Bilirubin Level Detection Using Different UV Light

By

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CERTIFICATION OF APPROVAL

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January 2017

CERTIFICATION OF ORIGINALITY

This is to certify that I am responsible for the work submitted in this project, that the original work is my own except as specified in the references and acknowledgements, and that the original work contained herein have not been undertaken or done by unspecified sources or persons.

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DAYANG DYANNA BINTI AWG AJIS

ABSTRACT

Phototherapy is one of the commonly used form of treatment for neonatal jaundice. It operates by exposing an infant to a certain light source. The most conventional ones are fluorescent lamp, halogen bulb, fibre optic and also light emitting diodes (LED). Currently, blue LEDs are favourable as it has long bulb life, low heat production and has a low cost. The determination of the efficiency of blue LEDs are to be calculated by observing the decrement concentration of the food colouring solution which represents bilirubin. In this experiment, blue LEDs are being compared to the commonly used UV fluorescent lamps. A spectrophotometer is used to retrieve data from the solution. The results of the experiment shows that the blue LEDs are 10% more efficient than UV fluorescent lamps in terms of colour difference for a 6 hour experiment.

ACKNOWLEDGEMENT

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CHAPTER 1

INTRODUCTION

1.1 Background

Jaundice occurs when there is excess of bilirubin in infants. Bilirubin is a product formed when a red blood cell breaks down and then is removed by the system. The inability of an infant's organ to remove bilirubin will cause excess bilirubin stored in the blood and may cause yellow discoloration of the skin and white of the eyes. Jaundice occurs when an infant has incompatible blood with the mother, lacking of certain enzymes, and also due to the immature liver which could not keep up with the rate of breakdown of red blood cells [1].

The most commonly used treatment to reduce bilirubin level is by phototherapy. These devices uses light sources such as fluorescent lamps, halogen bulbs, and blue LEDs. Most hospitals used conventional phototherapy devices which use light sources made of fluorescent lamps or halogen bulbs. These light sources are often not available in certain developing or third world countries because the extremely high cost of these devices along with the expensive replacement cost [2].

This project will investigate the efficiency of blue LEDs with fluorescent UVB lamps. The parameter that would be observed in this experiment is the decrement concentration of the bilirubin solution. The bilirubin level is observed by using a spectrophotometer and the changes of the solution before and after being exposed to different light sources are analysed. The aim of this project is to determine the efficiency of blue LEDs in reducing bilirubin level concentration compared fluorescent UV lamps.

1.2 Problem Statement

The most commonly used treatment to cure jaundice is by using phototherapy devices which uses a variety of light sources. Conventional phototherapy devices which uses light sources such as UV fluorescent lamps or halogen bulbs are often used in most hospitals [1]. Although conventionally used, there are a limited number of these devices in 3rd world and developing countries because of the high cost. These light sources are expensive and replacement cost for a set of these are very expensive. Furthermore, light sources like halogen bulbs and fluorescent lamps uses "filament" in which it has the probability to burn up easily hence has a low lifespan [2]. This shows that the maintenance cost of these devices are high. To overcome this problem, another alternative light source is the blue LEDs.

Compared with the risks associated with blood transfusion, phototherapy is considered a relatively safe procedure. However, between the various types of light sources, each has their own disadvantages which has to be considered as well. Diseases such bronze baby syndrome, purpuric eruptions in patients with cholestatic hyperbilirubinemia and mild dehydration are often associated with phototherapy, although rarely reported [2]. Moreover, after having exposed to light in the ultraviolet spectrum, photosensitivity from medications are often reported [3].

Previous researches had found that blue LEDs are more efficient in treating jaundice. It has more advantages than using UV fluorescent lamps and halogen bulbs [1]. It is also well known that conventional phototherapy devices has a lot of drawbacks. Halogen bulbs are favourable as it is compact, has low irradiance and lightweight [2]. However, the disadvantages of using halogen bulbs are they generate a high intensity of heat, increasing the risk of having burns and dehydration towards the infant [2,3]. UV fluorescent lamps are commonly used as its spectral output is well matched to the absorption spectrum of bilirubin. The drawbacks , however, infants are more prone to develop hypothermia, hyperthermia and skin rash after receiving the treatment [3]. These drawbacks are the cause to search for a better light source for phototherapy devices. However, it has not been proven yet that the blue LEDs are more efficient compared to UV fluorescent lamps and halogen bulbs in reducing the bilirubin concentration level.

1.3 Objectives

Two main objectives of this study are:

- To make different concentrations of food coloring solutions similar to bilirubin solution.
- To analyse the efficiency of different UV light sources when exposed to food colouring solution.

1.4 Scope of Study

The scope of this study is to make a comparative analysis between blue LEDs and fluorescent lamps by their ability to reduce the concentration of bilirubin. The light sources chosen to be used in this experiment are blue LEDs and fluorescent lamps. The results of the experiment is to be analyzed using a spectrophotometer device. A spectrophotometer is a device which could determine the change of colour of a solution before and after being exposed to each light source. The time of exposure and initial concentration of the solution is the constant variable meanwhile, the manipulated variable is the type of light source. The responding variable of this experiment would be the final concentration after the solution is exposed to the two light sources. The results would determine which light source is more efficient, in which corresponds to the problem statement of this project.

CHAPTER 2

LITERATURE REVIEW

2.1 Jaundice

Globally, 60% to 70% of infants aged between 35 weeks to 38 weeks has the higher probability of developing jaundice [1]. This may occur to full-term or even premature infants. Jaundice is a condition where the infants has yellowing of the skin, the white of the eyes, and damage of tissues because of the excess of bilirubin in the blood [1]. It is crucial to detect jaundice during one week of life of the infant because it may lead to other critical damages such as permanent neurological disability or severe hyperbilirubinemia [2]. There are four types of jaundice, a mild type of jaundice is called physiologic jaundice. Bilirubin levels of infants who are diagnosed with physiological jaundice does not harm the infant and does not require them to do treatment [3]. This mild jaundice occurs because of the immaturity of the infant's liver, which leads to a slow removal of bilirubin [4] . The severe jaundice is known as pathological jaundice that causes damage to the infant's brain, known as kerticterus, due to the deposition of bile pigments in the brain stem [1]. Kerticterus can also cause some complications such as late development in growth , loss of hearing, and yellow staining of the basal ganglio which if untreated may lead to death. Pathological jaundice causes bilirubin level to rise to a high level that put the infant at risk [3] . Jaundice would usually appear two to four days after birth and if not critical it would resolve by itself after 7-14 days [3].

Another type of jaundice is blood group incompability type [4]. This jaundice occurs due to the baby having different blood type from the mother. Typically blood types which have Rh or ABO problems. The drawbacks of having incompability blood type is that the mother might produce antibodies that destroys the red blood cells of the infant. Although Rh problems can now be prevented easily with an injection of Rh immune globulin to the mother, it had once be the main problem which leads to severe cases of jaundice [4]. Rh immune globulin is injected to the mother within 72 hours after delivery once the baby is known to have different blood type from the mother.

There are a few main reasons jaundice tends to develop in infants. First, the breakdown of fetal haemoglobin which is replaced with adult haemoglobin would lead to an accumulation of bilirubin in the blood. The second factor is because of the relatively immature hepatic metabolic pathways of the infant which are unable to excrete bilirubin as quickly as an adult [4]. The human body breaks down red blood cells and produce bilirubin. Bilirubin passes through the liver and excreted as bile. When an infant's liver could not keep up with the forming rate of bilirubin, this condition causes excess of bilirubin. When this happens, extra bilirubin will then be stored in the skin and it causes the baby's skin to appear yellowish green [1].

Another reason causing the excess of bilirubin is because infants produce more bilirubin than adults and infants have still-developing liver which may not able to excrete sufficient bilirubin from the liver [4]. Other contributing factors to the development of jaundice include blood incompatibility between the mother and infant, virus infections in infant such as rubella, herpes simplex and also syphilis, and immature liver condition during breakdown of red blood cells [1].

2.2 Bilirubin Level

It is normal for an infant to have a bilirubin level of $35\mu mol/L$ or $22mg/dL$ [1]. Treatment is only needed when the bilirubin level measurement exceeds this standard level. Previous researches had made an experiment using serum bilirubin concentration and had concluded that treatment should be discontinued when the serum bilirubin concentration dropped below $7.6 - 8\ mgdl^{-1}$ [2]. Phototherapy proceeds by helping the liver to excrete the bilirubin easier by exposing infants to high levels of colored light [4].

Serum Total Bilirubin (STB) level is measured to determine the efficiency of the treatment used. An absolute reduction of STB levels may not always be achieved if phototherapy is initiated during the first 3-4 days of life although the levels would normally be expected to increase. Phototherapy is most efficient when starts after 4 days of birth because it could reduce STB level up to 40-50% in 24 hours [3].

Phototherapy is the treatment by using light to convert bilirubin molecules into water soluble isomers that can be excreted by the body. Typically, when normal bilirubin (4Z,15Z-bilirubin) absorbs light , the skin undergoes photochemical conversion reactions and it creates two isomeric forms of bilirubin: structural isomers and configurational isomers [3]. These two principal photoisomers formed in humans are shown in FIGURE 1.

Configurational isomerization are reversible in process meanwhile structural isomers are irreversible. Products of configurational isomers are lumirubin which could be eliminated easily by the liver [3]. Structural bilirubin isomers are excreted in the urine and this isomerization process is muchslower compared to configuratonal isomers excretion. This also means that the most important factor when using phototherapy is the excretion of limirubin [3]. A minor product of phototherapy is a colorless oxidation product which goes through photooxidation but it occurs very slowly hence is not relevant as the others.

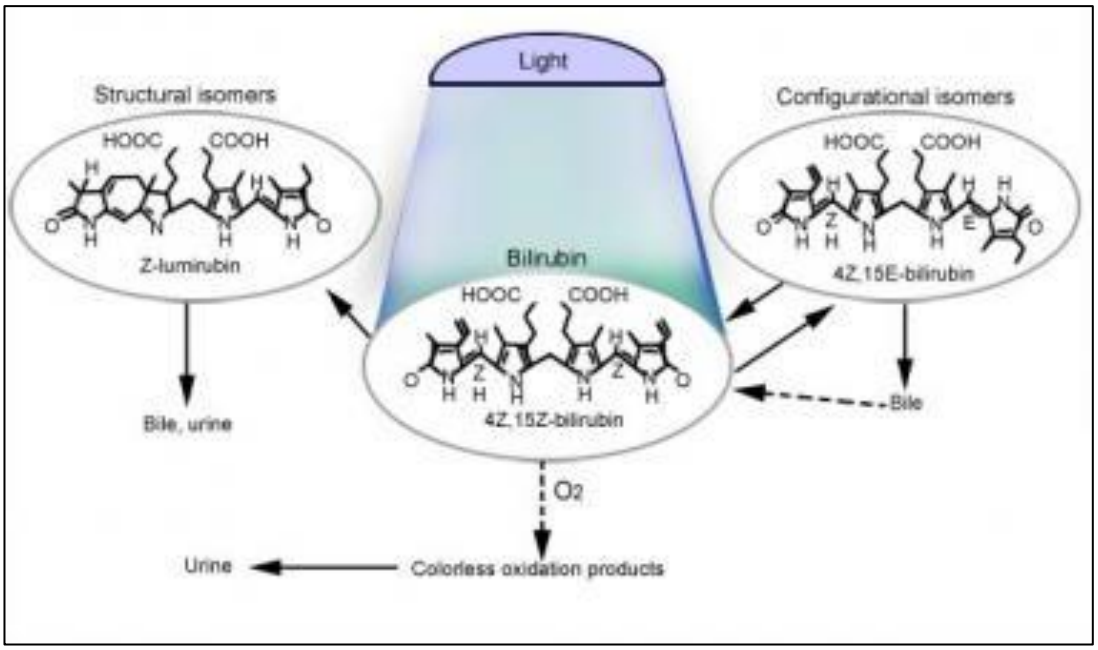

FIGURE 1. Products of Bilirubin [5]

It is a rule of thumb that phototherapy should start when STB level is 5 times greater than the birth weight of the infant. For example, for a 2-kg infant, phototherapy should start when the bilirubin level is 10 mg/dLand for a 3-kg infant, phototherapy should start when the bilirubin level is 15 mg/dL and so on. It is stated that bilirubin is more sensitive to colours closer to the bilirubin absorbance spectrum [1]. Bilirubin appears close to yellow because it mostly absorbs green and blue light [3]. This is the reason why blue and blue-green region which is close to the bilirubin absorbance spectrum is effective in reducing bilirubin level. The American Academy of Pediatrics (AAP) recommended a light source which has a range of 460 to 490 nm [3]. Conventional phototherapy devices these days uses light with peak intensity near 460 nm which is based on the absorption maximum of bilirubin bound to albumin in vitro [3].

The formula to calculate the rate of decrease of bilirubin level is as shown below in Equation. (1).

$$Rate\ of\ decrease = \frac{Initial\ bilirubin\ concentration - Final\ bilirubin\ concentration}{Total\ treatment\ time} \quad (1)$$

2.3 Treatment

Conventionally, jaundice is treated by using a traditional phototherapy method which executes by exposing an infant to sunlight [1]. The infant is exposed to sunlight preferably early morning or late evening to avoid direct sunlight. Although sunlight is found effective in treating jaundice, the drawbacks in this treatment is that sunlight could cause burns to the infant's skin and could impose biological hazards. However, sunlight could easily be filtered by using low-cost commercially available window-tinting films filtered sunlight is considered as a novel, practical and inexpensive method of jaundice treatment especially in tropical countries or any countries which has limited access to phototherapy units [3].

One of the most effective modern treatments to lower the bilirubin level among infants is phototherapy. Phototherapy involves exposing the skin of the infant under a UV light for a certain period of time until their bilirubin level reaches a certain safe level. The treatment method goes through a process of isomerization in which bilirubin is changed into water-soluble isomers which could easily be excreted by the liver [4]. The infant receives treatment in an incubator for approximately two to three days generally depending to the severity of jaundice.

Phototherapy treatments has a requirement in which the infant has to be uncovered as they have to expose the majority of skin area to the light [1]. The infant's posture is also changed every two to three hour in order to maximise the exposed body surface area. It can be concluded that the greater the exposed surface area, the greater the rate of reducing bilirubin concentration. Through phototherapy treatment , bilirubin will be discreted from the infant's body through their faeces and urine . The exposure to ultraviolet lights will aid the change of bilirubin to its break down compound [1]. Bilirubin will be converted into its isomers (photobilirubin and lumirubin) when ultraviolet light penetrates the skin, allowing bilirubin to be excreted easier without going through the liver.

There are a few light sources used in phototherapy devices which include halogen bulbs, fluorescent tubes, fibreoptic systems and LEDs. Each light sources has their own advantages and disadvantages .

Compared to blood transfusion method of treatment, phototherapy is considered as a relatively safe treatment [2]. Significant clinical toxicity of phototherapy are rarely reported, as well as bronze baby syndrome or dark, gray-brown discoloration of the skin, and purpuric eruptions in infants. However, there are a few known complications to phototherapy which includes congenital erythropoietic porphyria, or a family history of porphyria [3]. When infants are undergoing phototherapy, drugs containing photosensitizing compounds such as diuretics, nonsteroidal anti-inflammatory drugs (ibuprofen), and certain antibiotics are best to be avoided because it may cause bad burns.

Photosensitivity from medications generally occurs when they are exposed to light in the ultraviolet spectrum [3]. Not all phototherapy light produce a high significance of ultraviolet , hence it is a rare condition in which the infant will get phototoxic reactions when undergoing phototherapy.

Moreover , the infant are required to wear eye patches when undergoing phototherapy. Eye protection is important yet the problem is that the infants tend to remove the eye patches during the treatment. FIGURE shows an infant undergoing phototherapy wearing an eye patch.

FIGURE 2. Infant with Eye Protection [6]

Phototherapy is only done when the case of the infant is severe and is categorised as jaundice. There is a guideline made for the doctors as to aid them on deciding whether to diagnose the infants as having jaundice or not. Several guidelines has been developed as 'The American Academy of Pediatrics Subcommittee on Hyperbilirubinemia Guidelines on the Management of Hyperbilirubinemia in Newborns 35 or More Weeks Gestation' [3]. This guideline includes the conditions for making the decision of making an initiation of phototherapy based on STB levels, gestational age, age of the infant in hours, and individual risk factors. An algorithm for the management of jaundice in the newborn nursery is also included in the guideline.

2.4 UV Light Sources

2.4.1 Sunlight

Conventionally, jaundice is treated by simply exposing the infant to sunlight. In the early 1950's, sunlight was found to be able to reduce the yellowing effect of infants diagnosed with jaundice [1]. In a research by Fadhil M. Salih the absorbance of bilirubin was reported to be higher when sunlight was used compared to phototherapy unit considering the same time interval [1]. Less developed countries or 3rd world countries, sunlight may as well be suggested as a practical alternative source of light in the treatment of neonatal jaundice in circumstances where conventional phototherapy devices are not available. Conventional phototherapy devices often goes malfunction because of electrical power surges, are not readily affordable, and has a high maintenance due to the high cost of replacement parts [3]. Moreover, these light have a low life span, meaning that it has to be replaced regularly.

In certain areas having no access to phototherapy, it is common for the guardian of the jaundiced infant to expose their babies in direct sunlight, unconcern of the incoming harm and ignoring the safety risks. It is a novel, practical, and inexpensive method of phototherapy especially advantageous in tropical countries [3]. However, the use of sunlight is only practical if only the sunlight is filtered first to exclude the harmful spectral radiation. The most inexpensive filters of sunlight are the window-tinting films which are widely used in residential and commercial structures in sunny climates or in vehicles [3]. These tinting films are effective in reducing the amount of sunlight ultraviolet and infrared radiation from being exposed to the infant.

It has also proven that placing a baby outside in the sun or near a windowsill in the sunlight will not lower the amount of bilirubin level if treated without proper equipments [4] . Without the proper surroundings and lights, the baby's skin may be burned and tend to have a cold from long time exposure. This proves that the time for sunlight exposure is an important factor to be considered and should be monitored very carefully as sunlight could impose biological hazards to the infants [4].

2.4.2 Fluorescent Lamps

Fluorescent lamps is one of the conventionally used light source used for phototherapy . The maximum wavelength of the fluorescent lamp is at 450 nm and the range wavelength of the light is 400 nm to 500 nm [1]. A recent review recommends light used for phototherapy are in the wavelength range 400 to 520 nm and peaked at 450 ± 20nm meanwhile the AAP recommended a more narrow range around 460 to 490 nm [2]. FIGURE 3 shows the spectrum of light in which is most suited for phototherapy treatment.

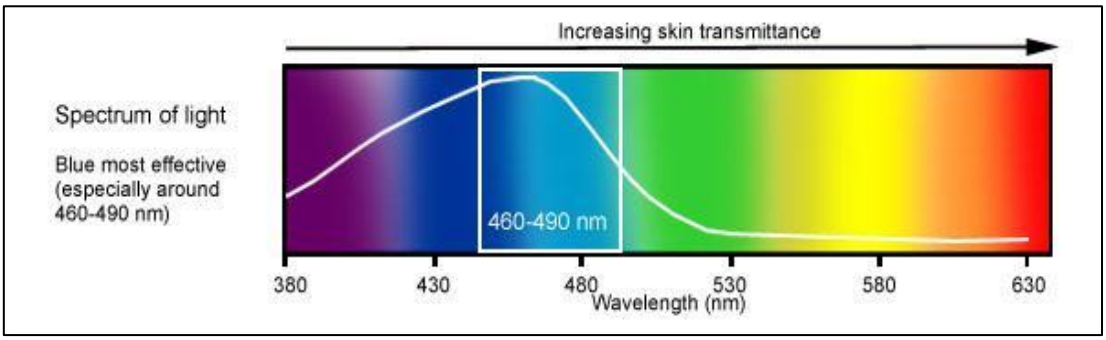

FIGURE 3. Spectrum Of Light Against Wavelength [5]

The set up of this phototherapy treatment when using fluorescent lamp is as shown in FIGURE 3 below . This means that the absorption spectrum of bilirubin is well matched to the spectral output of blue fluorescent bulbs, and that is the reason why these bulbs are recommended by the AAP for intensive phototherapy [3]. Fluorescent lamps is known to have a short lifespan in which it could stand between 1000 and 1500H. These lifespan is corresponding to 2–3 months of continuous usage. Hence, this lamps needs to be regularly replaced. The cost of a set of replacement fluorescent bulbs typically may add up to several hundred dollars. Furthurmore, blue fluorescent lamps irradiance levels ranges from 30-40 μW/cm^2/nm.

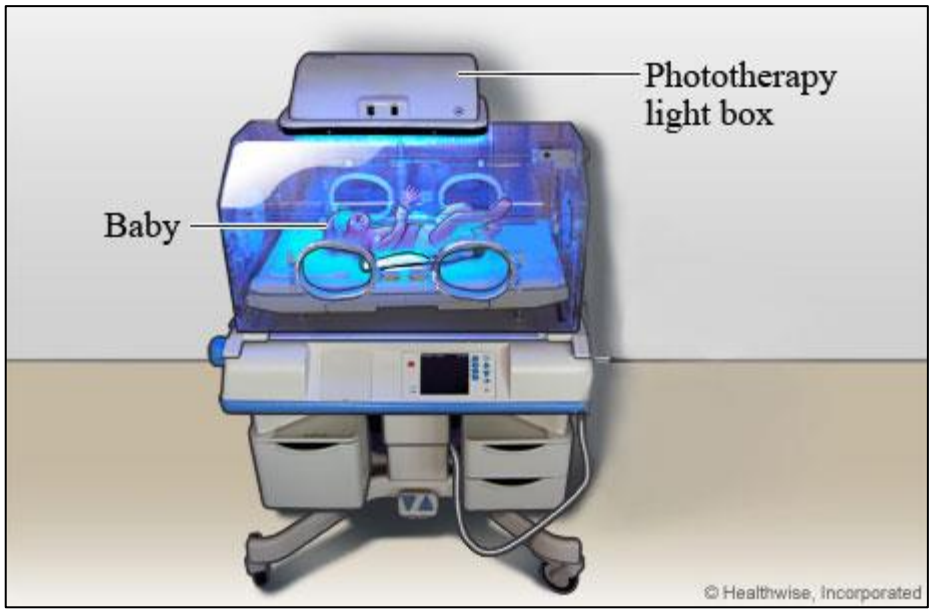

FIGURE 4. Set Up for Phototherapy [7]

Due to the ultraviolet characteristics of the light, the infants is placed on a distance of 40 to 50 cm from the light [2]. Moreover, the distance is essential as the heat formation from the fluorescent lamps may harm the infant. FIGURE 5 shows how far away should the infant be placed from the light source.

FIGURE 5. Infant Undergoing Photoherapy Using Fluorescent Lamp [8]

2.4.3 Halogen Bulbs

Halogen bulbs offers a compact and lightweight alternative for phototherapy. These bulbs have a recommended lifespan similar to fluorescent lamps in which ranges between 1000 and 1500 h [2]. This is assuming of to 2–3 months of continuous usage. A previous research was conducted by YS Chang *et al* [1]. In which it compared the percentage of bilirubin degradation for in vitro and in vivo experiment using LED and halogen bulb as the phototherapy light source [1]. The results of the experiment shows that the percentage of bilirubin degradation was higher when using blue LED compared to the halogen bulb.

Quartz halogen bulbs are never reported to reduce in intensity with time. These bulbs are also quite fragile, especially when in hot condition. Another type is the not commonly used gas discharge bulb. For this type, the bulb has to be changed after 1000 H [3]. The infant should be placed away from the halogen bulb as it has a high heat production [2]. These bulbs may cause burns and the preferred distance from the infant depends on the type of bulb used . The configuration of using halogen bulbs is shown in FIGURE 6.

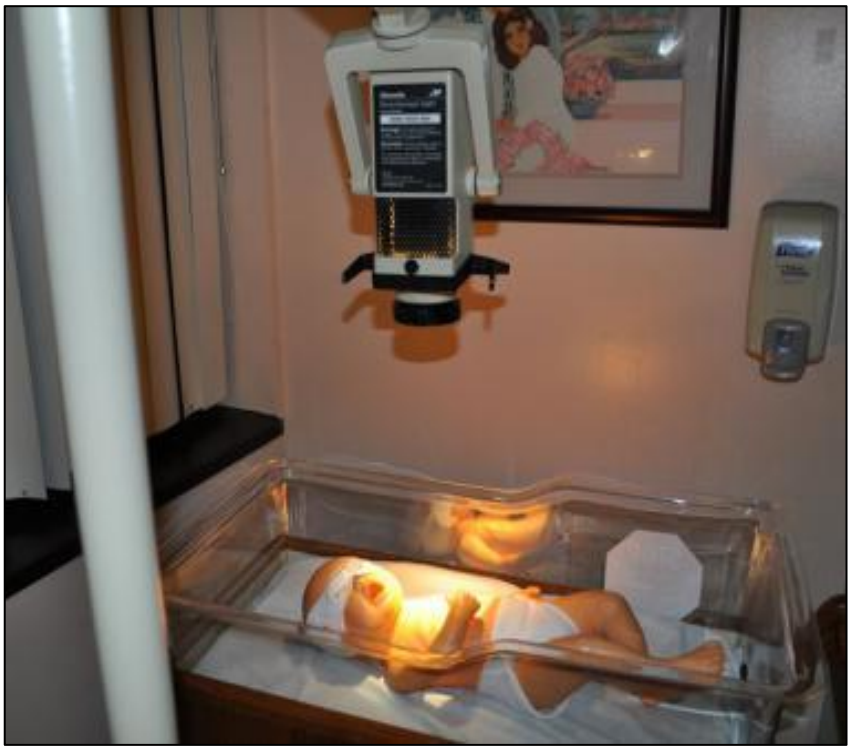

FIGURE 6. Phototherapy Using Halogen Bulb [9]

2.4.4 Blue LEDs

A LED is a special type of semiconductor diode which emits a certain colour of light when connected to an electrical circuit. The colour of the LED depends on the semiconductor utilized and the light produced is of narrower bandwidth [3] . LED devices usually contain gallium nitrate or nitride or indium or as semiconductor element. LEDs emit high-intensity light while generating little heat, meaning the distance of the infant from the light could be reduced hence increasing spectral irradiance. A research by Vreman *et al.* , compared the efficiency between different color of the LEDs and other light sources by its bilirubin degradation percentage [1]. The experiment concludes that blue LEDs was proven to be able to reduce bilirubin level by 28 % . It is followed by blue-green LEDs, white light and green LED with the percentage of bilirubin degradation of 18 %, 14 % and 11 % respectively [1]. FIGURE 7 shows an infant undergoing phototherapy using blue LEDs.

FIGURE 7. Phototherapy Using Blue LEDs [10]

Recently, it has been reported that an alarming number of phototherapy devices based on blue light emitting diode (LED) lights are being used [2]. These LEDs has long bulb life which offers more than 10 000 H. They have low heat production and the cost is low. It was found that bilirubin closer to the bilirubin absorbance spectrum causing it to be more sensitive to blue and blue-green regions of the visible spectrum[1]. The most suitable wavelength of the light source to be used ranges between 400nm – 520nm with a peak of 460nm ± 10nm . The dominant wavelength of the blue LED is ranging between 465nm –470nm, hence, it is suitable in reducing bilirubin [1] . In a recent study, phototherapy using low-cost LED lights was found to be as effecient as conventional light sources such as fluorescent lights or halogen bulbs [2].

The irradiance of the LEDs, however, decreases exponentially as the distance from the baby increases. By considering the safety precautions, placing the light source lights as near to the infant as possible could result in the irradiance to be maximized [3]. For LED lights, the distance from the infant is 20 cm. According to a previous research, blue LEDs has the greatest irradiance and it is the most effective light source for bilirubin degradation [1]. Commercially available LED devices which are used for the treatment of jaundice provides light from either above or underneath the baby [3].

The table below concludes the different characteristics of the light sources being used for phototherapy.

TABLE 1. Comparison table of characteristics of blue LEDs, conventional light sources, and sunlight.

Light source	Blue LEDs	Conventional light sources : Fluorescent lamps or halogen bulbs	Sunlight
Efficiency (%)	2 to 10 times more efficient than conventional light sources [1].	Less efficient than LEDs [1].	-
Bilirubin degradation percentage	44% for in vitro, 30% for in vivo [1].	35% for in vitro, 16% for in vivo [1].	Almost the same percentage as conventional light sources [1].
Lifespan	More than 10000 hours [2].	1000h to 1500h [2].	-
Heat production	Low [2].	High [2].	-
Cost	More than several hundred dollars [2].	Less than 100USD [2].	`
Wavelength	Dominant wavelength is between 465nm to 470nm [2].	Maximum wavelength is 452nm [3].	`

2.5 Advantages and Disadvantages of UV Light Sources

Each UV light sources has their own advantages and disadvantages respectively. TABLE 2. below explains what are those pros and cons.

TABLE 2. Advantages and Disadvantages of UV Light Sources

Light source	Advantages	Disadvantages
Blue LEDs	-Low heat production causing its distance is closer to the infant, spectral irradiance would be increased [3]. -Lightweight, compact, low energy consumption, non-fragile [3].	-High irradiance LED devices may cause hyperthermia and skin rashes [3].
Fluorescent Lamps	-Spectral output of fluorescent lights is well matched with the absorption of bilirubin [2].	-Light intensity and irradiance of fluorescent tubes reduce with time [3].
Halogen Bulbs	-Halogen bulbs are lightweight, compact, and has an acceptable level of irradiance [2].	-Halogen bulbs generate high heat causing high risk of burns and dehydration [2].
Sunlight	-Always available	-May cause burns if not monitored [1]. -Contains significant level of warming infrared radiation which could impose biological hazards to the infants [3].

CHAPTER 3

METHODOLOGY

3.1 Devices and Equipments

The table below shows the devices and equipments used for this research which is the spectrophotometer, fluorescent lamp, and blue LED strips. The specifications of each device are stated.

TABLE 3. Device Specifications

Device	Brand	Specifications
Portable Spectrophotometer (CM-2500c) 	Konica Minolta	-Wavelength range : 360 nm to 740 nm - Reflectance range : 0 to 175% - Display data : Spectral value & graph, , color difference value & graph, colorimetric value , PASS/FAIL result
Fluorescent Lights (TL20W/52) 	Philips	-Average lifespan : Abt 2,000 hrs -Brightness : 330 lm -Wattage : 20w - Overall length : 2 ft.
Blue LED Strips 	NA	- LED quantity: 15 per strip - Lamp bead type: SMD 3528 - Input voltage: DC 12V - Size: 30 x 1 cm per strip -Waterproof

3.2 Preliminary Experiment Flowchart

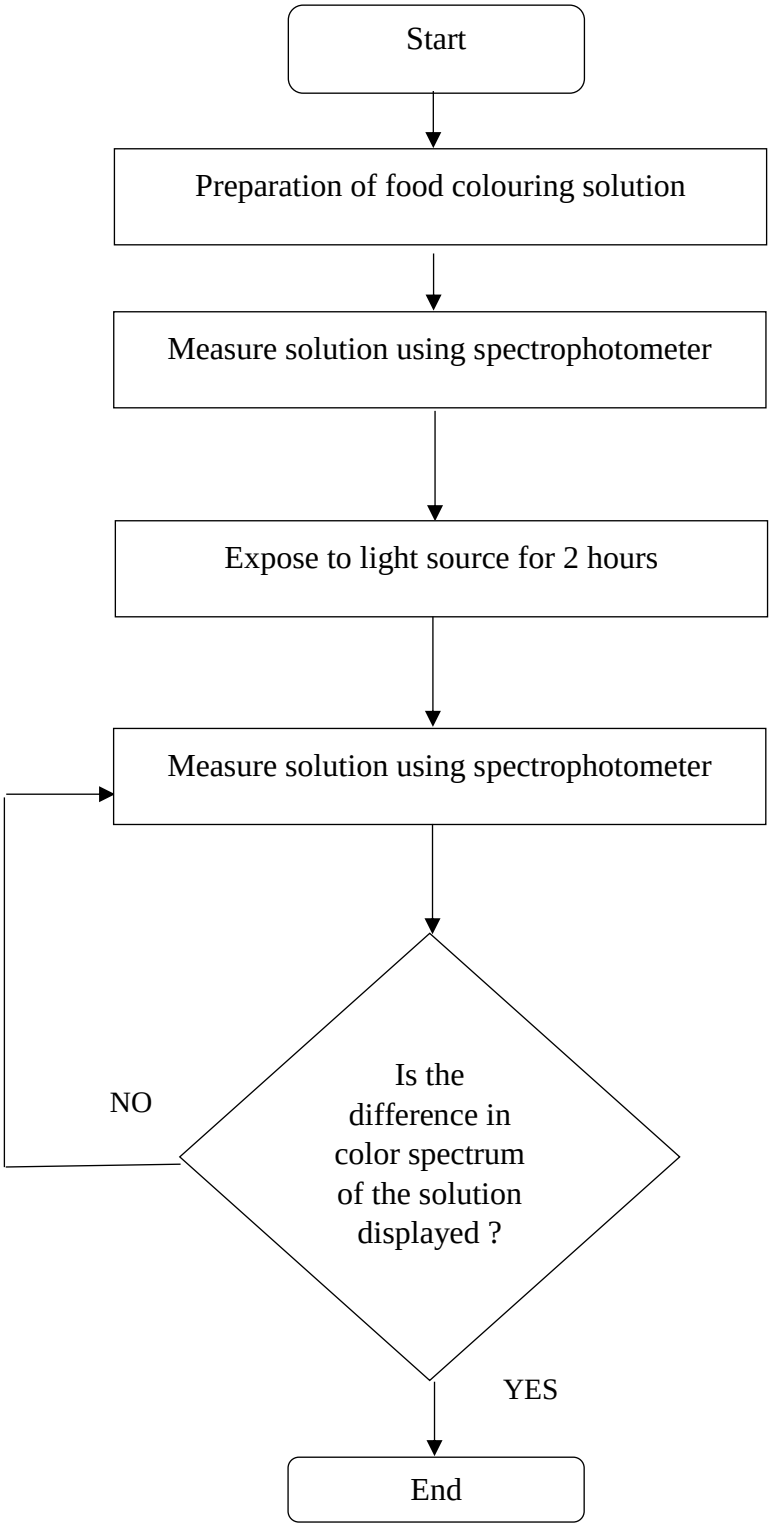

FIGURE 8. Preliminary Experiment Flowchart

The flowchart in FIGURE 8 shows the experimental methodology of this project. The first step is to make a food colouring solution. The solution is made by using a certain amount of food colouring into 10ml of water. The solution made is then measured to obtain the initial colour spectrum data by using a spectrophotometer. Next, the solution is exposed to a particular UV light for two hours.

The final color spectrum of the solution after 2 hours is measured again. If the initial and final concentration has a difference in measurement , the experiment ends. If not, the experiment is repeated again using the same concentration. The experiment is repeated for better accuracy.

FIGURE 9. Measure Using Spectrophotometer

This preliminary experiment was done to determine whether the spectrophotometer is capable of measuring the concentration of a solution or not. The limitation is this device is it could not detect the colour intensity or concentration of a solution as it is originally not suitable for detecting colour from solutions. This specific type of spectrophotometer is used specifically to measure colour of objects or solids hence this experiment is essential to determine whether the device is acceptable or not. It is a simple experiment by using food colouring solution . The fixed solution is made of four drops of food colouring into 10ml of water. This solution is measured for five

times repeatedly by using the device as shown in FIGURE 9 and the average reading is noted.

The experiment is the continued by exposing the food colouring solution to a light source which is the fluorescent lamp. The lamp is set up 10cm above the solution by using a box. This procedure is done for 2 hours as it is following the hospital standard in which infants are allowed to be fed every 2 hours [2] . The position of an infant is also changed during this time interval.

Lastly, the solution is measured once again for the final reading. The difference between the initial and final reading is displayed on the device. This experiment is also important to test whether the lamp could actually change the concentration of a coloured solution.

3.3 Experimental Flowchart

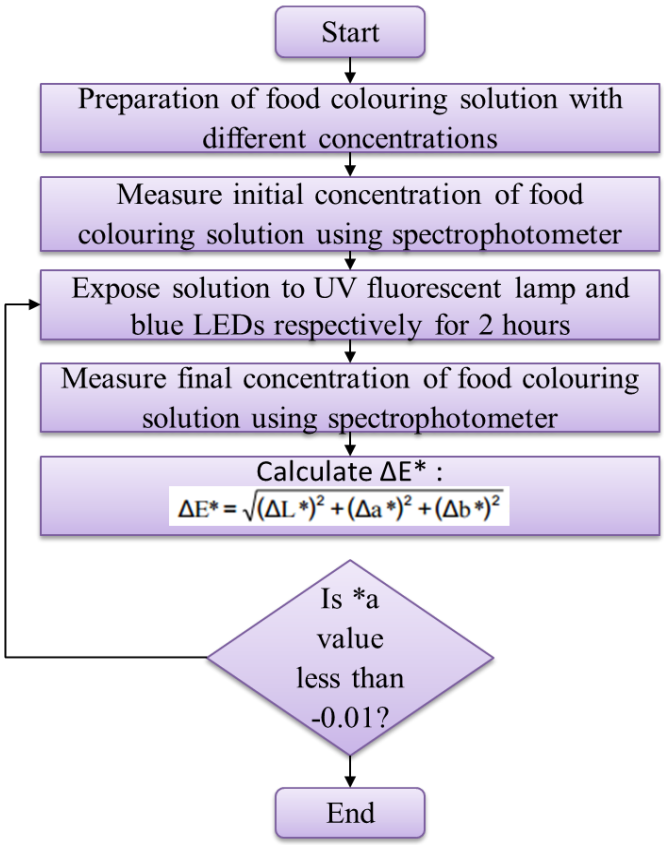

FIGURE 10. Experimental Methodology Flowchart

The flowchart in FIGURE 10 shows the experimental methodology of this project. The first step is to make different concentrations of food colouring solution. The solution is made by using a different amount of drops of food colouring solution into 10ml of water. This experiment is using green food colouring solution as yellow food colouring solution could not be detected well by the device. It is acceptable as bilirubin is actually yellowish green in colour [3]. Five different food colouring solution is made for each UV light. The solution is labelled as shown in FIGURE 11. The food colouring solution that is made has to be different in concentrations as to increase the precision of the experiment.

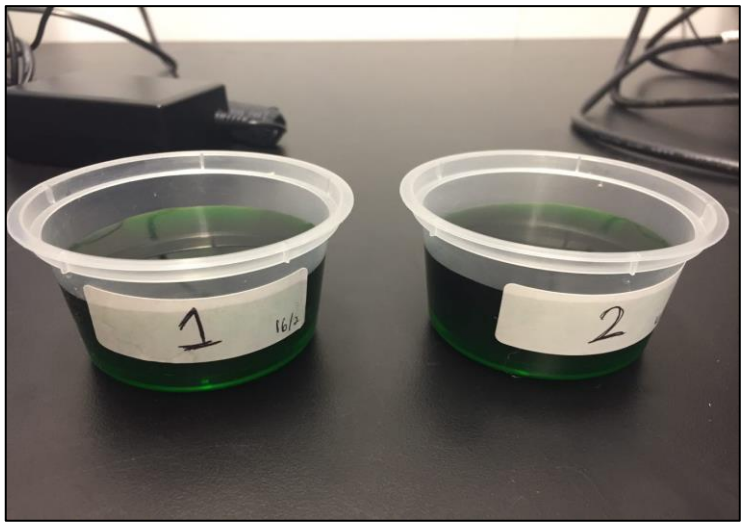

FIGURE 11. Labelled Food Colouring Solution

Each of the solution is then measured by using a spectrophotometer device as shown in FIGURE 12. The initial concentration of the solutions are recorded into a table.

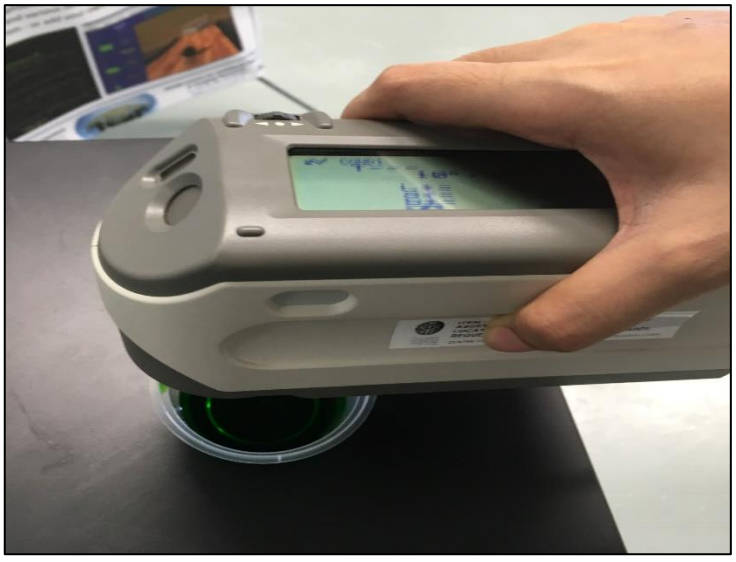

FIGURE 12. Measure Initial Concentration

After measuring the solution, next step is to expose the solution with two different light sources which is blue LEDs (LED strips) and fluorescent lamp (Philips TL20W/52) respectively. The front view of the LED strips used is as shown in FIGURE 13. This light source is arranged with 10 strips of 15 LEDs each. The reason for choosing this configuration of the LED strips is because it is stated in the specifications of the LED strips that it is best displayed when it is 20cm away from each other . Hence, that distance is maintained by placing the strips next to each other.

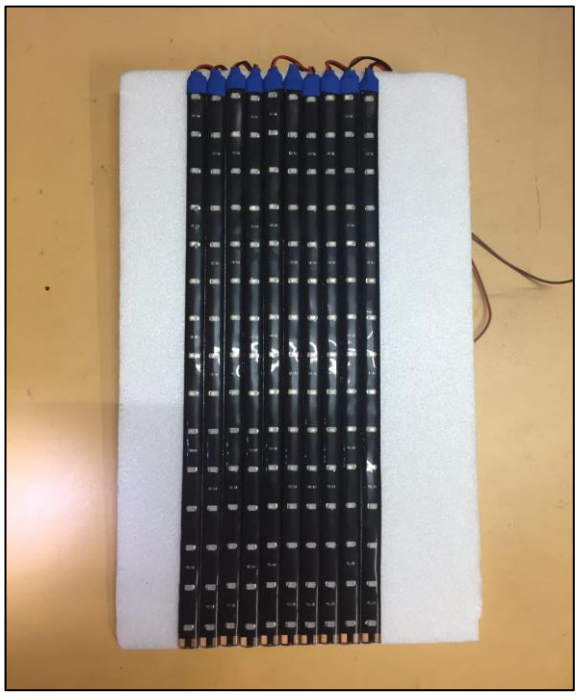

FIGURE 13. Front View of LED Strips Board

FIGURE 14 shown below shows the backside view of the LED strip. The positive and negative wires of all the LEDs into a breadboard. The advantage of this simple wiring is that if a LED strip doesn't work, the other LEDs are not affected. The output of this breadbord is connected to a power source which gives out 12V.

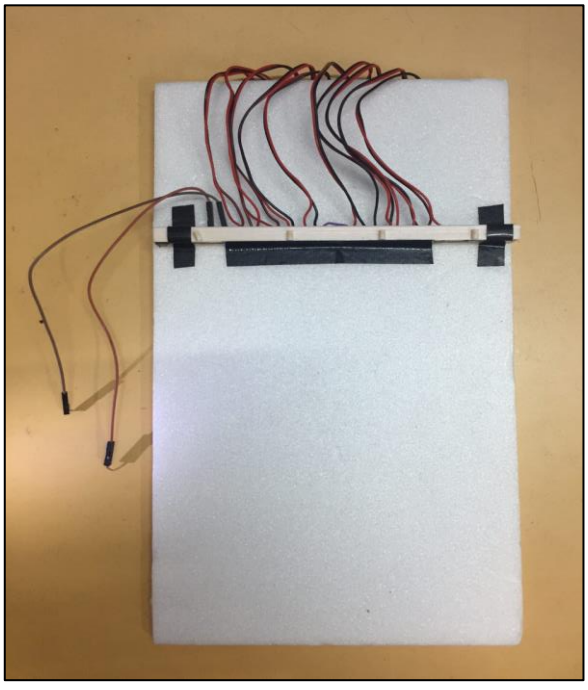

FIGURE 14. Back View of LED Strips Board

The set up of the experiment shown in FIGURE 16 is for when blue LED strips is used. Blue LEDs experiment is run by using a powerbank as a power source. The output of the power bank is only 5V hence a boost converter is used to increase the voltage up to 12V. A box is used to place the LED strip board 20cm above the solution.

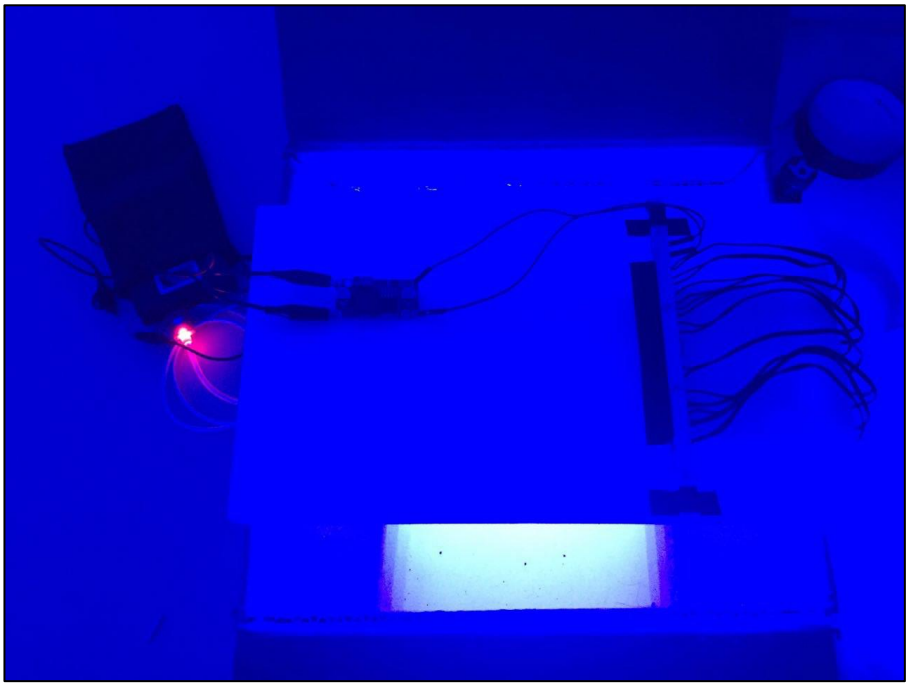

FIGURE 15. Blue LED Strip Experiment Configuration

Meanwhile in FIGURE 17 shows the experiment setup when a fluorescent lamp is used. This lamp is 2ft in length so the configuration is a bit different from the blue LED strip experiment. Two boxes are placed at each end of the lamp to elevate the lamp as practically it is not allowed to put the light close to an infant. The ultraviolet characteristics of the lamp is harmful to the infant [2].

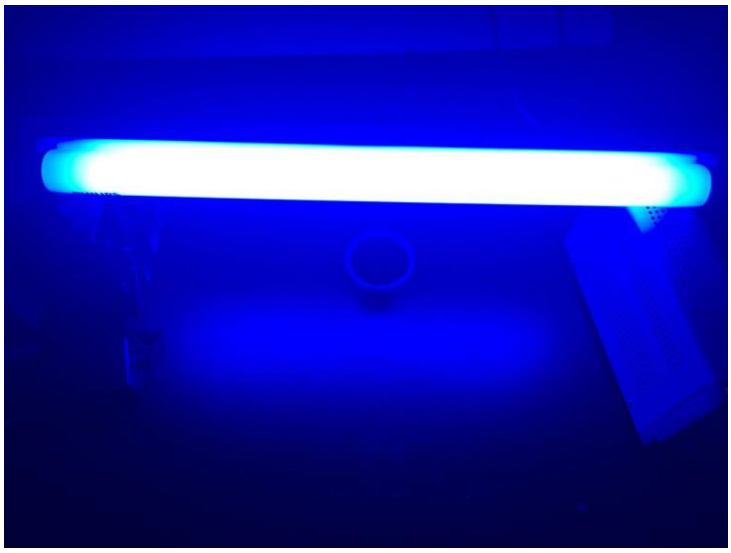

FIGURE 16. Fluorescent Lamp Experiment Configuration

Both of the solution is exposed to the light source for 2 hours before the reading is taken again. The reason for setting 2 hours as the interval to measure the solution is because it is using the hospital standard when treating jaundice.

For every two hours the bilirubin level of an infant would be supervised in conjunction with the feeding time of the infant. Besides that, the position of the infant should be changed for every 2 hours as it would increase the surface area of bilirubin absorption [2] . The final solution is measured and the data is tabulated.

3.4 Gantt Chart and Key Milestone

The table below shows the Gantt Chart and Key Milestone for FYP2. The schedule was made to keep the work progress in schedule and ensures that enough progress is made for the completion of FYP2.

TABLE 4. Gantt Chart and Key Milestone

Activities	Week No														
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Project Setup Work	■	■	■	■	■	■	■								
Literature Review Research Work		■	■	■	■	■	■	■	■	■	■	■			
Progress Report Submission							X								
Project Work Completion								■	■	■	■	■			
Pre-SEDEX											X				
Draft Final Report Submission													X		
Final Report & Technical Paper Submission														X	
Viva															X

■ Gantt Chart

X Key Milestone

CHAPTER 4

RESULTS AND DISCUSSION

1. Preliminary Experiment Results

FIGURE 17 below shows the set up for the preliminary experiment that had been done for this semester. It is a preliminary experiment which is carried out to test whether the spectrophotometer is able to calculate the readings of a solution or not. This experiment is necessary as it determines whether there is a change in the solution after being exposed to the light source. The spectrophotometer shows the L*a*b* color space of the solution . L*a*b* is a detailed color determination system which could differentiate every colour according to certain values.

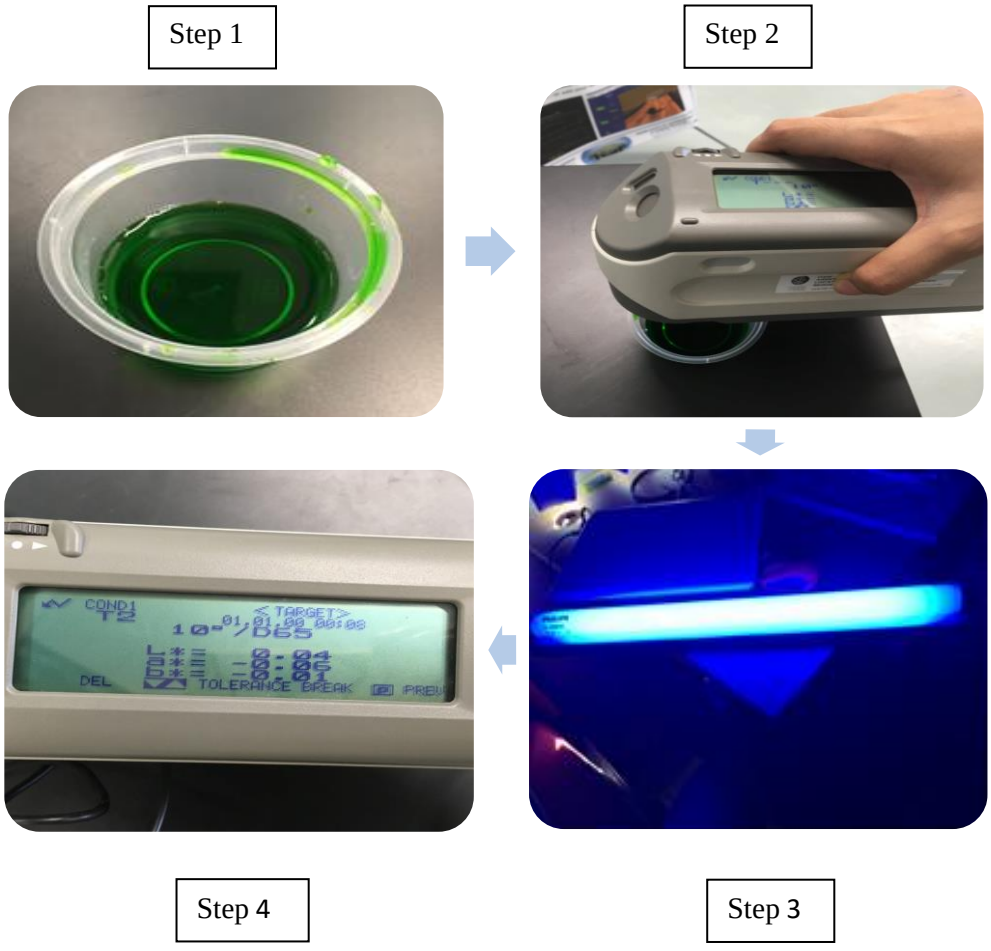

FIGURE 17. Preliminary Experiment Set Up

Step 1 is the preparation of the food colouring solution. Four drops of food colouring is dropped into 10ml water. Step 2 is the measurement of the initial reading of the solution. This step is repeated a few times and the average reading is noted down. Due to the high sensitivity of the device, for the same solution, different results may be obtained from the measurement. Step 3 would be exposing the solution to a light source, in this case, the fluorescent lamp. Step 4 is to measure the final measurement of the solution after 2 hours. The results are displayed on the device.

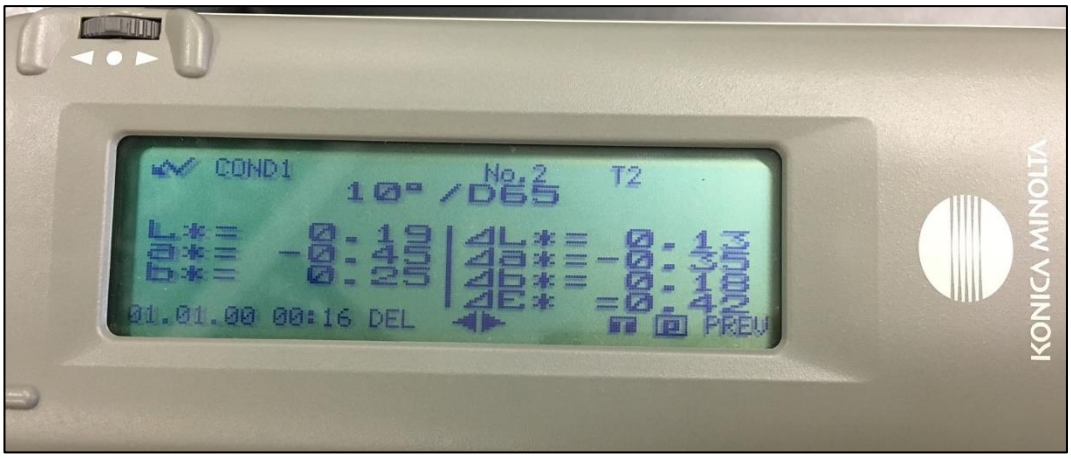

FIGURE 18. Preliminary Experiment Result

By setting the experiment as shown in FIGURE 18, the results obtained after exposing the solution to a fluorescent lamp for 2 hours is as shown above. ΔE shows the total difference in the color spectrum of the solution. It can be concluded that the lamp does changes the concentration of the solution. The experiment is to be continued further by replacing the food colouring solution by a bilirubin solution.

2. Experimental Results

TABLE 5 shows the measurements obtained from the experiment using fluorescent lamp for a period of 6 hours. An interval of 2 hours is taken as the time to take the measurement. Five different solutions is used for each UV light. The data obtained from the spectrophotometer is the form of CIELAB color space (L*, a*, and b*). The Lab color space is a system adopted by International Commission on Illumination (CIE) in 1976 which describes mathematically all perceivable colors in the three dimensions. L for lightness whose values starting from 0 (pure black) to 100 (pure white) meanwhile a and b for the color opponents green to red and blue to yellow. The color space model is as shown in FIGURE 19 below. The limitation of this results is that the device could only detect the colour difference of the solution and not other data.

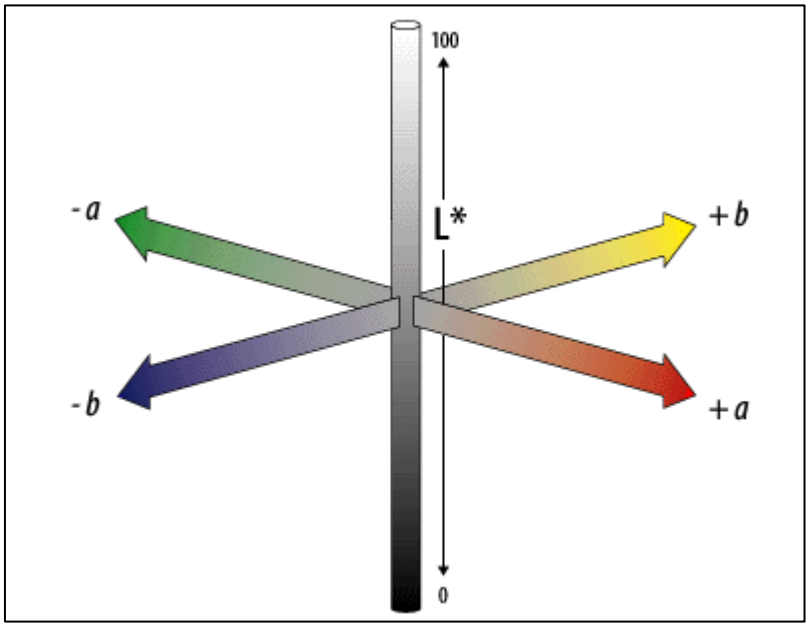

FIGURE 19. Lab Color Space Axis Model [11]

TABLE 5. Fluorescent Lamp L*a*b* Results

Name	Solution	Exposure Time (Hour)	*L	*a	*b
Fluorescent Lamp	1	Initial	0.01	-0.18	-0.02
		2	0.12	-0.10	0.00
		4	0.26	-0.05	0.00
		6	0.35	-0.01	0.00
	2	Initial	0.22	-0.15	0.00
		2	0.35	-0.09	0.00
		4	0.43	-0.02	0.00
		6	0.54	-0.01	0.00
	3	Initial	0.26	-0.25	-0.01
		2	0.39	-0.17	0.00
		4	0.40	-0.04	0.00
		6	0.52	-0.02	0.00
	4	Initial	0.08	-0.35	0.00
		2	0.14	-0.27	0.00
		4	0.22	-0.18	0.00
		6	0.31	-0.07	0.00
	5	Initial	0.30	-0.29	0.00
		2	0.34	-0.19	0.00
		4	0.40	-0.06	0.00
		6	0.45	-0.01	0.00

Meanwhile TABLE 6 below shows the data obtained from replacing the fluorescent lamp with 10 blue LED strips. The exact time period was also used to compare the efficiency of both solutions in reducing colour concentration. For both experiments, it can be seen that *b has a value of 0 or almost 0. This is because *b detects the blue or yellow region of the solution. The characteristic of the L*a*b* colour space is that it determines that a colour cannot be two colours at the same time. This means that the values could either be at a* or b* .

TABLE 6. Blue LEDs L*a*b* Results

Name	Solution	Exposure Time (Hour)	*L	*a	*b
Blue LEDs	1	Initial	0.03	-0.13	0.04
		2	0.10	-0.04	0.00
		4	0.24	-0.03	0.00
		6	0.36	-0.01	0.00
	2	Initial	0.12	-0.29	0.00
		2	0.26	-0.17	0.00
		4	0.34	-0.09	0.00
		6	0.47	-0.04	0.00
	3	Initial	0.04	-0.14	0.00
		2	0.15	-0.09	0.00
		4	0.20	-0.02	0.00
		6	0.34	-0.01	0.00
	4	Initial	0.23	-0.38	0.04
		2	0.36	-0.22	0.00
		4	0.41	-0.09	0.00
		6	0.49	-0.04	0.00
	5	Initial	0.10	-0.24	0.00
		2	0.23	-0.12	0.00
		4	0.27	-0.05	0.00
		6	0.40	-0.01	0.00

For both of the experiment, it can be seen that the values for L*, lightness, increases with time. This shows that the solution is from black region changing to pure white region. Furthermore, *a values can also be seen changing from more negative value to less negative value. This *a value denotes that the solution changes from green region to the middle region which is colourless grey. This data could be easier explained by FIGURE 20 which shows how does the values are matched with their colours. Hence the data obtained from both of these experiment is accepted and further calculations are done.

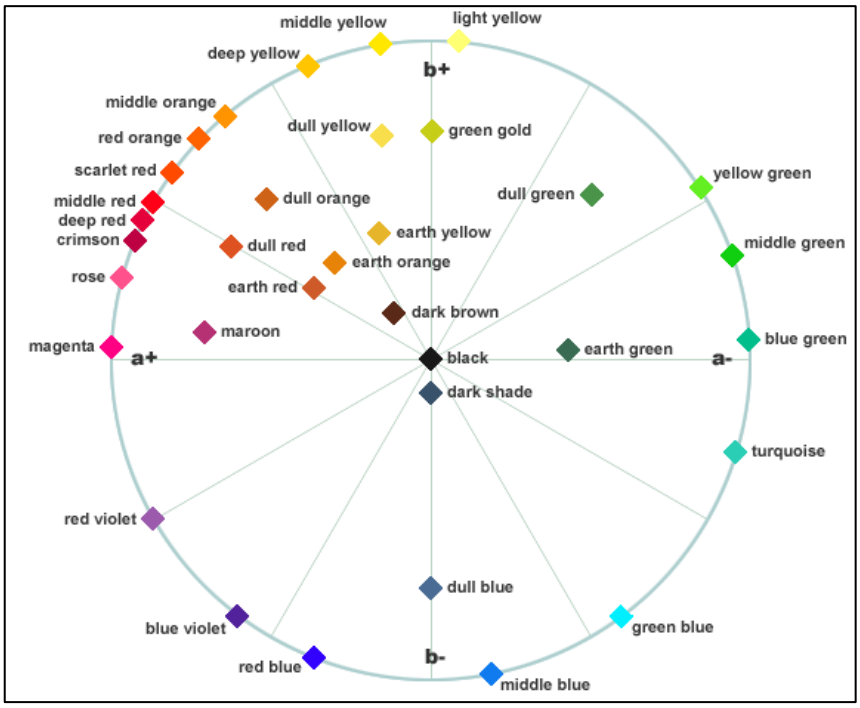

FIGURE 20. Descriptive Representation of CIELAB Colour Space [12]

TABLE 4 and TABLE 5 is merely the raw data obtained from the device. The difference between the L*, a* and b* values of the initial and final solution will be shown as Delta E (ΔE*). From this data obtained , ΔE* has to be calculated to see the difference of colour of all the solution. ΔE* is given by Equation. (2).

$$\Delta E^* = \sqrt{(\Delta L^*)^2 + (\Delta a^*)^2 + (\Delta b^*)^2} \quad (2)$$

To calculate ΔE*, ΔL*Δa*Δb* is first tabulated into TABLE 7 and TABLE 8 for the fluorescent lamp and blue LED experiment respectively.

TABLE 7 belows shows the calculated values of ΔL*,Δa*, and Δb* for the fluorescent lamp experiment. ΔL* spots a slightly larger difference than Δa*, meaning that the solution changes from the dark to white region. Δb* has a very small difference hence it can be disregarded.

TABLE 7. Fluorescent Lamp ΔL*Δa*Δb* Calculation

Name	Solution	Exposure Time (Hour)	ΔL*	Δa*	Δb*
Fluorescent Lamp	1	Initial	-	-	-
		2	0.11	0.08	0.02
		4	0.14	0.05	0.00
		6	0.09	0.04	0.00
	2	Initial	-	-	-
		2	0.13	0.06	0.00
		4	0.08	0.07	0.00
		6	0.11	0.01	0.00
	3	Initial	-	-	-
		2	0.13	0.08	0.01
		4	0.01	0.13	0.00
		6	0.12	0.02	0.00
	4	Initial	-	-	-
		2	0.06	0.08	0.00
		4	0.08	0.09	0.00
		6	0.09	0.11	0.00
	5	Initial	-	-	-
		2	0.04	0.10	0.00
		4	0.06	0.13	0.00
		6	0.05	0.05	0.00

TABLE 8 below shows the values obtained by calculating ΔL*,Δa*, and Δb* of the blue LED experiment. It can be seen that Δa* has almost similar values of ΔE* unlike the fluorescent lamp experiment which Δa* has only small difference. The relatively small values of Δb* may be disregarded as well because it has no significance to the results.

TABLE 8. Blue LEDs ΔL*Δa*Δb* Calculation

Name	Solution	Exposure Time (Hour)	ΔL*	Δa*	Δb*
Blue LEDs	1	Initial	-	-	-
		2	0.07	0.09	0.04
		4	0.14	0.01	0.00
		6	0.12	0.02	0.00
	2	Initial	-	-	-
		2	0.14	0.12	0.00
		4	0.08	0.08	0.00
		6	0.13	0.05	0.00
	3	Initial	-	-	-
		2	0.11	0.05	0.00
		4	0.05	0.07	0.00
		6	0.14	0.01	0.00
	4	Initial	-	-	-
		2	0.13	0.16	0.04
		4	0.05	0.13	0.00
		6	0.08	0.05	0.00
	5	Initial	-	-	-
		2	0.13	0.12	0.00
		4	0.04	0.07	0.00
		6	0.13	0.04	0.00

ΔL*,Δa*, and Δb* are just the data which shows the difference between each of the color space axis, In order to calculate the total difference of the solutions, a formula is used. Now that the values of ΔL*,Δa*, and Δb* are calculated, the values can be implemented to calculate ΔE*.

ΔE* is calculated by using the formula given in Equation (2). The results are tabulated in TABLE 9 and TABLE 10.

TABLE 9. Fluorescent Lamp ΔE* Calculation

Name	Solution	Exposure Time (Hour)	ΔE*
Fluorescent Lamp	1	Initial	-
		2	0.138
		4	0.149
		6	0.099
		TOTAL	0.386
	2	Initial	-
		2	0.143
		4	0.106
		6	0.111
		TOTAL	0.360
	3	Initial	-
		2	0.153
		4	0.131
		6	0.122
		TOTAL	0.406
	4	Initial	-
		2	0.100
		4	0.121
		6	0.143
		TOTAL	0.364
	5	Initial	-
		2	0.108
		4	0.143
		6	0.071
		TOTAL	0.322

The table above shows the total ΔE* for all the solutions used when using fluorescent lamp. By calculating the average of the total ΔE* for 5 solutions using Equation 3., the value obtained is 0.368.

$$Average\ \Delta E* = \frac{\sum \Delta E*}{5} \quad (3)$$

TABLE 10 below is the calculated values for ΔE* which is the main determination factor to prove that blue LEDs are indeed better than fluorescent lamps or not.

TABLE 10. Blue LEDs ΔE* Calculation

Name	Solution	Exposure Time (Hour)	ΔE*
Blue LEDs	1	Initial	-
		2	0.121
		4	0.140
		6	0.122
		TOTAL	0.383
	2	Initial	-
		2	0.184
		4	0.113
		6	0.139
		TOTAL	0.436
	3	Initial	-
		2	0.121
		4	0.086
		6	0.140
		TOTAL	0.347
	4	Initial	-
		2	0.210
		4	0.139
		6	0.094
		TOTAL	0.443
	5	Initial	-
		2	0.177
		4	0.081
		6	0.136
		TOTAL	0.394

Calculating the average ΔE* of both experiments using Equation 3 , the value obtained for fluorescent lamps is 0.368 meanwhile the value obtained for blue LEDs is 0.401. This concludes that blue LEDs is at least 10% more efficient than fluorescent lamps in terms of colour differentiation.

CHAPTER 5

CONCLUSION

As a conclusion, this research is made to discover the efficiency of UV blue LEDs in reducing bilirubin concentration level. This is essential as it has not been proven the efficiency of UV blue LEDs compared to conventional light sources in terms of reducing bilirubin level concentration. Current conventional phototherapy light sources are expensive and are often not available in some developing countries. Practically, the alternative solution for this problem is by replacing those light sources with the inexpensive UV blue LEDs. Through this project , it has been proven that blue LEDs are more efficient than UV fluorescent lamps in the aspect of color space differentiation. It can be concluded that blue LEDs could be used as an alternative way to replace conventional phototherapy lights. Overall, the objectives of this project is achieved but a few recommendations to further improve this project was determined. First is to use bilirubin serum instead of food colouring for better results. Next is to compare the efficiency of more light sources as a comparison. Lastly is to use a device that could measure the concentration of a solution more accurately and has less sensitivity. Another recommendation would be to add another manipulated variable which is the temperature of the light sources and the distance of the LEDs between each other.

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