Investigating to compare the biogas production of animal sourced wastes and plant sourced wastes.

Extended Essay (Biology)

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ABSTRACT

Research quesiton of this essay is ; 'To what extent do the effectiveness of biogas produced from animal-sourced waste and biogas produced from plant-sourced waste, differ from each other; in terms of energy production, measured with the volume of biogas produced by same mass of animal sourced waste and plant sourced waste ?'

This essay compares the biogas production of animal sourced and plant sourced wastes. The idea came from a school trip to Mamak Landfill Gas to solve the main problem of these days ; renewable,sustainable energy. To measure the amount of biogas produced, animal and plant wastes put into bottles , balloons used as caps to bottles which means increase in the volume of balloon shows increased biogas production. To prevent heat change caused by light, a thick blanket is used like a roof to system. According to results, animal sourced wastes produce 305.92 cm^3 and plant sourced wastes produce 213.89 cm^3 of biogas. It also shows, amount of biogas produced is directly proportional with the amount of carbon atoms inside substance. As the t-test and standart errors show, datas were consistent. As t value is bigger than 1.734, there was obvious compelling distinction between animal and plant wastes. T-test increases the accuracy of the datas by the way. The graph also shows clearly the difference between two types of wastes and reliability of the datas.

It was found that, when the amount of substance and water increased, biogas production increased. These datas scored in a constant time, 10 days and temperature stabiled for both systems. Maximum amount of biogas produced 7th day after that, the biological structure of substances started denaturation and biogas production decreases. On the other hand carrot, cucumber and chicken used as samples for individual's daily wastes. As a conclusion, animal wastes usage would be better in biogas producing facilities.

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Introduction

The first time I met with the main subject of this extended essay will target was during a school trip to Mamak Landfill, in Turkey. I was told, our daily wastes are producing huge amount of gases. In Mamak Landfill, there are a lot of wastes and trashes. People who is working there, find a way to use the energy comes with biogas. Also, Mamak Landfill is Ankara's 8th, Turkey's 326th largest power facility. The avarage production of electric is 149.954.008 kWh. It equals to 46.351 people's daily electricity demand (houses,industry, unerground transportation, lightning etc.), and for only residentral electricity, it can generate 48.282 houses.[1]

Affected, I commenced searching this affair. I accomplished this electricity was established by biogases. I was astonished to detect that Mamak Landfill is Turkey's 2nd largest biogas facility and Odayeri Çöp Biyogazı (Odayeri Landfill Gas) (which is in İstanbul) is the Europe's biggest biogas facility. It is going to produce 1 million people's electricity demand in 2015.[2] This amount of energy is crutial for Turkey because Turkey has had plans for establishing nuclear power generator since 1970. Today these plans nuclear power are a key of country's aim for economic growth.[3] This means Turkey is trying to find out renewable and sustainable energy.

While there have been considerable investigations for renewable energy, there is limited knowledge about biogases and how biogases are produce. This was one of several reasons why I choose the source of renewable energy, biogas for my essay. Its not only producing biogas, it can solve the environmental pollution caused by energy sources, it can satisfy %1 to %5 of electricity demand in Turkey.

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[1] http://www.enerjiatlasi.com/biyogaz/mamak-coplugu-biyogaz.html

[2] http://www.world-nuclear.org/info/Country-Profiles/Countries-T-Z/Turkey/

[3] http://www.world-nuclear.org/info/Country-Profiles/Countries-T-Z/Turkey/

Biogas is, a gas which have been produced by biological breakdown of organic matter in the absence of oxygen.It is primarily methane (CH_4), carbon dioxide (CO_2) and a little bit (H_2S) and it can be produced from raw materials such as agricultural waste, manure, municipal waste, plant material, sewage, green waste or food waste.[4] Biogas can be used as; electricity production, gas network, industry, vehicle fuel, battery.Biogas produced from plant sourced, animal sourced wastes generally and wastes can be formed as; carbohydrates, fats and proteins. Animal sourced biogas' are more efficient easy to make observation on it. So it is possible to observe the difference between biogas produced from fat waste and biogas produced from animal sourced waste. And their difference about usage of biogases. The reason why I chose animal and plant sourced wastes, is to make this investigation more realistic and useful. Because the chosen substances are the wastes of our daily life. Carrot, cucumber and chicken are found in every ordinary kitchen.

To measure the efficiency of the biogas, a place without oxygen such as closed vessel, syring, animal sourced wastes and fat wastes are enough. The system won't have any oxygen circulation and it has a syring connected, so when biogas is produced, syring will have a movement.

I elect to clearly plan and perform an experiment which has producing biogas. Because it is accessible to expose a place without oxygen and also it is reachable to construct protein and fat wastes in short period of time.As a result, this extended essay will devote itself the research question ;

[4] http://en.wikipedia.org/wiki/biogas

‘To what extent do the effectiveness of biogas produced from animal-sourced waste and biogas produced from plant-sourced waste, differ from each other; in terms of energy production, measured with the volume of biogas produced by same mass of animal sourced waste and plant sourced waste ?’and will consider the procedure of the experiment, furthermore checking the results achieved by evaluating their effectiveness and to analyse their conceivable effect.

Hypothesis

It is known that, biogas has high amount of methane gas in it and for producing methane gas, the source should have carbon atoms inside. According to this, it is enough to examine animal based waste's and plant based waste's structure to find out how many carbon atoms inside both of them. Nicholas A. Besley deduced that reaction of methane producing potential in substances, CH_4, changes with the weight of carbon atoms per unit area. According to observations, more atomic weight in terms of carbonic mass, means faster producing rate and more biogas produced.[5]

It can therefore be hypothesized that as the amount of carbon atoms inside the waste increases, the production rate of biogas will increase. It is expected that the animal based waste's biogas production rate will be more than plant based waste.Because animal based waste has more carbons than plant based wastes.

[5] The exact weight or amount of carbon atoms inside a living is directly proportional with the methane producing potential of the living substance.*Chemical Physics Letters- Volume 638.

Method Developing and Planning

Laying out an convenient method in order to reinforce or decline the designed hypothesis answer the given research question brought several problems with it. At first a measurement device had to detect. İnjector was easy to find and easy to observe, so injector was chosen for experiment. One of the problem was, how to prohibit oxygen entrance into the injector. Without harming the injector and not changing the volume of waste in the injector, blocking the needle part of the injector did not defeat the trouble. After additional research, the problem could definitely clarified by using dough as stopper.

Another problem occurred after oxygen prohibiting. It is essential to keep the temperature stabil, after a short research, I counted on changing the environment. I choose and aquarium to stabilize temperature all the time but it had a lot of problems, water flow inside the injector, vaporizing water, set water's temperature. As it turned out during the first trial that was performed, the water inside aquarium makes dough soft and melt it after 10 days. So when the top of the injector wants to move, it could not because the dough was not doing the stopping job. I thought that, using heat to melt the injector's needle part to prevent water flow in the injector would work.

There was no biogas production in the injectors. Enzymes inside both injectors need % 8-15 concentration of water inside to work properly. The water had to add from the needle part, and the cohesion force of water molecules always increase or decrease the water inside the injector. There was two possibility; first one was changing the need, using something else. The needle was chosen because it is easy to observe, easy to find, easy to

stabilize. Another material will work fine but it will be lost of time. Second possibility, changing the environment and find another way to stabilize the temperature instead of using an aquarium. Which means, making whole the experiment from the beginning. Also there is an obvious rising in the producing of biogas from when 100 gr more of raw chicken are added to bottles when 50 gr are added, the producing rate boost again from 312.12 cm^3 at 50 gr to 328.41 cm^3 at 150 gr.

Using aquarium was dangerous because the aquarium has to be near by a plug socket, which is very dangerous with water. After several environments, I decided to use a open system which was at 30^0-35^0 C. Also I changed the injectors with 330 CC water bottles. I filled bottles with 250 mL of water. Because it is optimum water amount for enzymes to work best. So my new experiment was in a box, which has 20 water bottles inside and a thick blanket on it for keeping temperature stabile and reach temperature to 30^0-35^0 C.Temperature was stabilized because blanket prevents hot or cold airflow and also prevents light. On the other hand temperature stabilized to approximately 32^0C[6] because enzymes optimum temperature is 32^0C .10 of the bottle's have animal sourced waste and the others have plant sourced waste. To observe and measure the biogas, I put balloon to both bottles and compared balloon's radius' before and after, each other. I chose chicken as a animal sourced waste and cucumber, carrot for plant sourced waste. Because both of them are easy to find for me.

Now it became important to make sure that all variables were being controlled. Same amounts of substances used to keep amount of waste stabile,an aquarium used to keep temperature stabile, same measuring injector used to keep amount of water stabile and same kind of waste used to keep kind of waste stabile. These are the most apparent of all variables and were dealt with accordingly. It was decided to perform the practical in a box, as it is without a hole and thus very stabile temperature because of the thick blanket. After

[6] http://academic.brooklyn.cuny.edu/biology/bio4fv/page/enz_act.htm

putting two thermometers in the box, it is obvious that temperature is stabile. Also putting the box to a place without light prevents sudden temperature changes. Early trials were carried out to monitor the biogas production and see if the balloons' radius get bigger. As was found, the balloons had maximum radius around 28^0-32^0C. It was also discovered that it was possible to made the radius more bigger with waiting through 2 or 3 more days. To ensure that biogas production circumstances would really be same for each bottle, the same amount of waste measured with precision scaled added to each bottle and remained constant throughout the entire experiment.

Method

Apparatus

20 water bottles of 330 cc
A box of 20m^2
20 Balloons
Thick Blanket
Electronic thermometer
Ruler of 30 cm
String of 20 cm

Materials

1500 gr of raw chicken
750 gr of cucumber
750 gr of carrot
4 Liters of still water

At first, balloons' radius was measured with a 50 cm ruler.200 mL of still water and 150 gr of chicken combined in 330CC water bottle and put a balloon to bottle's cap(x10). To 200 mL of water, 75 gr cucumber and 75 gr carrot added in a bottle of 330CC water bottle and put a balloon to bottle's cap(x10). After that, they all be labeled 1 to 20. All 20 bottles, placed in a box. A thick blanket placed on the box to prevent light and keep the temperature stabile on 32^0C. The bottles were left until the materials they contained had warmed up to a constant temperature.

Using a method which created by myself, radius' of balloons before and after biogas production would be compared for all trials. Finally the mean of all trials (10 for animal sourced waste, 10 for plant sourced waste) would be compared again to see the final results.

Results

Experiment I

Table 1: Set of results of radius of balloon, volume of balloon and perimeter of balloon after the procedure had been carried out at 32 Celcius temperature.

	Trials	Radius Of Ballon(cm) ±0.05cm	Volume Of Balloon(cm^3) ±0.05cm^3	Perimeter Of Balloon(cm) ±0.05cm
Animal Sourced Waste	1	4.27	327.26	17.10
	2	4.22	314.79	16.90
	3	4.28	328.41	17.14
	4	3.99	266.07	15.99
	5	4.06	280.32	16.25
	6	4.10	288.69	16.42
	7	4.19	308.12	16.78
	8	4.25	321.55	17.02
	9	4.27	326.11	17.08
	10	4.25	321.55	17.00
Plant Sourced Waste	1	3.82	234.41	15.30
	2	3.86	240.90	15.45
	3	3.76	222.66	15.04
	4	3.77	224.42	15.09
	5	3.64	202.01	14.56
	6	3.91	250.39	15.54
	7	3.49	178.05	13.97
	8	3.49	178.05	13.96
	9	3.64	202.01	14.59
	10	3.80	229.84	15.22

Key : Animal sourced waste : Chicken
Plant sourced waste : Cucumber

	Mean Radius Of Balloon(cm)	Mean Volume Of Balloon(cm^3)	MeanPerimeter Of Balloon(cm)	Standart Deviation of Volume(cm^3)	Standart Error
Animal-Sourced Waste	4.18	305.92	16.72	20.43	6.460
Plant-Sourced Waste	3.71	213.89	14.81	24.02	7.595

Table 2 ; Descriptive statistification of measurements

Calculations :

-Finding the mean values :

$$\bar{x} = \frac{x_1 + x_2 + \cdots + x_n}{n}$$

(327.26 + 314.79 + ... + 326.11 + 321.55) / 10

= 305.92

-Finding standart deviation

$$\sigma = \sqrt{\frac{1}{N}\sum_{i=1}^{N}(x_i - \mu)^2}$$

-Finding Standart Error

$$\mathrm{SE}_{\bar{x}} = \frac{s}{\sqrt{n}}$$

Standart Error of Animal Waste = 6.460

Standart Error of Plant Waste = 7.595

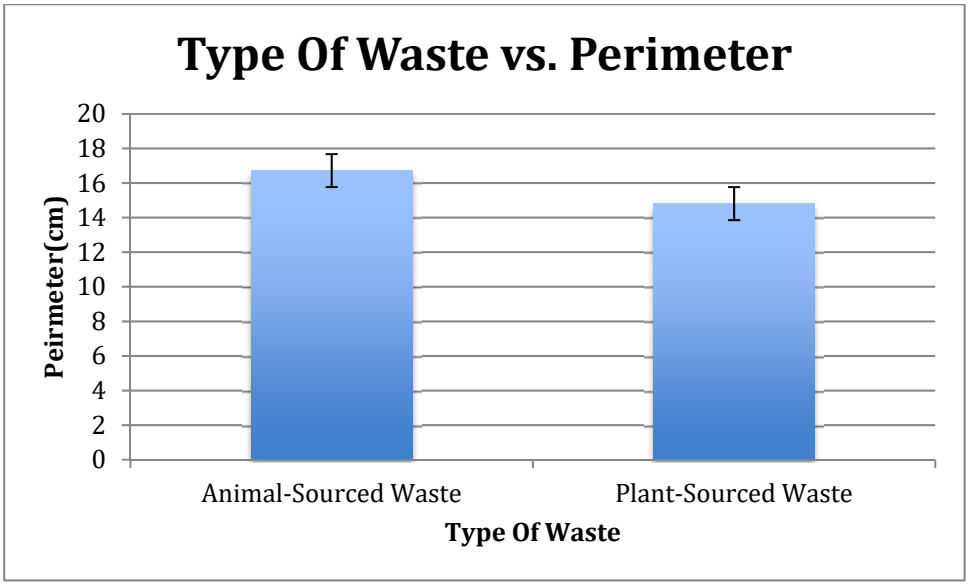

Figure 1 : Volume of gas in animal sourced waste balloon and plant sourced waste balloon(Error bars were drawn by using standart error.)

Statistical Analysis : Dichotomized sample t-test done to analyze the two sets of results from Animal Sourced Wastes and Plant Sourced Wastes.

$$t = \frac{\overline{x_1} - \overline{x_2}}{\sqrt{\frac{{S_1}^2}{N_1} + \frac{{S_2}^2}{N_2}}}$$

where;

x_1 is the mean of first data set (305.92)

x_2 is the mean of first data set (213.89)

S_1^2 is the standard deviation of first data set (20.43)

S_2^2 is the standard deviation of first data set (24.02)

N_1 is the number of elements in the first data set (10)

N_2 is the number of elements in the first data set (10)

H_0 = There is no compelling difference between two sets of data.(null)

H_1 = There is difference between two sets of data.

P = 0.05

t = 3.91

Critical values = 1.734

As $t > 1.734$ the H_1 hypothesis can be acknowledged and it can be pretended that there is obvious compelling distinction between the conclusion of plant waste sourced data's and animal waste sourced data's. It can also seen in the mean value table.

Evaluation

The conclusion backing the hypothesis that there is adjustment in biogas producing rate of wastes according to carbon atoms inside. Indeed, they accomodate to the idea that as the carbon concentration increases the amount of biogas which produced in a given time, 20 days, increases. The T-test which was completed , registered that there is compelling difference between the two groups of data and so, moreover there is some mutation between them, it could be pretended that, t value is bigger than the critical values (1.734). Pretending this to be accurate, the mean biogas producing rate could be determined from the outcomes of both data groups and a graph was sketched to display its distribution.(See graph 1.)

Allegedly, as all data models pretended, this is as a result of some error formed, but this experience may further be an authentic measurement which can be interpreted by the hardness of the water used, which had unknown substances in it. Hardness of water would have to be enough to define it. Because entering a reaction for hydrogen and oxygen atoms is easier than reaction of magnesium and carbon for biogas production. To solve these problems sourced from hard water, refined water used and worked well. However, the rise designated by the mean of the conclusion maybe purely incidental issue of the immense variation which the data shows. This aspect can not be disqualified and in the direction of getting a good appraisal of the mean and assure no error is made it is crucial to rerun the experiment as much as possible.

Sadly, not all errors done can be disqualified by basically rerunning the experiment much more times. Other errors which may have been shaped would have to be handled with by kind of developing the method. For example, since only the methane included biogas were observed it was not followed how much other gases absolutely produced and then stored in the bottle. The volume of the baloon will be fulfilled both by the methane and another gas produced; such as sulfur based biogas. So the amount of methane will not be detected specificly. The other gas may be hydrogen sulfade included biogas and may have, rather then changed the producing itself, cause a crippling in the capacity of the raw

chicken's biogas producing rate. To prevent this error, it is possible to separate gasses with molecular weights.

One more cause of error may have been arranged by the raw chicken itself. The chicken used may have include both muscle and fat parts. The protein (muscle) part of chicken has more carbons compared to fat parts of chicken. To be sure, the chickens would have to be inspected for their definite characteristics. Only if they have entirely muscle, can one be sure that the outcome of the producing rate which was noticed because of carbon atoms inside that part. On the other hand, it is really hard to measure the exact volume of chicken in the bottle. It may increase the water level which increase pressure directly proportional with volume of balloon. But this element did not change the data itself directly it may have margin to a unsuccessfull ideas as to how much biogas was exactly produced in the water in each bottle. About plant sourced waste, cucumber is the right decision but zucchini can be preferred to carrot. According to carbon atoms inside, cucumber has the largest number of carbon atoms, zucchini has second and carrot is third. But it was easier for me to find carrot instead of zucchini.

In this experiment temperature heat is the one of the most important contol variables. Because temperature is directly proportional with enzyms working rate. Through the reaction, substances will dissolve with water and the heat will occur in other words temperature will increse. So it is possible to observe the reaction with increasing temperature. It can be said that temperature difference directly effects the amount of gas produced in the bottles. Also balloons has different flexbilities. These balloons sell 20 of them together in a pack. Each of them has different flexibility. It is impossible to see it with human eyes but it is certain that it has effect on measuring gas. To prevent that, every balloon should manifactured exactly the same quality. As a solution it is possible to use elastic glowes' fingers to measure accurately.

Finally to make this investigation more accurate and stabile, the experiment should be made in a Professional biogas producing system as in Mamak Landfill instead of home made system which has baloons, bottles, and simple wastes like chicken or cucumber for increasing the amount of biogas produced and decrease the degraded biogas and enerygy to minimum.
The bottle and the baloon are not very sensitive as a device of measurement in this experiment. The results will be more accurate if an injector with a negligable piston mass used instead of ballons. Moreover, inside part of the injector could be used instead of bottles to prevent the loss of biogass. All of the above mentioned details will decrease the error percentage.

Conclusion

A question which has to be asked after bring in outcomes offer that the biogas producing rate of both plant sourced waste and animal sourced waste are effected by the amount of carbon in each one : why does the amount of carbon have such an effect on methane sourced biogas production ? Nicholas A. Besley gives an answer question below in his academic journal[7]. He deduced that reaction of methane producing potential in substances, CH_4, changes with the weight of carbon atoms per unit area. According to observations, more atomic weight in terms of carbonic mass, means faster producing rate and more biogas produced. The results of the experiment and hypothesis support this expression ; animal sourced wastes (chicken) has more carbonic mass compared to plant sourced wastes (carrot and cucumber), which means it is expected chicken to produce more biogas than carrot. As a result chicken produced more biogas than carrot.

İt would be delightful to research the effect of temperature to the biogas producing rate. Because in the real life there will be a huge range of temperatures which can effect producing rate directly ; How does temperature effect biogas production reaction rate ? Temperature may effect producing rate in two ways. It can increase the producing rate if it is close to optimum temperature ($25\text{-}28^0$) but if it is below optimum temperature or more than optimum temperature, it will effect negatively.This is the reason why such strong effects have been observed on optimum temperature such as in the experiment done and so the questions answer given.

[7] The exact weight or amount of carbon atoms inside a living is directly proportional with the methane producing potential of the living substance.*Chemical Physics Letters- Volume 638.

Furthermore, controlled variables of water are noticable. It can be easily changed by the existence of Ca^{2+} and Mg^{2+} ions,(Calcium carbonate and Magnesium Carbonate) which prevents the reaction of carbon atoms inside of the substance with water. (The ions creates a natural attraction between hydrogen, oxygen atoms and themselves. Which holds water molecules and prevent the reaction between carbon and water molecules.) For example, in the daily basis, the substances such as chicken ,pork or cucumber, zucchini, orange, will be in the same garbage which has hard water in it. In fact, that makes the position so dangereous, is that the exact amount Ca^{2+} and Mg^{2+} in garbage and nature are extremely harmful to the biogas production. Environmental issues and renewable energy are the most important concerns of era. Therefore both titles can be considerable research subjects together.

Crutially, GMO (Genetically Modified Organisms) has huge effect on biogas production and environment. Modifying an organism means change it's DNA. These changes may be physically or internally. Colour and shape can be example for physically change and taste can be an example for internal change. Reason doesn't important, in all circumstances substance's DNA will change. Which means, basically the carbon amount will be more or less. It seems like, increasing carbon amount has positive effect on biogas production but for the environment they are harmful. Bacterias turns the natural plant wastes to nitrogen, and chemicals make these process impossible for bacterias. And also decrease in the number of carbons, slows down the biogas production process. It is the same about the chicken or animal sourced wastes. On these days genetically modified pigs and chickens are very popular which creates the same situation with plant sourced wastes. So it is impossible to decline the effect of chemicals or GMO about the nature, biogas production or any other renewable energy source such as fossil fuels.

According to the results of experiments and researches done, the biogass rate produced by chicken is more than carrot and cucumber. The average volume value of the chicken (305.92) is higher than the avarage volüme value

of the plant (213.89). Plus, the margin of error is not very high according to standart deviation. For animals: 20.43, for plants: 24.02. So the results are accurate. As it can be understood from the graph, the biogass production rate of animal sourced wastes (chicken) are higher than plant sourced wastes (carrot and cucumber). On the other hand error bars in graph and standart error show that, there is a small percentage of error. This percentage error caused by the materials used in the experiment ; bottle, balloon, rope as a measurement device, chicken, carrot and cucumber. They were not scientific materials and aparattus but they were act like system and finalize the experiment.

Bacterias have ability to reproduce once in 20 minutes[8] if there is suitable circumstances. Food and wet environment are enough for their optimum reproduction performance. In our daily lives, our garbage is rich for bacterias because inside, there is enough water and food in it. So there will be a lot of biogas producing bacterias and material for biogas production such as chicken or another protein. If there will be biogas producing systems in landfills, the energy created from that garbages can solve the world's renewable energy problem and also it will create enough heat to heat the houses near landfill.

3837 words.

[8] http://www.microbiologyonline.org.uk/about-microbiology/introducing-microbes/bacteria

APPENDIX

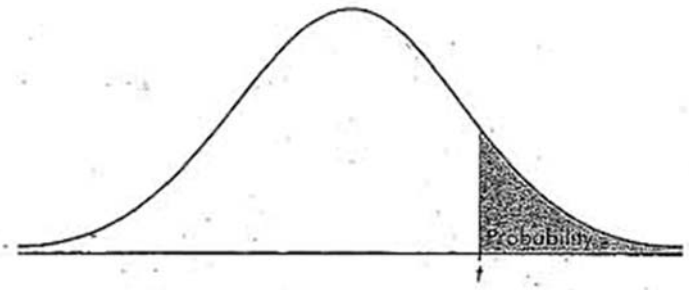

TABLE B: *t*-DISTRIBUTION CRITICAL VALUES

	Tail probability p											
df	.25	.20	.15	.10	.05	.025	.02	.01	.005	.0025	.001	.0005
1	1.000	1.376	1.963	3.078	6.314	12.71	15.89	31.82	63.66	127.3	318.3	636.6
2	.816	1.061	1.386	1.886	2.920	4.303	4.849	6.965	9.925	14.09	22.33	31.60
3	.765	.978	1.250	1.638	2.353	3.182	3.482	4.541	5.841	7.453	10.21	12.92
4	.741	.941	1.190	1.533	2.132	2.776	2.999	3.747	4.604	5.598	7.173	8.610
5	.727	.920	1.156	1.476	2.015	2.571	2.757	3.365	4.032	4.773	5.893	6.869
6	.718	.906	1.134	1.440	1.943	2.447	2.612	3.143	3.707	4.317	5.208	5.959
7	.711	.896	1.119	1.415	1.895	2.365	2.517	2.998	3.499	4.029	4.785	5.408
8	.706	.889	1.108	1.397	1.860	2.306	2.449	2.896	3.355	3.833	4.501	5.041
9	.703	.883	1.100	1.383	1.833	2.262	2.398	2.821	3.250	3.690	4.297	4.781
10	.700	.879	1.093	1.372	1.812	2.228	2.359	2.764	3.169	3.581	4.144	4.587
11	.697	.876	1.088	1.363	1.796	2.201	2.328	2.718	3.106	3.497	4.025	4.437
12	.695	.873	1.083	1.356	1.782	2.179	2.303	2.681	3.055	3.428	3.930	4.318
13	.694	.870	1.079	1.350	1.771	2.160	2.282	2.650	3.012	3.372	3.852	4.221
14	.692	.868	1.076	1.345	1.761	2.145	2.264	2.624	2.977	3.326	3.787	4.140
15	.691	.866	1.074	1.341	1.753	2.131	2.249	2.602	2.947	3.286	3.733	4.073
16	.690	.865	1.071	1.337	1.746	2.120	2.235	2.583	2.921	3.252	3.686	4.015
17	.689	.863	1.069	1.333	1.740	2.110	2.224	2.567	2.898	3.222	3.646	3.965
18	.688	.862	1.067	1.330	1.734	2.101	2.214	2.552	2.878	3.197	3.611	3.922
19	.688	.861	1.066	1.328	1.729	2.093	2.205	2.539	2.861	3.174	3.579	3.883
20	.687	.860	1.064	1.325	1.725	2.086	2.197	2.528	2.845	3.153	3.552	3.850
21	.686	.859	1.063	1.323	1.721	2.080	2.189	2.518	2.831	3.135	3.527	3.819
22	.686	.858	1.061	1.321	1.717	2.074	2.183	2.508	2.819	3.119	3.505	3.792
23	.685	.858	1.060	1.319	1.714	2.069	2.177	2.500	2.807	3.104	3.485	3.768
24	.685	.857	1.059	1.318	1.711	2.064	2.172	2.492	2.797	3.091	3.467	3.745
25	.684	.856	1.058	1.316	1.708	2.060	2.167	2.485	2.787	3.078	3.450	3.725
26	.684	.856	1.058	1.315	1.706	2.056	2.162	2.479	2.779	3.067	3.435	3.707
27	.684	.855	1.057	1.314	1.703	2.052	2.158	2.473	2.771	3.057	3.421	3.690
28	.683	.855	1.056	1.313	1.701	2.048	2.154	2.467	2.763	3.047	3.408	3.674
29	.683	.854	1.055	1.311	1.699	2.045	2.150	2.462	2.756	3.038	3.396	3.659
30	.683	.854	1.055	1.310	1.697	2.042	2.147	2.457	2.750	3.030	3.385	3.646
40	.681	.851	1.050	1.303	1.684	2.021	2.123	2.423	2.704	2.971	3.307	3.551
50	.679	.849	1.047	1.299	1.676	2.009	2.109	2.403	2.678	2.937	3.261	3.496
60	.679	.848	1.045	1.296	1.671	2.000	2.099	2.390	2.660	2.915	3.232	3.460
80	.678	.846	1.043	1.292	1.664	1.990	2.088	2.374	2.639	2.887	3.195	3.416
100	.677	.845	1.042	1.290	1.660	1.984	2.081	2.364	2.626	2.871	3.174	3.390
1000	.675	.842	1.037	1.282	1.646	1.962	2.056	2.330	2.581	2.813	3.098	3.300
∞	.674	.841	1.036	1.282	1.645	1.960	2.054	2.326	2.576	2.807	3.091	3.291
	50%	60%	70%	80%	90%	95%	96%	98%	99%	99.5%	99.8%	99.9%
	Confidence level C											

Figure 2 – T-test table

Figure 3 – Bottles and balloons

Figure 4 – Inflated balloon

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