Extended Essay (Biology)

"Investigating The Effect Of Varying Wavelengths Of Visible Light On The Rate Of CO_2 Gas Production With Ethyl Alcohol Fermentation Of Saccharomyces Cerevisiae Cells In A Certain Time"

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Abstract

A characteristic feature of protist cells is that they favor dark environments. The reason for this behavior is that UV radiation annihilates these cells. This phenomenon provided the basis of the research about ethanol fermentation that this paper deals with. Although there are extensive researches about effect of UV radiation there is little research about the effect of differing wavelengths of visible light on these creatures. Since the yeast cells are one of the best known organisms in science and UV radiation affects them terribly, the scope of the experiment is chosen as *Saccharomyces Cerevisiae* cells. The objective of this study was to observe whether the volume of carbon dioxide produced by the *S.Cervisiae* during fermentation, in a certain time, is affected by varying wavelengths of visible light spectrum. Thereupon, fixed masses of yeast were put into glucose solutions in respiration chambers illuminated by different wavelengths of visible light for ten minutes and the alteration in the concentration of carbon dioxide were noted.

It was found that as wavelength of visible light increase the carbon dioxide formation of *S.Cerevisiae* cells increase. However it was as the wavelength of the visible light increases its affect on the ethanol fermentation decreases. The highest carbon dioxide formation rate is achieved by the cells which were put in respiration chambers lighted by the wavelength of 460 nanometers with an average of 29154 ppm. The maximum wavelength which was applied was 650 nanometers and the result acquired was 17646 ppm. Overall, the fit of the data was a negative correlation supporting the hypothesis that the increase in wavelength will decrease the fermentation rate. Possibly, the reason of this effect that increasing wavelength of visible light has on this species is that it hastens the process by giving energy to the species

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Introduction

The first time I have encountered with the topic which my extended essay will focus on was during a conversation with my father about how alcoholic beverages are made and what they are made from. During this conversation I found out that yeast which is the primary key to make ethyl alcohol is kept in dark moist places in the process of ethanol fermentation. A theory for this was proposed about this fact is linking the growing places of yeast to the rays of sun. The light rays which are coming from the sun is decreasing the number of yeast colonies significantly by inhibiting their rate of carbon dioxide formation which signifies their rate of respiration. Evidence supporting this theory is the fact that fungi can be found naturally in dark and moist places such as tangled up amongst the roots of trees.[1]And the fact that yeast can also be found on outside of the fruits[2]

Interested, I commenced researching this issue and I surprisingly found out that this destructive effect of the sun rays are apparently happening because of the UV radiation contained in sun rays. As an article[3] indicates as the time spent by yeast in UV radiation increases the number of yeast colonies decreases. In another article[4] J.N Davidson indicates that exposing yeast to UV radiation for six hours causes the sixty percent of them to perish. This evidence is surprising since it shows how destructive UV light can be to the yeast cells. By this information, an unavoidable question follows as, how does visible light spectrum affect the yeast cells because of the fact that sun rays are also composed of different wavelengths of visible light.

[1] http://www.naturegrid.org.uk/biodiversity/crypfungi.html#where
[2] "The Many Faces of Yeast" *Steffan Hoffmann*
[3] "The Effect of Ultraviolet Light on Yeast Colonies" *Laila M. Nikaien*
[4] "The Effect Of Ultraviolet Light On Living Yeast Cells" *J. N. Davıdson*

While there have been considerable amount of studies about the effect of UV radiation on yeast, there are limited amount of studies therefore less knowledge as how visible light spectrum can affect the yeast cells despite the fact that the sun rays are notably composed of varying wavelengths of visible light spectrum. This was one of the reasons why I determined varying wavelengths of visible light spectrum for my study and also an UV sensitive yeast type *Saccaromyces cerevisiae* which is on the phylum of Ascomycota, the family Saccharomycetaceae and the genus Saccharomyces, for my study. Not only *Saccaromyces cerevisiae* is an ideal representative of yeast, they are also relatively uncomplicated to find. It also has a fairly short generation time, making it an optimal organism for short term investigations. Furthermore, it is one of the most experimented unicellular fungi so there is a less possibility of unexpected and unrelated situations to occur. They also have evident importance in human lifestyle due to the fact that they are used in brewery and bakery. Because of their nature they can simply grow in every kind of sugar except lactose and cellobiose.

S.cerevisiae are found mostly in the wild growing on the skins of grapes and other fruits like most of its relatives and also adapted in few important ways and these adaptations allows them to live in different environments. This is another reason why *S.cervisiae* is a satisfactory organism for the experiment which will be discussed in this paper. If they are affected from the visible light spectrum it will become very likely that the other environment sensitive relatives will have affection as well.

I especially selected planning and carrying out an experiment involving the rate of carbon dioxide formation of *S.Cervisiae* because of their simplicity and accuracy in experimentation process, also their performance in short period of time. Thereupon this paper will center on the research question:

“Is the volume of carbon dioxide produced by the *Saccromyces cervisiae* during the process of ethanol fermentation, in a certain time affected by varying visible light spectrum?”

And will argue how the experiment performed was arranged and achieved. Moreover this paper will center on examining the results collected by validity evaluation and analyzing the possible consequences of the results.

Hypothesis

There is evidence that lights that have short wavelength likewise Ultraviolet, has a devastating effect on yeast cells.[5] Evidence additionally suggests that UV radiation is damaging the cells of plants and bacteria.[6] There is also evidence that visible light is beneficial for plants.[7] Furthermore It is known that rate of photosynthesis of plants' exposed to short wavelength of light is higher than those exposed to direct sunlight. Therefore it is very likely that visible light spectrum has a aiding effect on the rate of ethanol fermentation and on the volume of carbon dioxide produced by the *S.Cervisiae.*

Consequently it can be hypothesized that visible light spectrums will assist the ethanol fermentation process but as the wavelength of visible light spectrums decrease, the assistance will increase and the volume of carbon dioxide formed by the process of ethanol formation at a certain time will increase. It is expected that visible light spectrums will be beneficial for the *S.Cervisiae* by helping them in their respiration process but visible light spectrums which have long wavelength will , in some way, intervene with the *S.Cervisiae's* ability to initiate anaerobic respiration and reducing the assistance therefore it will affect the ability to produce carbon dioxide by the fermentation of ethanol and so the volume of produced carbon dioxide by *S.Cervisiae* will be less compared to the visible light spectrums with a short wavelength.

[5] "The Effect of Ultraviolet Light on Yeast Colonies" *Laila M. Nikaien*
[6] "The Effects of Over Exposure to Ultraviolet Radiation on the Growth of Plants and Bacteria" *Mildred C. Chaffin,*
[7] " Visible Light Spectrum & Photosynthesis" *David Chandler*

Method Development and Planning

Designing an adequate method in order to support or reject the suggested hypothesis and answer the given research question brought numerous problems with it. One of the problems was measuring the wavelength of the visible light spectrum which the *S.Cerevisiae* were exposed. Without being able to determine that independent variable, the whole quantitative analysis of the effect of light wavelength on the carbon dioxide production rate of *S.Cerevisiae* not only would make very little sense but also would be significantly unreliable. After further research, it is seen that the difficulty could completely be solved by using a continuous optical spectrum, a device which shows the visible light spectrum according to the nanometer and frequency continuously. By using comparison the approximate nanometer of the emitted visible light can be found with ease.

Another significant problem was determining the light source. This was a rather crucial matter due to the fact that the light source has the utmost effect on experimentation process on the basis of creating the different nanometers of visible light. It is seen that incandescent lamps[8], will create error because of the fact that approximately 90% of energy given will be emitted as heat[9] which is a factor which can alter the ethanol fermentation rate of the *S.Cervisiae.* Fluorescent lamps will also not be beneficial because of their working procedure[10] florescent lamps became risky to use due to the fact that ultraviolet light has serious destructive effect on *S.Cervisiae.* After in depth research it is seen that LED lamps[11] can be used as a light source

Another important complication was to find the appropriate *S.Cerevisiae* to use in the experiment. It was rather complicated because of the sheer number of *S.Cerevisiae* products

[8] A lamp which initiate light emission by heating the filament wire with electricity to certain extent
[9] Keefe, T.J. (2007). "The Nature of Light". Retrieved 5 November 2007.
[10] Fluorescent lamps produce light by emitting ultraviolet light to a phosphate layer to create visible light.
[11] A lamp type which uses light emitting diodes (LED) for illumination

that are available to use. With this information it was clearly seen that a wise picking of baker's yeast should be made. After research it is found out that instant baker's yeast types should be used in order to ease the experimental process since other types of yeast need some time for preparation. It is also found out that some baker's yeast products have not just *S.Cerevisiae* but other contents such as food additives. Therefore it was necessary to make further research so as to find a instant baker's yeast that contain only *S.Cerevisiae*. After extensive researches at the local food stores Dr Oetker® branded baker's yeast product which has nothing except *S.Cerevisiae* inside is found.

A further problem was to quantitatively determining the carbon dioxide formed by the ethanol fermentation process of *S.Cerevisiae.* As it turned out that measuring the volume of carbon dioxide formed is not sufficient and also too difficult to be performed due to the fact that gas substances can easily leak out from their containers. After further thinking a solution of measuring the rate of formation by using the data probe device and carbon dioxide measuring probe by Vernier® which will be put in a closed plastic respiration chamber of 250 cm^3 is found. This device will measure the volume of carbon dioxide formed and the rate of carbon dioxide production during ethanol fermentation of *S.Cerevisiae.*

Determining and securing the optimum temperature for *S.Cerevisiae* to initiate ethanol fermentation proved additional problem. Optimum temperature should be gained since if it cannot be attained the yeast cell can be damaged or the process will become too slow and prove the results measured unreliable. After some research it is found that optimum temperature for ethanol fermentation is 30 degrees Celsius. Therefore it can clearly be seen that the temperature for this carbon dioxide production rate experiment must be between 28 - 32 degrees Celsius. With this information it is clear that water bath and hot and cold water

supplies should be used with thermometers in order to stabilize the temperature of the *S.Cerevisiae* solutions.

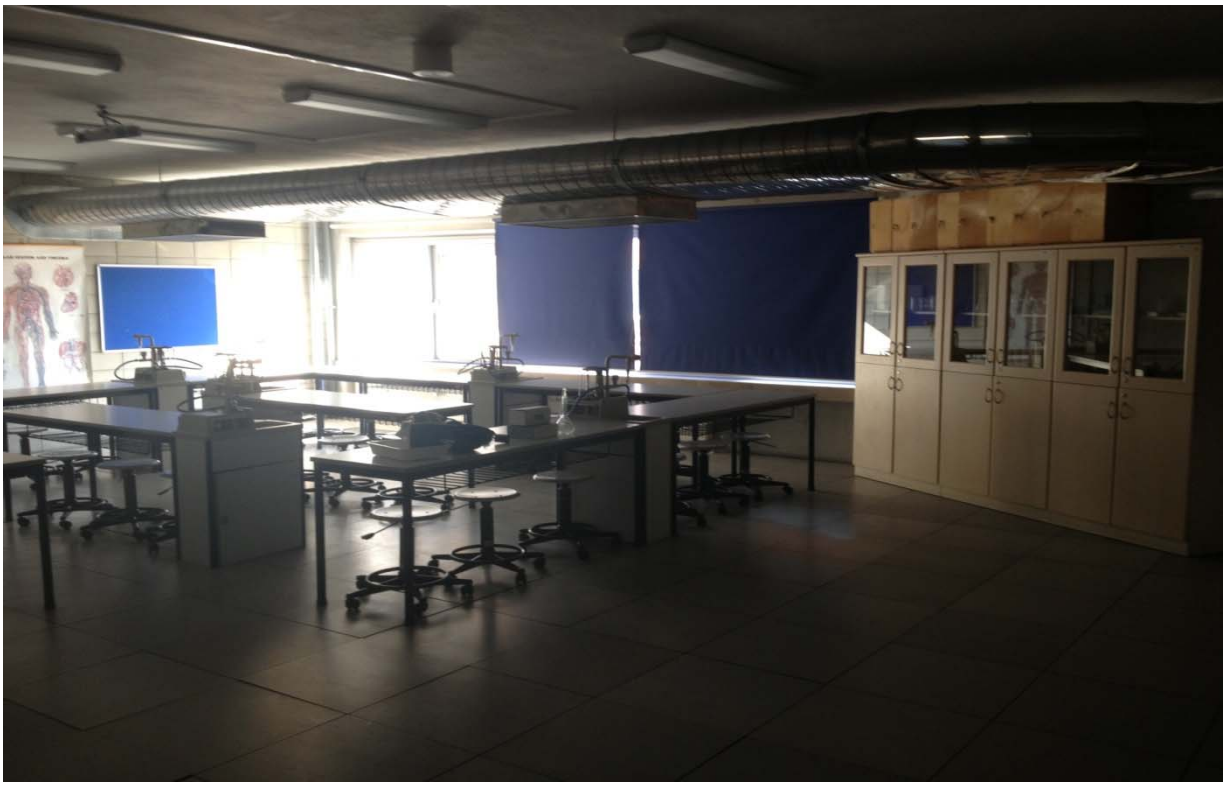
Now it became important to make sure that all variables are being controlled. Light intensity, pH, pressure and concentration of sugar solution as a substrate used for fermentation, volume of sugar solution, mass of yeast and time were most apparent of these variables and these variables were dealt accordingly. It was adjudged to perform the experiment in the school laboratory as it has a stable pressure and temperature in addition to these factors, this environment can also have a great assistance in stabilizing the oxygen concentration. Furthermore it is rather uncomplicated to achieve darkness needed. For the problem of controlling the light intensity it was found that the lamps should be placed 15 cm directly above of the each ground and 15 cm away from the beakers. Moreover it was found that every lamp should have the energy of 0.23 watts, which is equivalent of 18 watts of incandescent lamps, and should be one same product of the one same company which is chosen to be Osram® Vario. These countermeasures ought to be taken in order to stabilize each lamps energy emittance. It is also seen that if the jars were arranged in 50 cm intervals not only it would minimize their ability to shade each other but also it would minimize the light absorption differences. Additionally, to ensure that the *S.Cerevisiae* and glucose solutions were identical, 2 grams of *S.Cervisiae*[12], were taken and mixed with 100 ml of 10% glucose solution which was prepared beforehand by adding 10 grams of solid glucose[13], to 100 milliliters of pure water and assumed that it would remain unchanged during the experimental process. pH was at first thought to be another factor that needs to be stabilized but after consulting to my instructors I have learned that the pH of the solution must alter when the ethanol fermentation process starts due to the CO_2 gas production during the process. So it only became necessary to adjust the initial pH of the 10% glucose solution

[12] The calculation will be made by using an accurate and sensitive weight scale
[13] The calculation will be made by using an accurate and sensitive weight scale

Thereupon pH of the glucose solution were stabilized by using pH meter and buffers at a pH of 8.1 and assumed it did not change in the short period of arrangement of the experimental process. Finally the time for the experiment is set for ten minutes in order to stabilize the time taken.

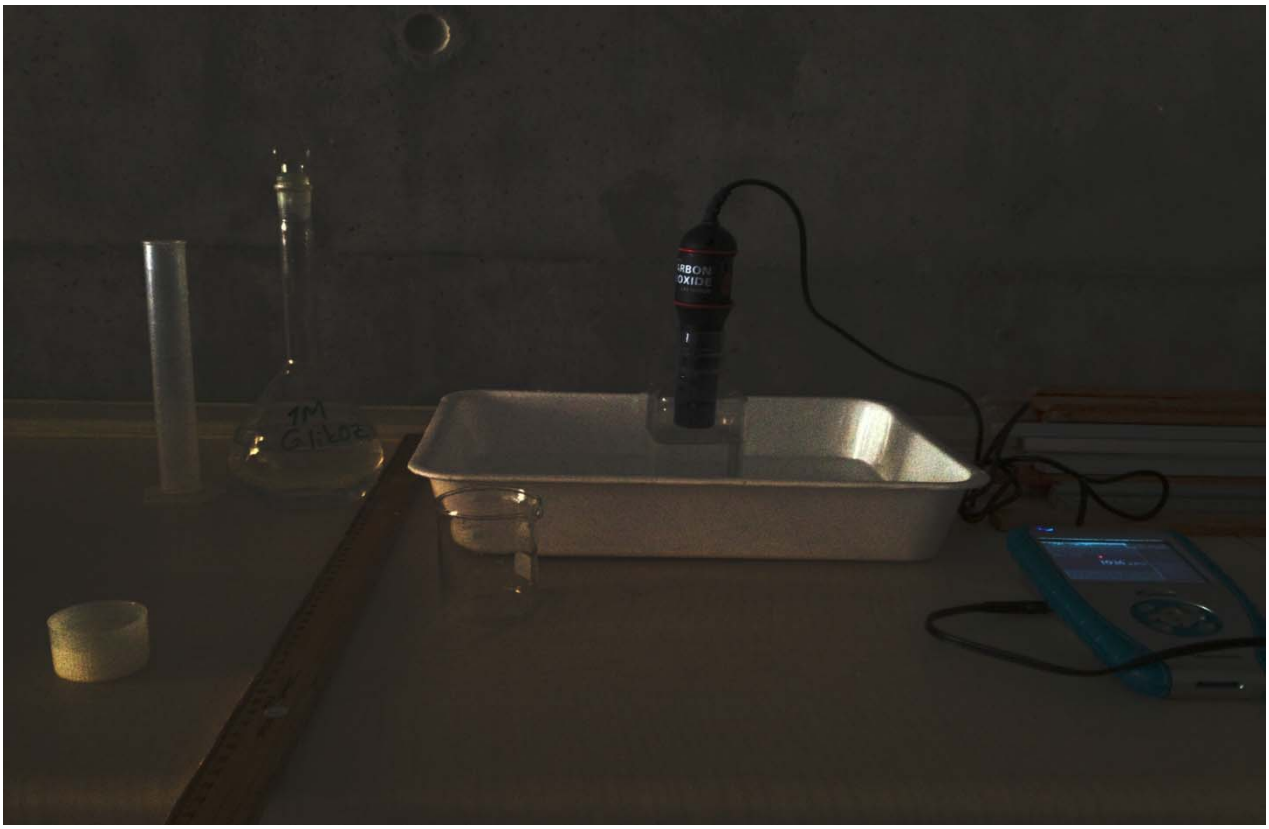
Collecting data also established auxiliary difficulty. In first few trials it is observed that there is already some carbon dioxide inside the respiration chambers. If that was not seen, this event would disrupt the reliability of the data taken due to the fact that each respiration chamber has different amounts of carbon dioxide in it. Therefore a method has been used which consists of observing the change of the carbon dioxide particles per million (ppm) by subtracting the initial amount of carbon dioxide which is observed before the trials of the experimental process had initiated, from the final amount of carbon dioxide which is observed at the end of the trials of the experimental process.

Photographs

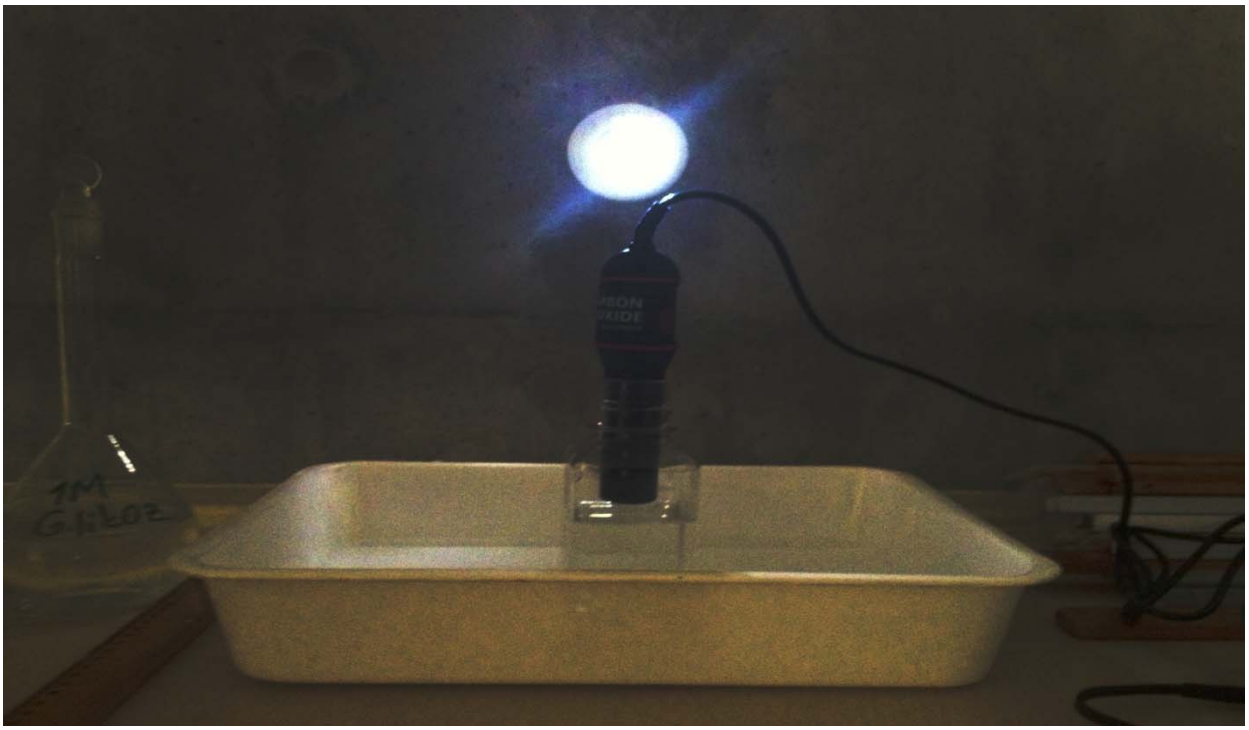


Photograph 1: School's laboratory the place where the experiment is conducted

Photograph 2: The arrangement of the sunlight batch



Photograph 3: Arrangement of the dark batch.



Photograph 4: Arrangement of the colored batches without their gelatins.

Method

Materials and Apparatus

1. 5 respiration chambers of 250cm^3 (taken from Vernier®)
2. Water (Both distilled and tap)
3. 5 Vernier® Data Probe
4. 5 Thermometers
5. 5 Vernier® Carbon Dioxide Sensors
6. 2 Burners
7. 11 Measuring cylinders of the school laboratory (5 10cm^3, 5 100cm^3 and 1 500cm^3)
8. 200 gr of Solid Glucose
9. Ruler (30cm)
10. 5 plastic boxes
11. pH meter
12. 5 different colors of gelatin
13. 5 Osram® Vario LED Lamps
14. Accurate Weight Scale
15. 20 bags of Dr Oetker® Instant Dry Yeast (1 Bag = 30 grams)
16. 1 Thermos bottle
17. Stopwatch

50 grams of solid glucose is added to 500cm^3 of water and stirred thoroughly in order to create 10% glucose solution. Its pH is measured by using a pH meter and noted as 8.1 in order to eradicate the occurrence of any pH difference in the mediums. The glucose solution is heated to 29 degrees Celsius and put into a thermos bottle in order to stabilize the temperature while two grams of *Saccharomyces Cerevisiae* which is obtained from Dr Oetker® Instant Dry Yeast is measured out by using 10cm^3 measuring cylinder and accurate weight scale. Then five respiration chambers of 250cm^3 were filled with the 10% glucose solutions from the thermos bottle and each chamber were placed 50 cm (which is measured and stabilized by using a ruler) away from each other in order to create a control variable. The five Osram® LED lamps were stuck into the wall in a dark environment with 50 cm (which is measured and stabilized by using a ruler) intervals. Meanwhile rectangular gelatin of five different colors (green, yellow, orange red, blue) and known wavelength were put in front of the light sources to create the different wavelengths of light source. Subsequently the two grams of *S.Cerevisiae* were put into the respiration chambers and closed quickly and carefully with the carbon dioxide probe which was connected with the data probe beforehand and the initial carbon dioxide level of the five jars were noted.

Unless there is a problem of heat loss to the surrounding which needed the addition of water the respiration chambers were left undisturbed for ten minutes which is stabilized by using a stopwatch. The data acquired from the data probe about the final level of carbon dioxide were noted. The room and water temperature were taken each minute in order to stabilize them efficiently. The procedure was repeated five times in order to obtain sufficient relevant data and minimize the errors made.

However in order to obtain data from the dark and sunlight batches the procedure is changed. In the dark trial the respiration chambers which are filled with glucose solutions and

yeast were put in a dark place and in the sunlight trial the jars were put 15cm away from the sunlight.

Observations

Nanometer of light (nm) (Δnm= ± 10 nm)	Trials	Mass of Yeast (gr) (Δgr = ± 0.010 gr)	The Volume of CO_2 gas produced by *S. Cerevisiae* during fermentation (ppm) (Δppm = ± 10%)	Temperature (°C) (Δ°C= ± 0.5 °C)	Pressure (mmHg) ΔP=±0.5 mmHg	Concentration of Glucose Solutions (%)	Distance of the Light Sources from the Respiration Chambers (cm) (Δcm= ± 0.5 cm)	Power of the light sources (watt)	Time (sec) Δsec = ± 0.5 sec
650 Red	1	2.00	17210.00	29.0	769.6	10	21.0	0.23	600
	2	2.00	17605.00	29.0	769.6	10	21.0	0.23	600
	3	2.00	18249.00	29.0	769.6	10	21.0	0.23	600
	4	2.00	17719.00	29.0	769.6	10	21.0	0.23	600
	5	2.00	17450.00	29.0	769.6	10	21.0	0.23	600
620 Orange	1	2.00	20529.00	29.0	769.6	10	21.0	0.23	600
	2	2.00	20144.00	29.0	769.6	10	21.0	0.23	600
	3	2.00	20270.00	29.0	769.6	10	21.0	0.23	600
	4	2.00	19725.00	29.0	769.6	10	21.0	0.23	600
	5	2.00	19491.00	29.0	769.6	10	21.0	0.23	600
580 Yellow	1	2.00	21624.00	29.0	769.6	10	21.0	0.23	600
	2	2.00	22180.00	29.0	769.6	10	21.0	0.23	600
	3	2.00	21553.00	29.0	769.6	10	21.0	0.23	600
	4	2.00	21606.00	29.0	769.6	10	21.0	0.23	600
	5	2.00	21774.00	29.0	769.6	10	21.0	0.23	600
500 Green	1	2.00	24524.00	29.0	769.6	10	21.0	0.23	600
	2	2.00	25131.00	29.0	769.6	10	21.0	0.23	600
	3	2.00	25075.00	29.0	769.6	10	21.0	0.23	600
	4	2.00	24302.00	29.0	769.6	10	21.0	0.23	600
	5	2.00	25127.00	29.0	769.6	10	21.0	0.23	600
460 Blue	1	2.00	29114.00	29.0	769.6	10	21.0	0.23	600
	2	2.00	29406.00	29.0	769.6	10	21.0	0.23	600
	3	2.00	29214.00	29.0	769.6	10	21.0	0.23	600
	4	2.00	29521.00	29.0	769.6	10	21.0	0.23	600
	5	2.00	28519.00	29.0	769.6	10	21.0	0.23	600
Dark	1	2.00	9136.00	29.0	769.6	10	21.0	0.23	600
	2	2.00	9306.00	29.0	769.6	10	21.0	0.23	600
	3	2.00	9413.00	29.0	769.6	10	21.0	0.23	600
	4	2.00	9144.00	29.0	769.6	10	21.0	0.23	600
	5	2.00	9090.00	29.0	769.6	10	21.0	0.23	600
Sunlight	1	2.00	7497.00	29.0	769.6	10	21.0	0.23	600
	2	2.00	7509.00	29.0	769.6	10	21.0	0.23	600
	3	2.00	8232.00	29.0	769.6	10	21.0	0.23	600
	4	2.00	7136.00	29.0	769.6	10	21.0	0.23	600
	5	2.00	7613.00	29.0	769.6	10	21.0	0.23	600

Table 1: Observing the carbon dioxide produced by of *S.Cervisiae* which is exposed to different wavelengths of light with the same intensity of light, temperature, pressure, mass of yeast put in each solution.

Qualitative Observations

- In this experiment formation of foam above the *S.Cerevisiae* solution is observed. It is further seen that the volume of foam increased directly proportional with the volume of carbon dioxide formed.

- In this experiment it is seen that the pH of the solution decreased at the end of the trial process. It is also seen that the pH of the solution is inversely proportional with the carbon dioxide formation rate.

- In this experiment it is also observed that the *S.Cerevisiae* suspension smelt sour.

- In the clearing process it is seen that some of the *S.Cerevisiae* suspension stuck to the sides of the respiration chamber.

Data Analysis

	Red (650 nm)	Orange (620nm)	Yellow (580 nm)	Green(500nm)	Blue (460 nm)	Dark	Sunlight
MEAN of the change CO_2 Level (ppm)	17646,6	20031,8	21747,4	24831,8	29154,8	9217,8	7597,4
MODE of the change CO_2 Level (ppm)	#NONE	#NONE	#NONE	#NONE	#NONE	#NONE	#NONE
MEDIAN of the change CO_2 Level (ppm)	17605	20144	21624	25075	29214	9144	7509
RANGE of the change CO_2 Level (ppm)	1039	1038	627	829	1002	323	1096
VARIANCE of the change CO_2 Level (ppm)	149782,3	175781,7	65215,8	152809,7	151653,7	18588,2	158436,3
SD of the change CO_2 Level (ppm)	387,0171831	419,2632824	255,3738436	390,9088129	389,4274002	136,3385492	398,0405758
SE of the change CO_2 Level (ppm)	173,079346	187,50024	114,2066548	174,8197357	174,1572278	60,9724528	178,0091571
T of the change CO_2 Level (ppm)	2,776445105	2,776445105	2,776445105	2,776445105	2,776445105	2,776445105	2,776445105
%95 CI (SE X T) of the change CO_2 Level (ppm)	480,5453029	520,5841235	317,0885077	485,3773995	483,5379827	169,2866681	494,2326528
%95 CI (EXCEL) of the change CO_2 Level (ppm)	379,2698701	410,8704668	250,261768	383,0835973	381,6318395	133,6093231	390,0725965

Table 2: The descriptive statistics of the carbon dioxide production rate of *S. Cervisiae* with regards to the wavelength of the light source

	Red (650 nm)	Orange (620nm)	Yellow (580 nm)	Green(500 nm)	Blue (460 nm)	Dark	Sunlight
MEAN of the change CO_2 Level (ppm)	17646,6	20031,8	21747,4	24831,8	29154,8	9217,8	7597,4
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Table 3: The important Descriptive Statistics of the carbon dioxide production rate of *S. Cerevisiae* with regards to the wavelength of the light source

I have decided to use Anova Single Factor since there is only one variable in the experiment and I was looking for the alterations that had been made by it. Thereupon it is the most suitable analysis method for me to achieve my goal. Moreover It seemed more suitable to use it because of the descriptive statistics of the data.

Anova: Single Factor

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
Red (650 nm)	5	88233	17646.6	149782,3
Orange (620nm)	5	100159	20031.8	175781,7
Yellow (580 nm)	5	108737	21747.4	65215,8
Green(500nm)	5	124159	24831.8	152809.7
Red(460 nm)	5	145774	29154.8	151653.7
Dark	5	46089	9217.8	18588.2
Sunlight	5	37987	7597.4	158436.3

ANOVA

Source of Variance	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	1,86E+09	6	310155882.2	2489.01934	7.73E-37	2,445259
Within Groups	3489071	28	124609.6714			
Total	1,86E+09	34				

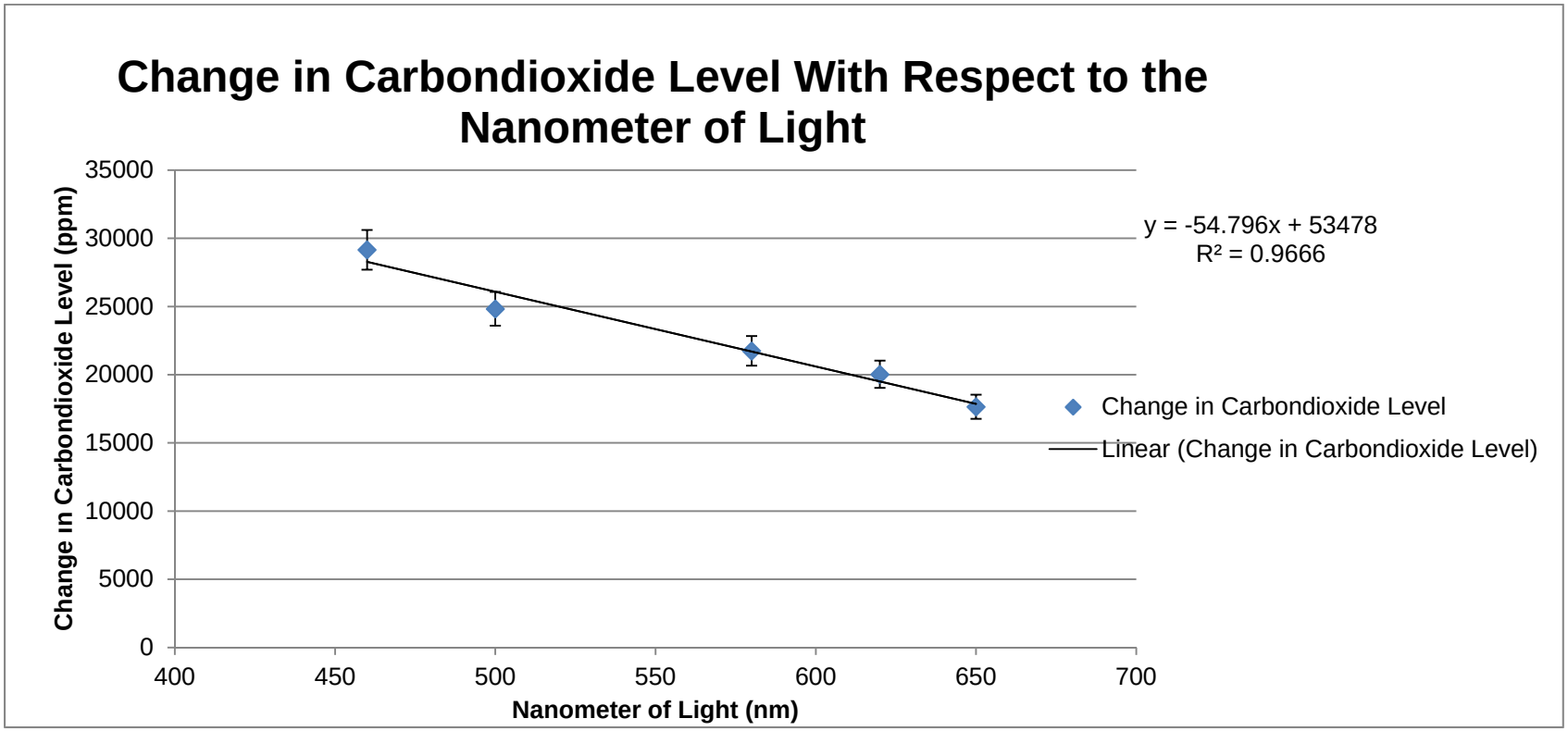
Table 3: Anova Single Factor test of the collected data

$$P\text{-value} = 7.73 \times 10^{-37}$$

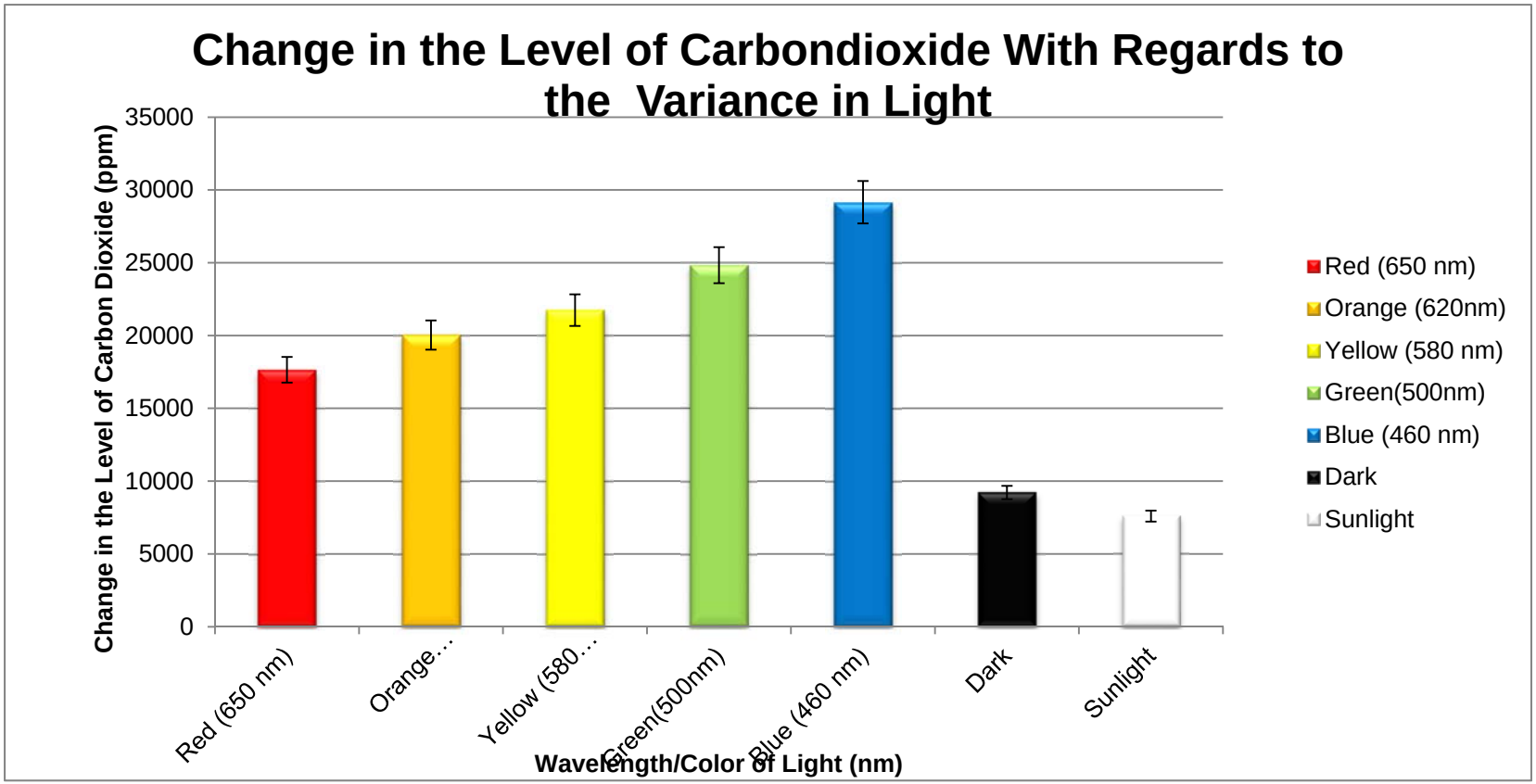
$$P\text{-value} < a$$

$$7.73 \times 10^{-37} < 0.05$$

Null hypothesis of there is no relation between the carbon dioxide production rate of *S. Cerevisiae* with regards to the wavelength of the light source is rejected



Graph 1: Observing the carbon dioxide production rate of *S. Cervisiae* according to the increasing wavelength of light



Graph 2: Observing the carbon dioxide production rate of *S. Cervisiae* according to variant lighting situations

Evaluation

The outcome of the experiment supports the hypothesis that there is a variation in the change in carbon dioxide concentration therefore ethanol fermentation rate of *S.Cervisiae* when they are exposed to differing wavelengths of visible light. In fact they adjust to the hypothesis (see Hypothesis) that as the wavelength of visible spectrum decreases the change in the concentration of carbon dioxide in the respiration chamber, in a given time (ten minutes for this experiment), will increase. The **ANOVA** test which is performed with the data of different nanometers of light (varying from 460 nm to 650 nm) and the data taken from the batches which are exposed to sunlight and kept in the dark environment has shown the p value of $\mathbf{7.73 \times 10^{-37}}$ (See Table 3) Therefore it can be assumed that there is a relation between the wavelength of visible light and ethanol fermentation rate of *S.Cerevisiae*

So as to analyze how varying wavelengths of the light spectrum influences the anaerobic respiration of *S.Cerevisiae* the experimental data is compared with one another by the usage of several graphing methods which can be seen in Graph 1 and Graph 2. The data from the Graph 1 indicates the assistance of visible light towards ethanol fermentation. The Data from the Graph 2 indicates a negative correlation between the wavelength of light and the assistance towards ethanol fermentation which signifies that the respiration rate of *S.Cerevisiae* will decrease as the wavelength of light increases, as was expected. Regarding the scatter graph (Graph 2) the $\mathbf{R^2}$ **value** is **0.9666** which displays that there is a likelihood of linear correlation between the ethanol fermentation rates of yeast with regards to the wavelength of visible light. According to the graph it is almost equally likely that as the graphs equation suggests, the ethanol fermentation of *S.Cerevisiae* will cease once the lights wavelength is above 975 nm.

However it will be hasty and inappropriate to say that the data will follow a linear regression and the ethanol fermentation will end once the wavelength of the light reaches to 975 nm. However R^2 value is significantly near to 1 and the value falls on the 1%. Thereupon because of this confidence it can be said that the data is linear although it is not a certainty. In order to improve the experiment done it should be repeated far more times with far more independent variables which will give a better clue about the correlation between the wavelength of visible light and the ethanol fermentation rate of *S.Cerevisiae.*

Although there is a clear increase in the ethanol fermentation rate of yeast even when 650 nm is applied, the increase of fermentation between the nanometers of 500 and 580 is very little with regards to the increase between other wavelengths of light. This may be caused by some error. However this occurrence can also show the fact that green light is not greatly beneficial to the *S.Cerevisiae.* Albeit it can show a anomaly and it is highly reasonable to state that this is due to some error made because the data shows a great range even in dark control batch as it can be seen in descriptive statistics (see Table 2). This factor cannot be eliminated and created a unreliability in our experiment and in order to diminish that effect the experiment should be repeated several times more.

Even though some errors can be eliminated with simply repeating the test, other errors which may have been made require some slight alterations in the experimental method. For instance, the handmade water bath which is created in order to stabilize the temperature was not effective enough. This fact created an unstable temperature thus created an error. In order to surmount this problem electric water baths should be used.

Another source of error was the presumption about intensity of light. In the experiment Osram® Vario hand lights were used. These light sources works with batteries this means that if the batteries start to deplete the intensity of light may alter. However, it was presumed that

the intensity of light remained stable during the process albeit this may not be valid. The alteration of the light intensity may have affected the experiment and created an error. So as to overcome this error lighting devices which use city electricity should be used.

More significantly, there was also an assumption about the wavelength of light. In the experimental process gelatins of different colors were used and It is a known fact that gelatins ,if they have been built properly, will let only one wavelength of light to pass through. However, the gelatins used may have not been designed properly. Furthermore the wavelength of light was found with comparison (see Method Development and Planning) so they were only an estimation. This may have caused an error. In order to subjugate this error source a spectrometer[14] should be used.

Despite the room for error, the results which are obtained can be seen as valid and acceptable. Consequently, it is very logical to say that varying wavelengths of visible light spectrum has an aiding effect in the ethanol fermentation of yeast and the assistance increases when the wavelength of light decreases due to the experimental results obtained.

[14] An instrument which is used to measure properties of light over a specific portion of electromagnetic spectrum

Conclusion

According to the test results the decrease in the wavelength of visible light increases the ethanol fermentation rate of yeast. Now a question should be asked: Why do the varying wavelengths of visible light affect *Saccharomyces Cervisiae* cells in such way? This question is answered by physics. According to physicists if the wavelength of the light decreases its energy increases. With that being said; it is easy to assume that the increase in energy of the cells, increases the cells' effectiveness in ethanol fermentation. It is likely that the energy of the visible light acted as a catalyst in the chemical reactions of fermentation by giving the energy needed in a lesser amount of time in some way.

It would be interesting to investigate the change in the cell structure of yeast when it is exposed to the differing wavelengths of visible light as it has been found to do in other species such as many forms of species including many members of kingdom *Plantae*. This investigation may assist us to comment on how and why the difference of wavelength of visible light affects the ethanol fermentation of yeast more clearly and efficiently. Moreover it can bring light to the question: "Why UV radiation causes cells of *S.Cervisiae* to perish?" which is one of the things that initiated this research.

Even more of interest is the alterations in the chemical reaction of fermentations which is caused by the differing wavelengths of visible light. This will again enable us to comprehend on why and how the disparity in the wavelength of visible light acts in this way. But more importantly examining the reaction took place will assist us to benefit from this newly found phenomenon in many aspects of physics, biology, chemistry and daily life.

The potential benefits of this newly found marvel is highly intriguing. The increase in fermentation of *S.Cerevisiae* means that this particular being is creating ethanol more efficiently and this further means that producing ethanol will be easier and cheaper. With that

being said the potential benefit of this foundation extends to various parts of chemistry, dental hygiene and alcoholic beverage industry such as but not limited to the companies of Listerine® and Bacardi® and of course the consumers due to the fact that these companies will purchase alcohol relatively cheaper and the consumers will achieve their related goods relatively cheaper. Thereupon this new foundation will assist the economy and marketing tremendously.

However, even if the evidence clues us about a wide variety of aspects there is still copious amount of research that needs to be done before we can have any judgment about this very contemporary issue and its benefits.

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