The Hygroscopic Capacity of Different Types of Paper

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Abstract

Background

The design of different types and brands of paper towels may be related to the hygroscopic capacity. This study aims to compare different paper towels and have a short conclusion on which has a relatively high hygroscopic capacity.

Methods

A cup of water will be placed on a digital scale measuring the pre-weight. A piece of paper towel will be picked up by the forceps and immersed in the water. After 10 seconds, the paper towel will be removed from the water. The post-weight of the water will be measured.

Results

One hundred and fifty (150) testing results were collected in the experiment, 50 per each treatment. As three types of treatment (kitchen paper, mini pocket tissue, and toilet paper) are categorized with a single factor, one-way classification model, which is $Y_{ij} = \mu_i + \varepsilon_{ij}$, was adopted in the experiment. The means for both min pocket tissue (9.88g) and toilet paper (9.72g) were found to be equal, and the amount of water absorption by kitchen paper (13.02g) is significantly greater among the other treatments.

Conclusion

In this pilot, the differences between different brands of paper towel are shown. Having more precise instruments may definitely help improve the reliability of the study. For sure, further studies are needed to have a comprehensive comparison on paper towel.

Background

Paper towel plays an important role nowadays. It can be said as a part of our daily life. For instance, we use it after the toilet, or after washing our hands. In order to handle the respective situation, the paper towel has been developed into different types, such as tissue, disinfection wipes.

When my research team was determining the topic of our study, one of our members came to an idea out suddenly. She broke a cup of water and had to clean up the place. Therefore, she took the paper towel near to her and did her duty. After that, she regretted using the tissue paper but not the kitchen paper.

Why would she want to use the kitchen paper instead of other types of paper towel? Is it really having better performance on absorbing water? To figure it out, we determined to do this study to find out the difference between different types and brands of paper towel.

Define the objectives of the experiment

The purpose of this experiment is to compare the hygroscopic capacity of different types of paper towel. Are there any different weight losses of water when the paper towel was put into water and taken away? What are these differences? It is expected that the experiment will answer those questions.

Kitchen paper, toilet paper and mini pocket tissue have different levels of hygroscopic capacity because of different usage. Each paper towel will be cut to the same size and put it into the water to test the weight loss of the water. Because of the limited budget, the experimental condition may contain some errors that are expected, and we will discuss below.

Identify all sources of variation

The hygroscopic capacity of paper towel and the weight loss of water is the source of variation. Paper towel can absorb water and different types of paper absorb different weights of water.

a. Treatment factors and their levels

The treatment factor, paper towel, has been chosen as three types: kitchen paper, mini pocket tissue and toilet paper. The paper towel will be purchased at a local popular store and cut into similar size. Each type of paper towel is designed for different use. Therefore, the weight of the water which is absorbed by the paper towel is different.

b. Identify the experimental units

The experimental unit in this experiment is the weight loss of water. An experimental unit consists of different types of paper towel and water. A cup of water will be put on a digital scale. The paper towel can be completely beneath the water. The paper towel will be cut to the same size by using rulers and scissors. The paper towel is put under the water for 10 seconds. When taking the wet paper towel away, the water will drip. Then wait for 10 seconds to drip water into the cup.

c. Blocking factors, noise factors, and covariates

Blocking factors: The first one is the water trapping ability of the paper. After the paper towel absorbed water and be picked up, the paper towels are held and extra water on the paper surface would be dripped off. Due to weak water trapping ability, the dripping may not stop and causing extra of water is dripped out, causing the data collected is smaller than expected and cannot show the true power of water absorption of the paper.

Noise factors: Air humidity may affect the performance of water absorption of paper towels. Hong Kong has a humid weather and paper towels used for the experiment may unavoidably absorb the moisture in the air. This causes the data collected would be smaller than expected and cannot show the true power of water absorption of the paper. The accuracy of the digital scale may affect the result of the experiment. The digital scale was bought in the local popular store and the small error of the digital scale was neglectable.

Covariates: The difference in brands of paper towel may resulting in different hygroscopic capacity. To prevent the situation, cluster random sampling is used in the experiment. The method of sampling will be discussed below.

Choose a rule by which to assign the experimental units to the levels of the treatment factors

The cluster random sampling is used. First, three brands of paper towels are randomly selected. Then, the kitchen paper, toilet paper and mini pocket tissue from each brand of paper towels are selected. An equal number of observations will be made on each of the three treatment factor levels, which is chosen to be 50 observations for each. Thus, 150 pieces of different types of paper towels will be prepared. The sample size is set to be 150 because of the budget of the experiment.

One of the blocking factors is the variation of hygroscopic capacity due to the difference in brands of paper towels. The effects are removed by using different brands of the same type of paper towels. Paper towels will be cropped with the same area (10×20cm) for fairness, as different types of paper towels have various areas. It would be difficult to measure the weight of paper towels due to the lack of delicate digital scale. The paper towels will be immersed in the water. To prevent different immersion time for the paper towels affecting the measurement, the time for absorption is unified to be 10 seconds. The time is sufficient for the paper towels to completely saturated with water. When the paper towel is taken out of the water, there is continuous water dripping. To ensure the fairness of the measurement, the time for water dripping for all observations will be set to be 10 seconds. Furthermore, all paper towels are newly bought. Because paper towels are prone to be exposed to moisture. Wetness in paper towels would affect its hygroscopic capacity.

Specify the measurements to be made and the experimental procedure

A container with 1000g of water will be placed on a digital scale. A piece of paper towel will be picked up by the forceps and be immersed in the water. The immersion time will be measured by a timer for 10 seconds. After 10 seconds, the paper towel will be removed from the water and is allowed to drip for 10 seconds. The post-weight of the water will be measured correct to the nearest gram.

The digit after the decimal point of the data will be neglected as daily use of paper towels to wipe off moisture need not be exact. There is no meaning of finding out if this type of paper towel can absorb one more drop of water than the other one.

The hygroscopic capacity can be calculated in term of how much grams of water is absorbed by comparing the pre-weight (1000g) and post-weight of the paper towels.

Expected Difficulties

There are three expected difficulties. The first difficulty would be the damage of paper texture due to unified size of paper. For the fairness of experiment, the area of each paper sample has to be regulated through cutting the paper into a specific size. The action of cutting may pose an effect on the hygroscopic capability of paper, making the experiment unable to simulate the reality of the hygroscopic capability of different papers.

The second expected difficulty would be tools used to apply on the experiment may have water stuck on. The experiment is repeated a large enough time to ensure there is a large enough sample size. Tools, such as forceps and digital scale applied in the experiment may be inevitably stuck some water on them, which may also result in a slight reduction on the data collected and unable to show the true ability of water absorption of the paper.

The third expected difficulty would damage on sample due to operations. After the sample paper is soaked into water, the texture of the paper would be softened and is fragile. Sharp tools such as forceps may damage the texture of paper, damaging the hygroscopic capability of the paper.

With these 3 expected difficulties, regulation has to be made to ensure the reality and reliability of the collected data. For the first difficulty, regulating a specific size would reduce the size of cut, reducing the error caused by the inevitable damage. Regarding the second difficulty, the only measurement would be a gentle flick after a sample is collected since the usual time that the water is stuck is the time when using forceps to pick up the moist paper. Water is stuck on the forceps after the dripping process of the experiment. A gentle flick to the container of water would reduce the error of the data. To the third difficulty, a gentle handle and dull surface of tool would be applied on the experiment, reduce the chance of causing unnecessary cut due to tools. After making these 3 regulations, a pilot experiment would be processed.

Pilot experiment

The experiment is simulated, and the procedure is listed below:

1. Put a random cup onto a digital scale and set the scale into zero.
2. Filled the cup with a random amount of water and record the weight as a starting point.
3. Soak a sample paper with a specific size in the water for 10 seconds.
4. Pick the sample paper up by a pair of forceps and hold it right above the cup for 10 second
5. Record the weight change.

The focus of the pilot experiment is on the procedure of the experiment. There are some differences between the pilot experiment and actual formal experiment. The first is that a random amount of water is used while a specific amount in the actual experiment for the convenience of calculation. After the pilot experiment, there are some other problems is found. The first difficulty is that the irregular shape of soaked paper would affect the levels of data collected. There is space inside the paper picked up from the container if the paper is not flatly put. The irregular shape of the paper provided space for water so the water may not be dripped off, increasing the data collected.

The second difficulty would be water may splash due to the ungentle or uncareful operation of the experiment. Water would splash when the paper is not gently put into or picked up from the container. If the paper is picked up ungentle, water stuck on the paper surface or inside the paper due to above difficulty may be flipped out and dripped outside the cup, causing a diminished result in collected data.

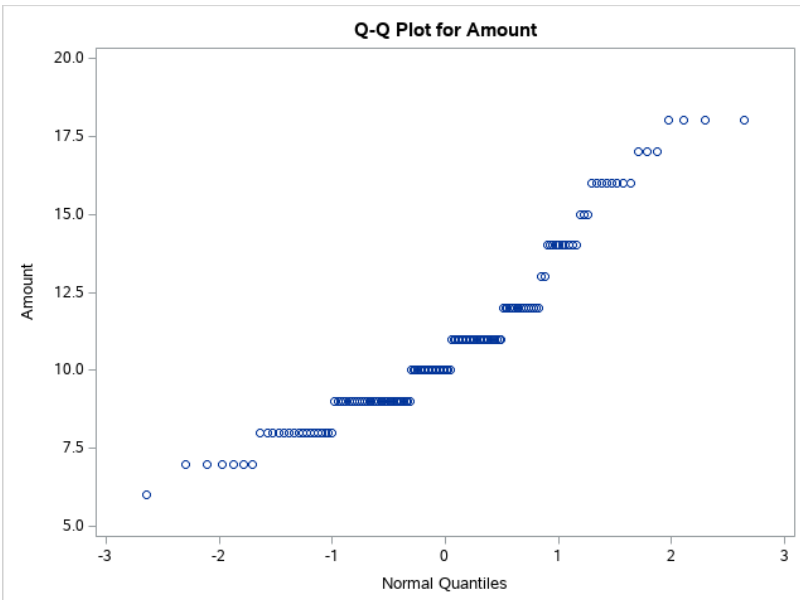
Difficulties encounter

Regarding two difficulties found in the pilot experiment, regulation is made for the reality and reliability of the collected data. For the first difficulty, there are two reasons would cause the problem: a small area of the cup and the random method of putting the paper into the cup. Concerning this, a larger area of the container, such as a larger bowl or pot, would be used, ensuring paper can be flatly put into the container and no gap inside the moisture paper. For the second difficulty, a gentle manner of operation would apply to the experiment to reduce the error due to the operator. With these regulations, the experiment would be processed fairly.

Data management

Excel 2020 (Microsoft Corp) was adopted for data organization in our experiment, including data entering and cleaning. SAS University Edition (SAS Institute) was used as the major part in statistical analyses, such as preparing graphs and constructing hypothesis testing tables.

To ensure the appropriate use of statistical methods, we set up a QQ plot as below to study the normality of data. The majority of data are allocated at the center of the graph. Although we have some restrictions in our measurement as mentioned previous, the QQ plot still show a nearly $45°$ straight line. We concluded that the data collected are normally distributed.



(Figure 1)

Having the above result, we adopted the one-way classification model, which is $Y_{ij} = \mu_i + \varepsilon_{ij}$, to identify the fixed effects for verifying the effectiveness of our treatments. Given that the response variable (amount of water absorbed) is normally distributed, the model is established. In our experiment, a different type of papers is categorized with a single factor, and such characteristic gives us an insight into the different population means from others. While multiple linear regression does a good job in factor studies, it requires a precise design matrix to fit the model. To make things easier, thus, we chose the one-way analysis of variance (ANOVA) instead of calculating the tedious full-scale matrix. The level of significance is set to be 5%, which is considered to be good enough for the purpose of our experiment.

We rewrite the model into $Y_{ij} = \mu + \alpha_i + \varepsilon_{ij}$, where μ_i is the ground means and α_i indicates the fixed effects for the 3 types of paper. The objective of the experiment is to discover which type of paper has the highest hygroscopic capacity. We established hypothesis testing for the existence of fixed effects in the model.

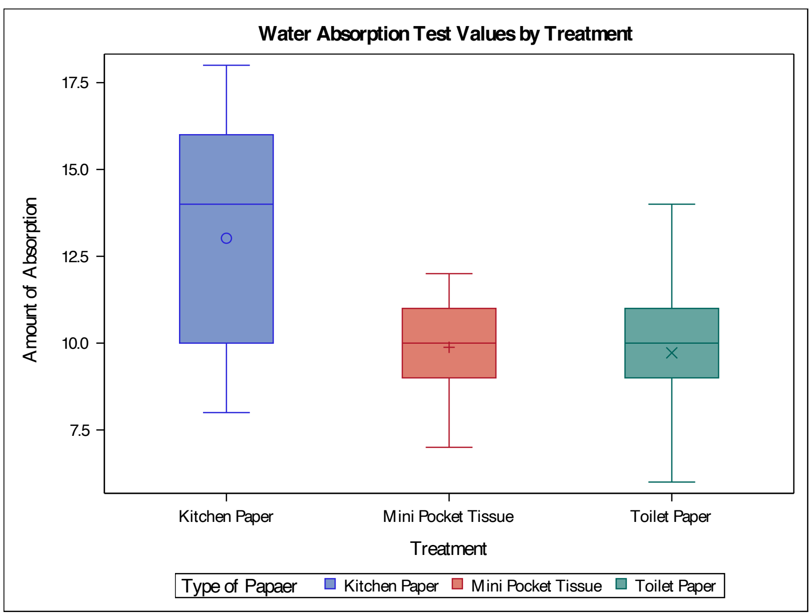
Results

One hundred and fifty of data were collected in our experiment. The following SAS output describes the summary statistics grouped by different treatments in the paper.

Analysis Variable: Amount							
Level of Type	**N**	**Mean**	**Std Error**	**Minimum**	**Maximum**	**Lower 95% CL for Mean**	**Upper 95% CL for Mean**
Kitchen Paper	50	13.02	0.46	8.00	18.00	12.10	13.94
Mini Pocket Tissue	50	9.88	0.21	7.00	12.00	9.46	10.30
Toilet Paper	50	9.72	0.22	6.00	14.00	9.28	10.16

(Table 1)

The upcoming box plot gives us intuition about the dispensation of the amount of water absorption by different types of paper.



(Figure 2)

The box plot shows that kitchen paper has a high variation in the amount of water absorbed, which may be caused by different quality by brands. However, it is noticeable that the mean of kitchen paper is not significantly greater than that of both mini pocket tissue and toilet paper. Therefore, we have the following hypothesis testing for the fixed effects. As we interested in the existence of fixed effects, we have the subsequent hypothesis.

$$H_0: \alpha_{kitchen} = \alpha_{tissue} = \alpha_{toilet} = 0 \quad vs \quad H_1: at\ least\ one\ \alpha_i\ is\ NOT\ zero$$

The ANOVA Procedure Dependent Variable: Amount					
Source	**DF**	**Sum of Squares**	**Mean Square**	**F Value**	**Pr > F**
Model	2	346.25	173.13	34.19	<.0001
Error	147	744.34	5.06		
Corrected Total	149	1090.59			

(Table 2)

We obtained the above one-way ANOVA table from SAS output. We can see that the p-value is smaller than 0.05, and we rejected H_0 at the 5% level of significance. There is sufficient evidence to indicate the means of different types of paper are differ. In other words, our treatment is effective.

Our experiment aims to find out which type of paper can absorb the most amount of water. We, subsequently, constructed another hypothesis testing for two sample means for both mini pocket tissue and toilet paper. Before we have such testing, we need to find the equal variance assumption first. The hypotheses are stated as follow.

$$H_0: \frac{\sigma^2_{toilet}}{\sigma^2_{tissue}} = 1 \quad vs \quad H_1: \frac{\sigma^2_{toilet}}{\sigma^2_{tissue}} \neq 1$$

Equality of Variances				
Method	**Num DF**	**Den DF**	**F Value**	**Pr > F**
Folded F	49	49	1.08	0.79

(Table 3)

From table 3, we assumed the variance for mini pocket tissue and toilet paper are set to be equal. The pooled method takes over in the hypothesis of 2 sample means.

$$H_0: \mu_{tissue} - \mu_{toilet} = 0 \quad vs \quad H_1: \mu_{tissue} - \mu_{toilet} \neq 0$$

Method	Variances	DF	t Value	Pr > |t|
Pooled	Equal	98	0.53	0.6006

(Table 4)

As the p-value is greater than 0.05, we do no reject the H_0 at the 5% level of significance. There is insufficient evidence to conclude the means of mini pocket tissue and toilet paper are different. Simply put, the amount of water absorption for both mini pocket tissue and toilet paper are equal on average. Since either the mean of mini pocket tissue and toilet paper is said to be equal, we used the mean of mini pocket tissue as a reference in representing both means of mini pocket tissue and toilet paper. Having the above result, we construct a similar process with kitchen paper and mini pocket tissue.

$$H_0: \mu_{kitchen} - \mu_{tissue} \leq 0 \quad vs \quad H_1: \mu_{kitchen} - \mu_{tissue} > 0$$

Equality of Variances				
Method	**Num DF**	**Den DF**	**F Value**	**Pr > F**
Folded F	49	49	4.73	<.0001

(Table 5)

Method	Variances	DF	t Value	Pr > t
Satterthwaite	Unequal	68.83	6.21	<.0001

(Table 6)

Since the unequal variance assumption is defined in table 5 as p-value is less than 0.05, the Satterthwaite method is used instead. From table 6, the p-value is smaller than less than 0.05, and we reject H_0 at the 5% level of significance. There is sufficient evidence to conclude the means of kitchen paper is greater than that of mini pocket tissue.

Discussion

In the experiment, we found that there is a fixed effect in our treatment, which means there is a difference in absorbing water among kitchen paper, mini pocket tissue, and toilet paper. Having the statistical result constructed above, we concluded that kitchen paper has the highest hygroscopic capacity. It absorbs 13.02g of water on average, and it is far away from the means of mini pocket paper (9.88g) and toilet paper (9.72g). Interestingly, we figured out that the water absorption has no difference between mini pocket tissue and toilet paper on average. Moreover, although there is a huge variation in the amount of water by the treatment of kitchen paper, we obtained the result in above showing that kitchen paper is better than others in absorbing water.

Conclusion

In this experiment, it carries out a result that there is a different amount of water absorption in different types of paper. It shows that kitchen paper has a relatively high hygroscopic capacity. As there are some constraints in the experiment, such as limited budget, the outcome of the study may contain some oversights. Having such restrictions, we have tried our best to minimize possible errors. To enhance the reliability of the further study, more precise tools could be adopted. For instance, a digital scale along with floating-point measurement would make the result more accurate. For sure, longer studies are necessary for having a comprehensive comparison on paper towel. The returns out of the experiment are clearly that the kitchen paper acts effectively in absorbing water. So, next time when you break a cup of water, you do should use kitchen paper as a powerful tool to clean up the place.

Appendix

Table: Data collected from the experiment

Types (Levels)	Paper towel	Pre-weight of the water (grams)	Post-weight of the water (grams)	Weight loss (grams)
Kitchen Paper	1	1000	992	8
	2	1000	991	9
	3	1000	991	9
	4	1000	992	8
	5	1000	991	9
	6	1000	992	8
	7	1000	990	10
	8	1000	990	10
	9	1000	991	9
	10	1000	992	8
	11	1000	991	9
	12	1000	991	9
	13	1000	985	15
	14	1000	983	17
	15	1000	982	18
	16	1000	984	16
	17	1000	986	14
	18	1000	983	17
	19	1000	986	14
	20	1000	982	18
	21	1000	987	13
	22	1000	986	14
	23	1000	983	17
	24	1000	984	16
	25	1000	984	16
	26	1000	984	16
	27	1000	984	16
	28	1000	982	18
	29	1000	986	14
	30	1000	985	15
	31	1000	984	16
	32	1000	985	15
	33	1000	989	11
	34	1000	987	13
	35	1000	988	12

	36	1000	991	9
	37	1000	982	18
	38	1000	990	10
	39	1000	988	12
	40	1000	986	14
	41	1000	988	12
	42	1000	989	11
	43	1000	986	14
	44	1000	984	16
	45	1000	988	12
	46	1000	986	14
	47	1000	992	8
	48	1000	986	14
	49	1000	986	14
	50	1000	984	16
Mini pocket tissue	51	1000	991	9
	52	1000	990	10
	53	1000	993	7
	54	1000	989	11
	55	1000	991	9
	56	1000	991	9
	57	1000	992	8
	58	1000	993	7
	59	1000	991	9
	60	1000	993	7
	61	1000	989	11
	62	1000	989	11
	63	1000	989	11
	64	1000	990	10
	65	1000	989	11
	66	1000	990	10
	67	1000	988	12
	68	1000	990	10
	69	1000	988	12
	70	1000	990	10
	71	1000	989	11
	72	1000	991	9
	73	1000	989	11
	74	1000	991	9
	75	1000	989	11
	76	1000	990	10

	77	1000	991	9
	78	1000	990	10
	79	1000	989	11
	80	1000	991	9
	81	1000	990	10
	82	1000	988	12
	83	1000	988	12
	84	1000	988	12
	85	1000	989	11
	86	1000	988	12
	87	1000	989	11
	88	1000	988	12
	89	1000	989	11
	90	1000	988	12
	91	1000	991	9
	92	1000	991	9
	93	1000	991	9
	94	1000	991	9
	95	1000	993	7
	96	1000	992	8
	97	1000	992	8
	98	1000	991	9
	99	1000	992	8
	100	1000	991	9
Toilet Paper	101	1000	991	9
	102	1000	993	7
	103	1000	990	10
	104	1000	992	8
	105	1000	992	8
	106	1000	991	9
	107	1000	993	7
	108	1000	994	6
	109	1000	992	8
	110	1000	992	8
	111	1000	990	10
	112	1000	989	11
	113	1000	991	9
	114	1000	990	10
	115	1000	989	11
	116	1000	991	9
	117	1000	991	9
	118	1000	990	10

	119	1000	989	11
	120	1000	988	12
	121	1000	989	11
	122	1000	989	11
	123	1000	989	11
	124	1000	989	11
	125	1000	990	10
	126	1000	990	10
	127	1000	988	12
	128	1000	989	11
	129	1000	991	9
	130	1000	990	10
	131	1000	991	9
	132	1000	992	8
	133	1000	992	8
	134	1000	991	9
	135	1000	991	9
	136	1000	991	9
	137	1000	992	8
	138	1000	991	9
	139	1000	992	8
	140	1000	991	9
	141	1000	988	12
	142	1000	988	12
	143	1000	989	11
	144	1000	990	10
	145	1000	986	14
	146	1000	989	11
	147	1000	989	11
	148	1000	989	11
	149	1000	990	10
	150	1000	990	10