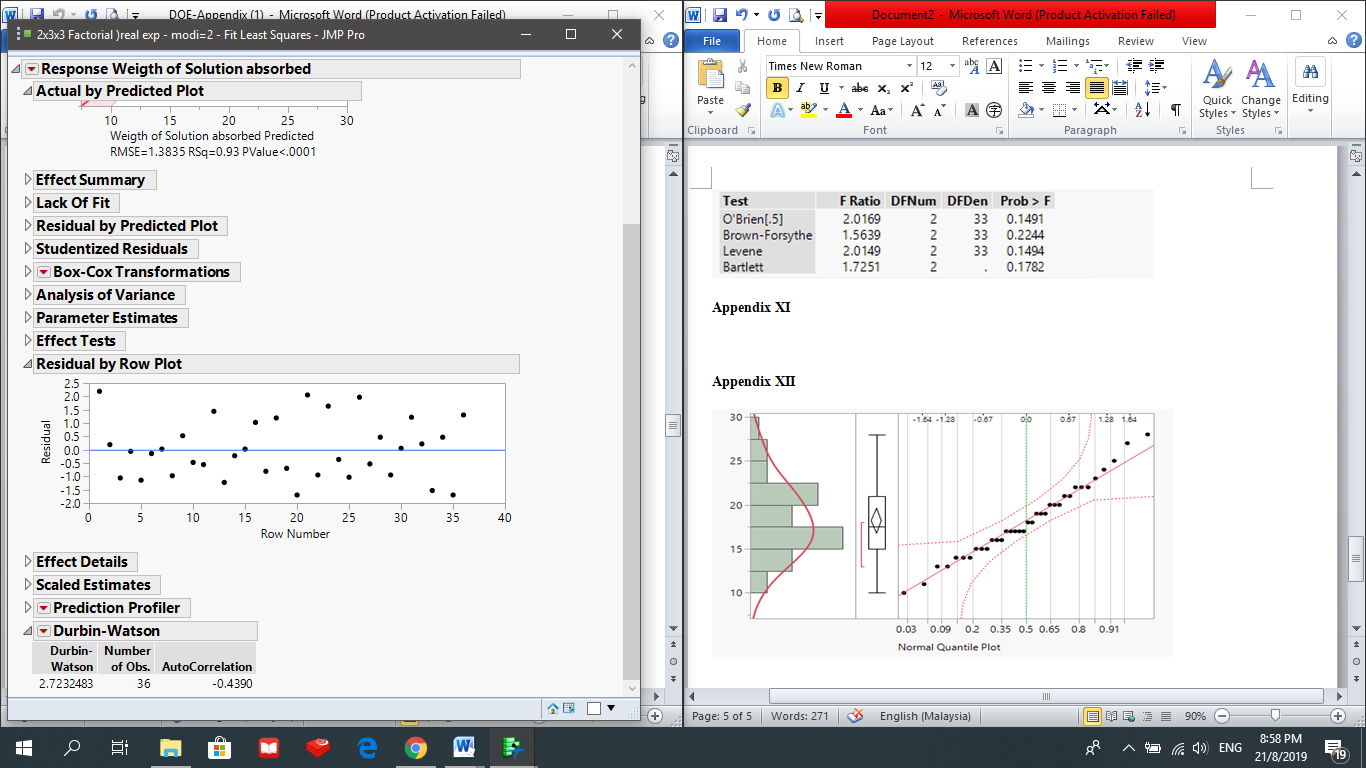


**Appendix X**

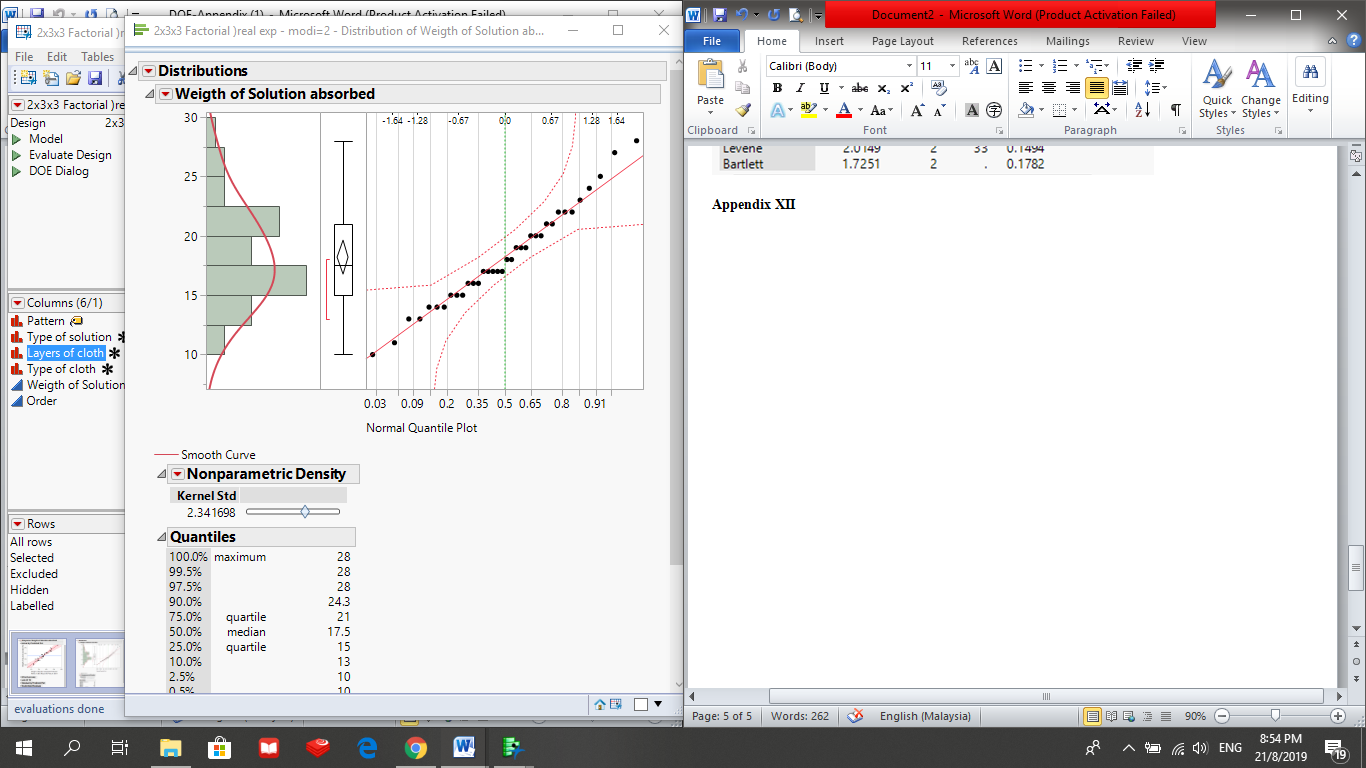


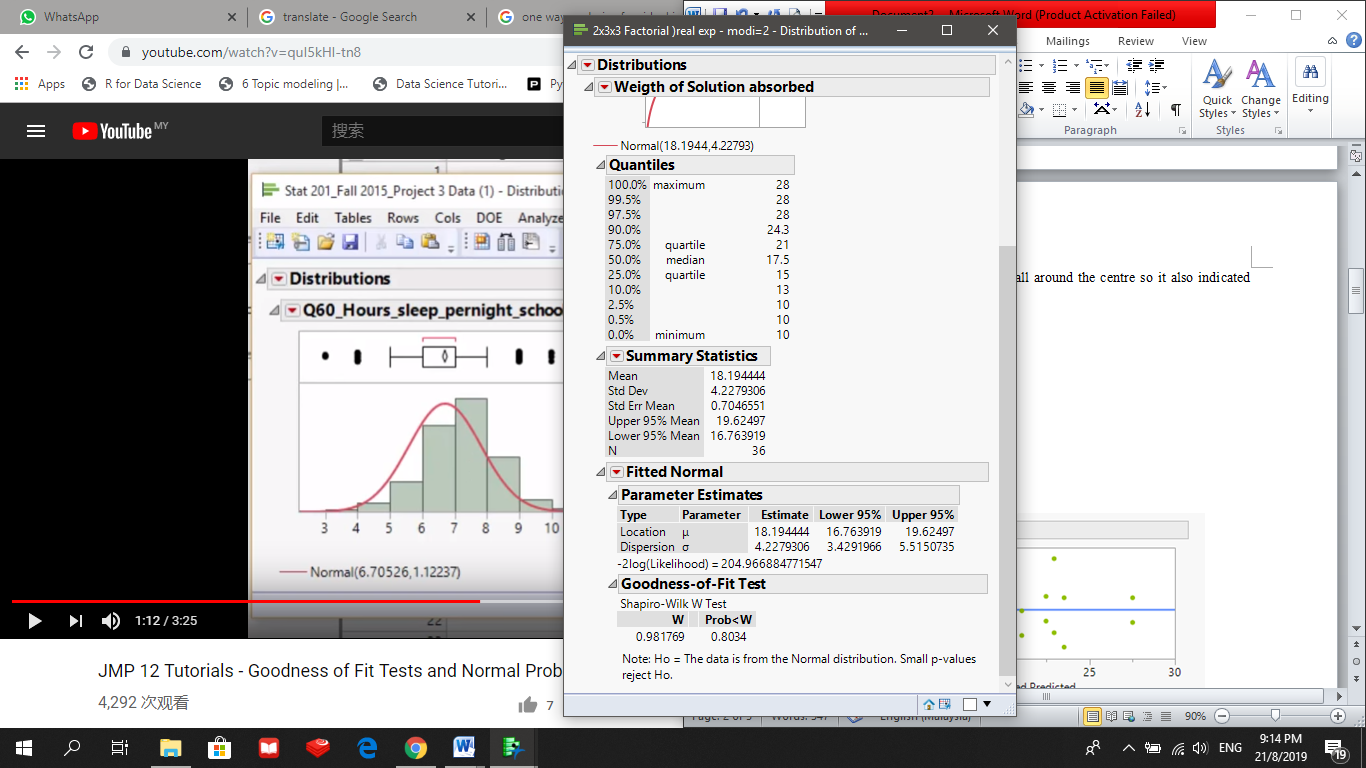


**Appendix XI**



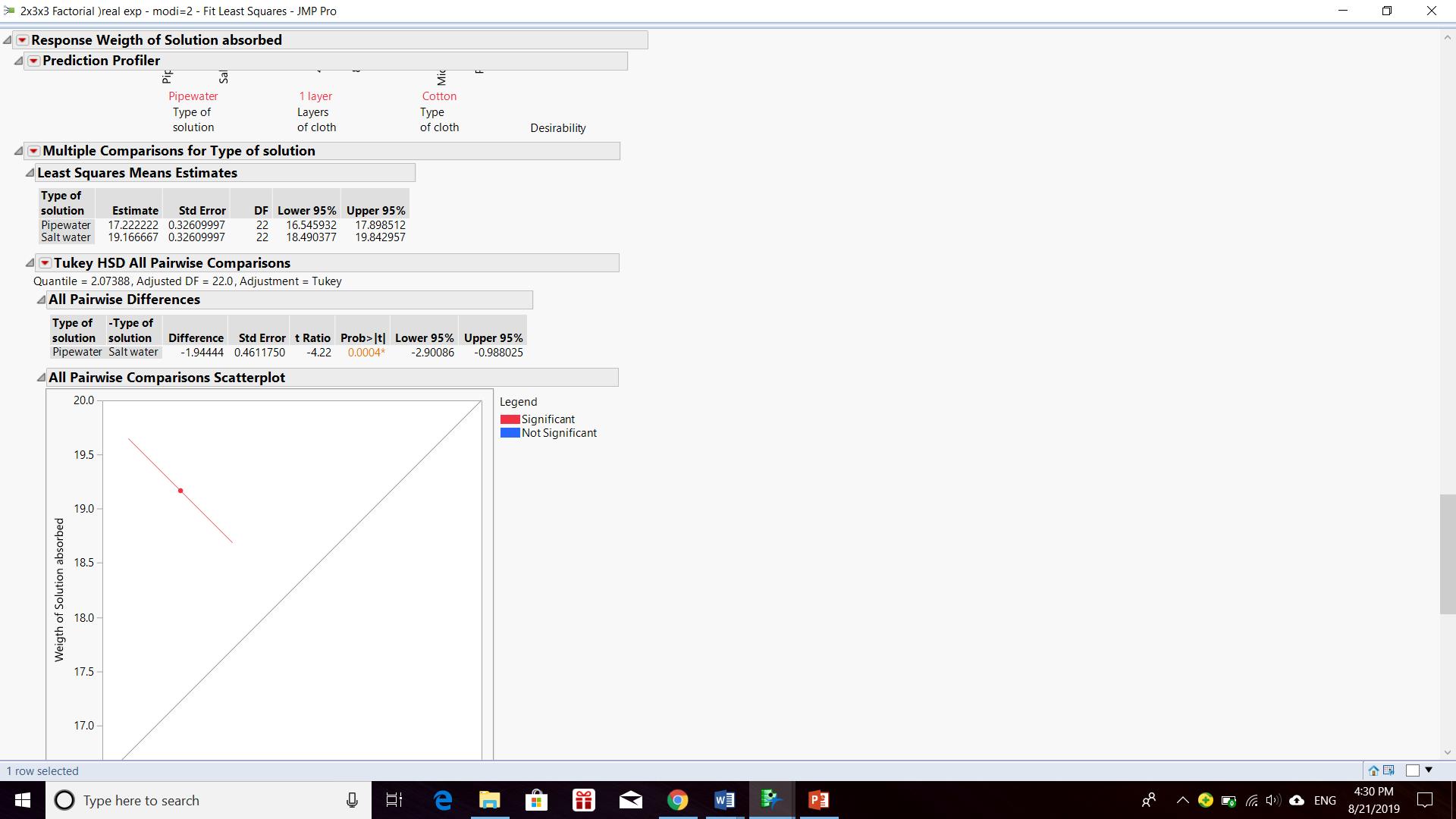
**Appendix XII**





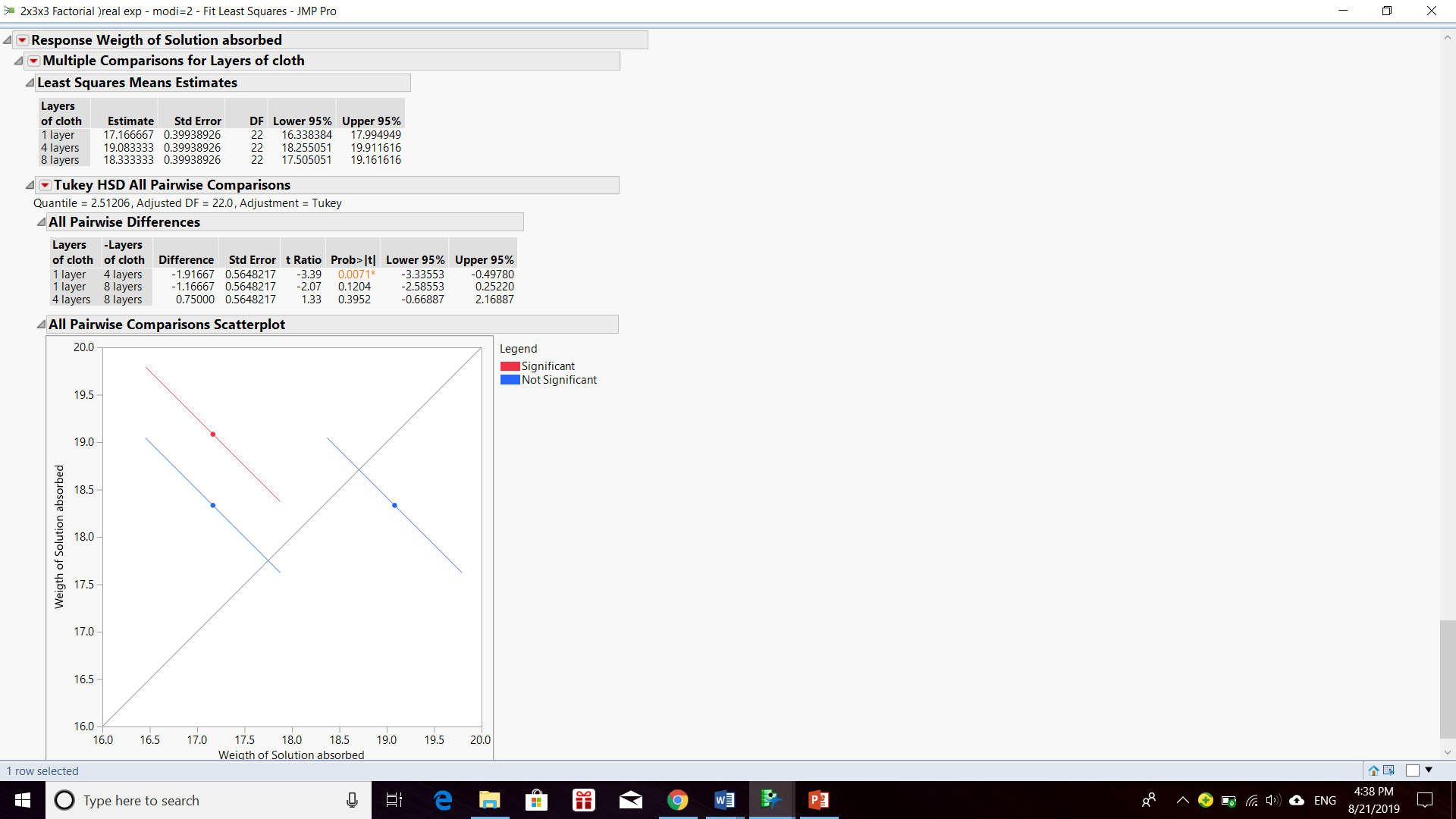
**APPENDIX XIII**

Adjustment D. F=22.0, Adjustment= Turkey



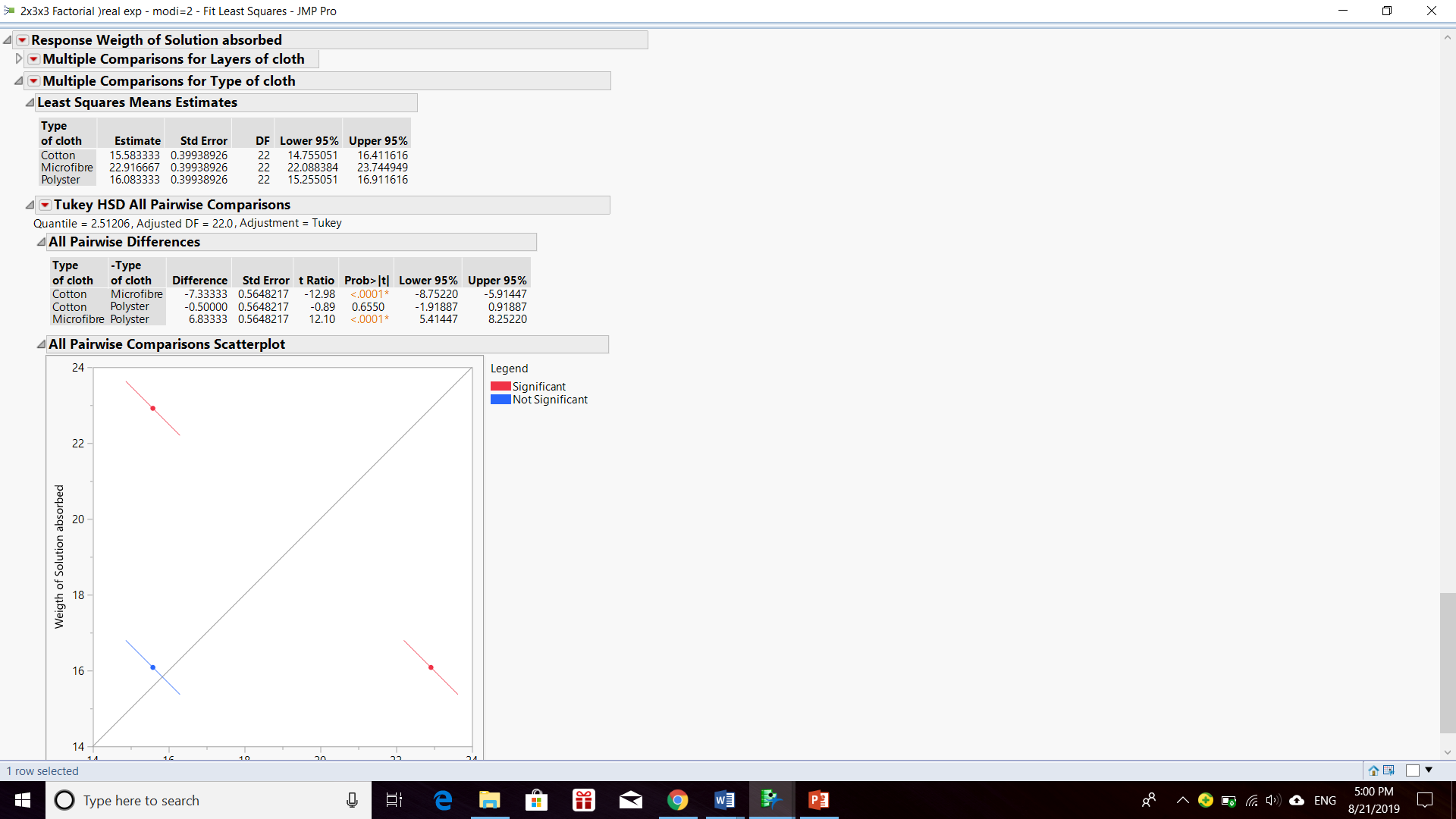
**APPENDIX XIV**

Adjustment D. F=22.0, Adjustment= Turkey

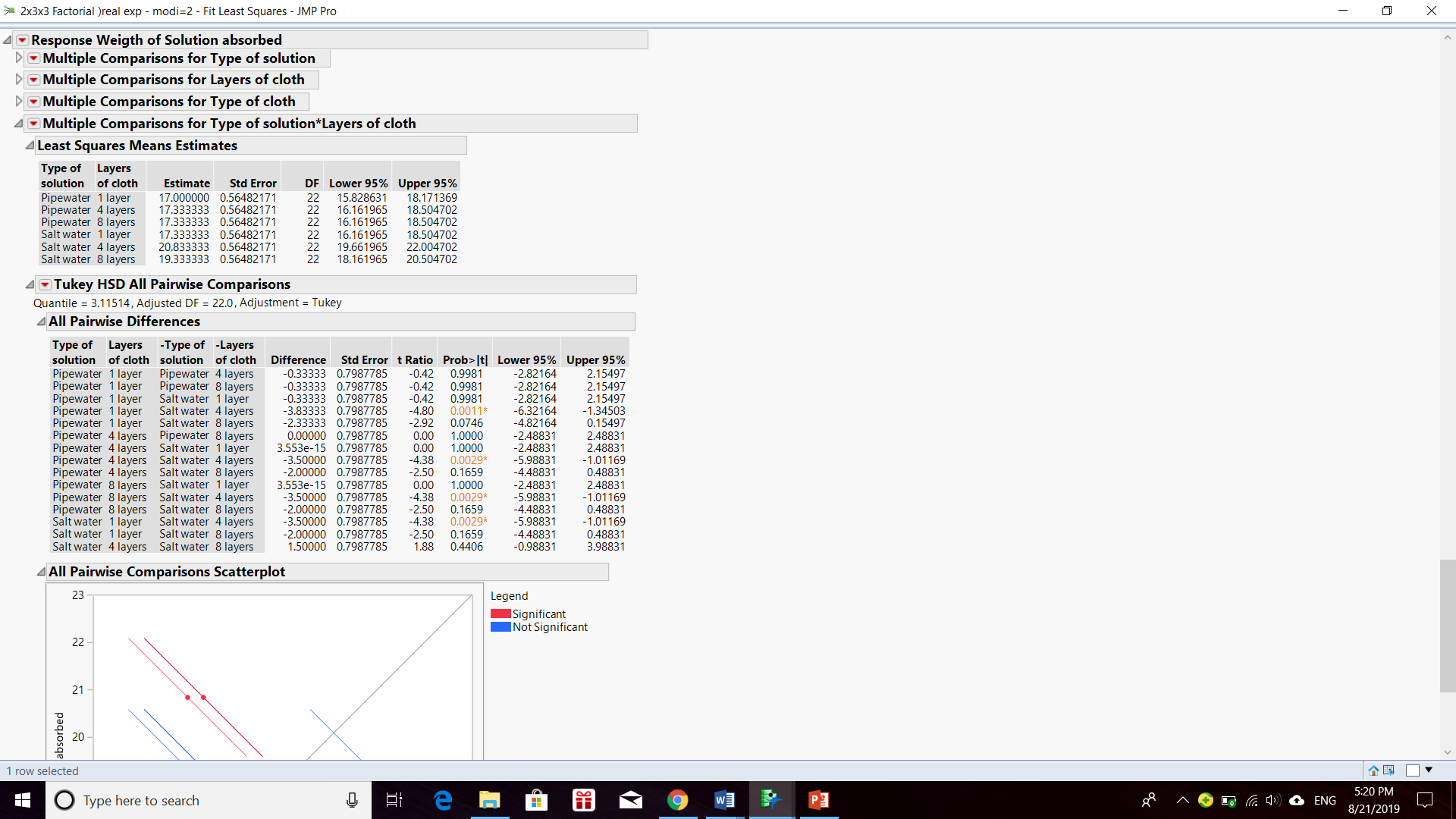


**APPENDIX XV**

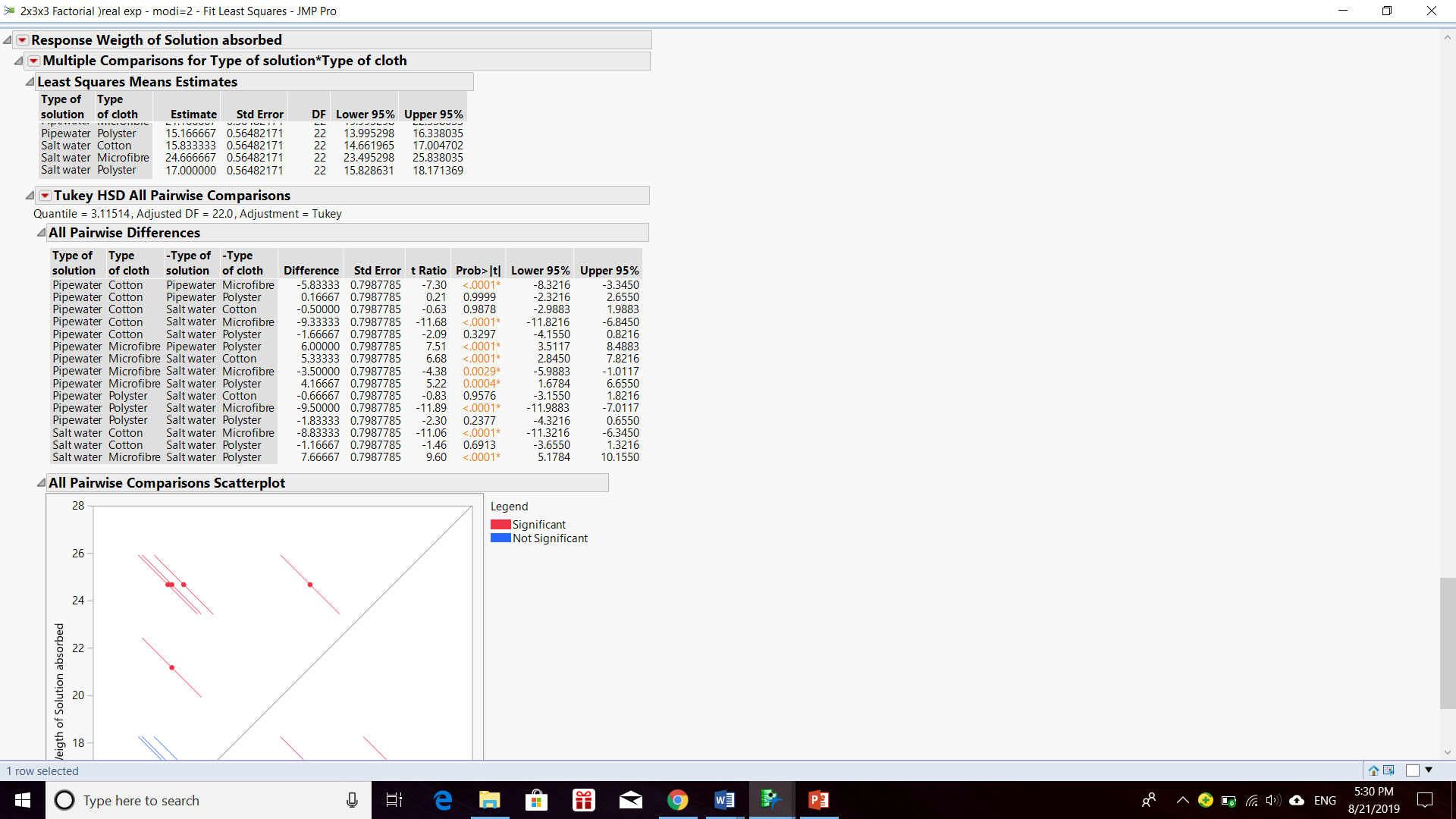
Adjustment D. F=22.0, Adjustment= Turkey



**APPENDIX XVI**



**APPENDIX XVII**



**APPENDIX XVIII**