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Using Analytical Hierarchy Process (AHP) to Select the Best Thermo Scientific CO_2 Incubator

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ABSTRACT

Incubators are used in the tissue culturing laboratories to maintain a stable environment for the growth of cells, cultures and antibodies. It is considered to be an important tool in the technology development arena. Since incubators involve significant investment, it is important to select the best incubator for the purpose. The purpose of this study is to find the best incubator among the four Thermo Scientific CO_2 Incubators, using Analytical Hierarchy Process (AHP) with five criteria. Each Incubator has its own range of precision to control the temperature suitable for tissue cell growth, humidity to maintain a stable environment, CO_2 range to avoid the desiccation of the cells and the number of shelves, which signifies the storage volume available inside the incubator.

KEYWORDS: thermos scientific CO_2 incubators, analytical hierarchy process, tissue culturing, biotechnology

INTRODUCTION

Tissue culture is an advanced biological research technique, which concentrates on the growth of tissues or cells from animal or plant separate from the organism. These tissues are transferred to a liquid or semi solid medium to create an artificial environment which would help the cells to survive and grow. The medium considered for the growth of the cell must contain appropriate proportions of acid or alkaline. This medium is taken in either a flask, tube or plate and it is incubated at specifications, which are close to tissue's normal environment. Sterile conditions are required throughout the experiment, since there is a huge chance of contamination with the tissues.

An incubator is designed to maintain a stable environment for the cells, which includes constant temperature, high humidity for the growth of tissues under CO_2 atmosphere. The simplest of incubators are used at 36 to 37°C but they can reach to a temperature of 70°C. They can control humidity between 95% to 98% and CO_2 concentrations from 0.3% to 19.9%. Modern day incubators come with special features such as refrigerated temperatures, automatic shaking measured by revolutions per minute, programmable controls with alarms. The interior of an incubator is of non-corrosive stainless steel or antimicrobial copper surfaces in order to prevent contamination.

First incubator was introduced in the twentieth century in which the sample was first transferred to the petri dish and it was placed on the rack inside the incubator. The sample was heated to a temperature of 37°C with an appropriate amount of CO_2 resulting it to survive, grow and multiply. The first CO_2 incubator was developed in 1800s and consisted only of simple bell jar with lit candle. The culture to be developed was placed near the candle and then was dried, this particular method can be termed as air jacketed CO_2 incubator. The first commercial incubator was developed in late 1960s, which included refrigerated incubator shaker. The year of 1984 marked an innovative incubator design, which provided uniform temperature distribution. This was achieved using warm air jacket design, heated outer door and five heating elements that left no hot spots. The first chilling and heating incubator was introduced in 1990s under the

name of Echo Therm. In 2001, an ambient temperature stabilization control system was implemented which would help control the temperature range and the rate of heat loss from the incubator. In 2003, direct heat, fan less design incubators were in fashion because of their lightweight and advanced CO_2 controllers. A new invention was made during this time to save the space inside the incubator. A high efficiency microplate incubator was constructed with multiple incubation chambers and a water reservoir inside the chamber. These chambers could be controlled by a single control and would conserve a lot of space. The first IR-CO_2 incubator was introduced in the market in 2008. This incubator had all the high-end features such as large capacity, automatic moist heat decontamination cycle which could cleanse overnight, interiors that could support shakers, cell rollers and water recirculation system. In 2010, BINDER launched a gas supply kit which the life of researchers very simple. This kit would automatically change the second the gas bottle when the first one was empty, which reduced the researchers' labor. (Encyclopædia Britannica 2005; Buie J. 2010; Labcompare 2017).

The Analytical Hierarchy Process (AHP) is a multi-criteria decision-making approach, which is based on the evaluation of the number of alternatives in terms of the number of criteria. It was introduced by Thomas Saaty in 1980 with an aim to help the decision makers to set correct priorities and make the best decision. AHP is considered a tool which can be used to solve complex decision problems faced during engineering applications. It uses hierarchical structure approach, which consists of objective, criteria, sub criteria and alternatives. The selection of the best alternative is based on pairwise comparisons using the subjective and objective data. AHP consists of a set of criteria to be evaluated and a set of alternatives amongst which one needs to find the best option. The decision maker does a pairwise comparison of the criteria in order to generate weights for each criterion. The importance of a particular criterion is determined by the weight corresponding to it. Next step in AHP is to fix a criterion and assign weights to the alternatives based on the pairwise comparison done by the decision maker. The best alternative for that particular criterion is the one with the highest weight. At last, AHP combines all the weights determining a score, which helps in ranking the alternatives. AHP is considered to be flexible and powerful tool because of its special feature of evaluation of both criteria and alternatives using pairwise comparison. The results obtained by this method are based on the decision maker's experience and hence it is a tool that can translate all the quantitative and qualitative evaluations into multi criteria ranking (Triantaphyllou & Mann 1995). AHP is easy to implement because the user needs to compare two criteria or alternatives and assign certain relative scores.

Table 1: Relative Rating Values

Value	Interpretation
1	j and k are equally important
3	j is slightly more important than k
5	j is more important than k
7	j is more important than k
9	j is absolutely more important than k
2,4,6,8	Values between two adjacent judgement

The remainder of the paper is organized as follows. The section on literature review discusses incubators and AHP. The section on research methodology and results describes the methods in details and presents the findings of this paper. Finally, the section on conclusion draws some conclusions.

LITERATURE REVIEW

Biotechnology is an ever growing field and holds a great interest for all the scientists throughout the world. Prasetya & Deswina state the impact of biotechnology in the fields of agriculture, health, environment and economy. The agriculture biotechnology is mainly related to the improvement of plants and protecting it against the pests and increasing their disease and virus resistance. The agriculture biotechnology aims in producing high quality bio fertilizer, bio decomposer, bio pesticide and bio insecticide which would support the agriculture production. This will increase the productivity which in turn will help the economy of the nation. Genetic engineering is performed in order to manipulate certain genes which is important for biotransformation of cellulose, this in turn would help in the development of paper industry. Pharmaceutical biotechnology deals with the research in the active compounds antioxidant, anticancer, antidiabetics, antivirus. With the help of this study, diagnostic kits are developed which would help the medical biotechnology field on a large scale. In case of animal biotechnology, technology is used to produce artificial insemination and embryo transfer, enriched feed production, probiotics and enzymes, and vaccine for animal diseases. Industrial biotechnology includes enzymes for replacing chemical process and biocatalyst. Environmental biotechnology is used for waste treatment, bioremediation and biosensor for environmental condition and quality control. Biotechnology research is considered as an important way to strengthen the economic, social and environmental factors (Prasetya & Deswina 2009).

John invented a plant incubator which improved the hotbeds for germinating the seeds of plants of all kinds. The heated moisture is controlled by supplying the heat and vapor both above and below the seed bed. Another interesting invention in this incubator is its completely enclosed structure and removable seed bed which helps the seeds get full moisture from the top and heat and vapor from the bottom. This setup of the incubator helps the growth of seeds rapidly. In order to prevent injury to the seeds, there would be an escape route for the steam which would also help in case of overheating of water. Another incubator which was widely used commercially was Combination propagator, incubator, and brooder invented by Wade Sr George H. This device is designed in such a way that it can be used for propagation, incubation and brooder which means that it is a combination incubator for plant and animal cells. This device would eliminate the need to use different incubators for different purposes. The incubator is an enclosed structure which has a closed top and an open bottom which consist of heating element. Just above this heating unit would be a tray of seeds. This would help both the plant and animal cells derive equal amount of heat, moisture and vapor from the device setup and would give desired results (U.S. Patent 1942; Wade Sr 1950).

Bioreactors are used in incubators in order to accelerate the cultivation process and this acceleration takes place in different ways. Vijay Singh explains a bioreactor which helps in the cultivation of animal, insect, and plant cells using wave agitation induced by a rocking motion. This motion is beneficial to the cells as it spreads the nutrients and oxygen evenly without damaging the gas bubbles. This bioreactor is disposable and hence it requires no cleaning or sterilization. The advantages of using a bioreactor are it takes no additional space in the incubator and is very much cost effective. The bioreactor plays an important role in eliminating the sparging of air and damage done due to mechanical rotors. It is a closed system which does not require complex controls. The bioreactor consists of plastic chamber which is partially filled with media and cells while the other half of the chamber is filled with air. The mixing and mass transfer is achieved by rocking the chamber back and forth. This rocking motion enhances the oxygen transfer, bulk mixing and off-bottom suspension of cells and particles. The cultivation chamber is discarded since it is disposable and this helps in the elimination of sterilization or cleaning. Another sinner used in incubator was invented by Heidemann et al.. This low cost spinner is made of polypropylene hollow fiber membrane which is installed to improve the

oxygen supply by bubble-free aeration. This aeration is carried out by CO_2 conditioned incubator gas which is pumped a membrane stirrer using a pump. The outcome of this spinner is similar to the bioreactor but the only difference is the construction of the membrane. The spinner also provides uniform distribution of nutrients and eliminates any damage to the cells (Singh 1999; Heidemann et al. 1994).
The incubators require another important equipment called cellular monitoring. Hung et al. invented an array for this purpose. It is achieved by a cell culture array on a single self-cultured microfluidic system. IT helps in the cell growth, reagent introduction and real time optical analysis. The single unit of the array consists of a circular microfluidic chamber, multiple narrow perfusion channels surrounding the main chamber, and four ports for fluidic access. . The cell culture array is used for many applications such as drug screening, bioinformatics, and quantitative cell biology. David Malinge invented a shaking system which handles the cell culture vessels. Every incubator has a rotatable support which has all the vessels fixed to its predetermined positions. The shaking system helps the rotating shaft to move in such a way that each vessel can be positioned conveniently for loading and unloading at any given time. This loading and unloading operations are performed by a robotic arm attached to it. The shaft can move in number of axis such as upright axis and eccentrically about an axis (Hung et al. 2005; Malinge & Malinge 2005).
In the incubation process, it takes a lot of efforts to maintain the state of the cell. This is achieved by Ho et al.. They have constructed a mini chamber that would maintain the structure of the cell throughout the experiment by using an enclosed system and a steady $CO2_2$circulation. This system can also support long term cellular monitoring with time lapse recording which would help in monitoring the multiplication of cell minutely. This system can find applications in developmental biology, cell biology and cancer biology. Another invention by Chenite et al. is related to a temperature-controlled pH-dependent formation of ionic polysaccharide gels. These gels are used in the incubation chambers in order to maintain temperature throughout the experiment (Ho et al. 2005; Chenite et al. 2002).
There are two critical factors that are controlled in cell culture, dissolved oxygen (dO2) and pH. Naciri et al. describe the monitoring of these factors using optical sensors. The fluorescent sensors used for monitoring are chosen because they do not damage the cells during cultivation. A high throughput while monitoring results in success of bio production and drug discovey programs. This monitoring is reliable and very feasible in terms of cost (Naciri et al. 2008; Tekniscience 2017).

RESEARCH METHODOLOGY AND RESULTS

Analytical Hierarchy Process (AHP) is used to determine the best Thermo Scientific CO_2 Incubators. The aim is to find out the most efficient incubator in terms of cost and other technical specifications.
While investing in an incubator, there are certain specifications which are considered to be the most important. Those specifications are considered to be the criteria for AHP. The alternatives considered are the most invested incubators in the market. After a thorough research, the four alternatives are Thermo Scientific Midi 40 CO_2 Incubator, Thermo Scientific Heracell 150i CO_2 Incubator, Thermo Scientific Water Jacket CO_2 Incubator, Thermo Scientific Large Capacity CO_2 Incubators
There are five criteria chosen for this AHP: Temperature, Humidity, Capacity, Unit Heat Load, Cost.

1. Temperature: Temperature is one of the most important factor that needs to be considered in the incubation. The temperature inside an incubator has to be maintained constant during the entire process of culturing. This is achieved using water jacket

mechanism. This system includes a combination of direct heating which is surrounded by air jacket that provides uniformity to maintain cultured samples at the optimum temperature. Another mechanism is fan less system with six-sided direct-heating profile which prevents fluctuations that can cause direct shock to the cells.

2. Humidity: Humidity is the next important factor in incubation. The reason humidity should be maintained is because a slight fluctuation can result in the drying out of a cell and it helps in maintaining uniform osmotic cell pressure. The system is established which can measure and maintain the level of water level which leads to condensation free walls. Change in humidity leads to evaporation of media which can change the nature and structure of the cell and cause the desiccation of it.
3. Capacity: This involves the number of shelves present in the incubator. The number of shelves decide whether the incubator would be used for small, medium or large scale purposes.
4. Unit Heat Load: It is used to maintain the CO_2 and O_2 range inside the incubator. CO_2 interacts with the buffering system of the cell culture media to determine the media's pH.
5. Cost: This is one of the most important criteria because the investment in any product needs to be cost effective.

Figure 1: Hierarchical structure of the decision problem

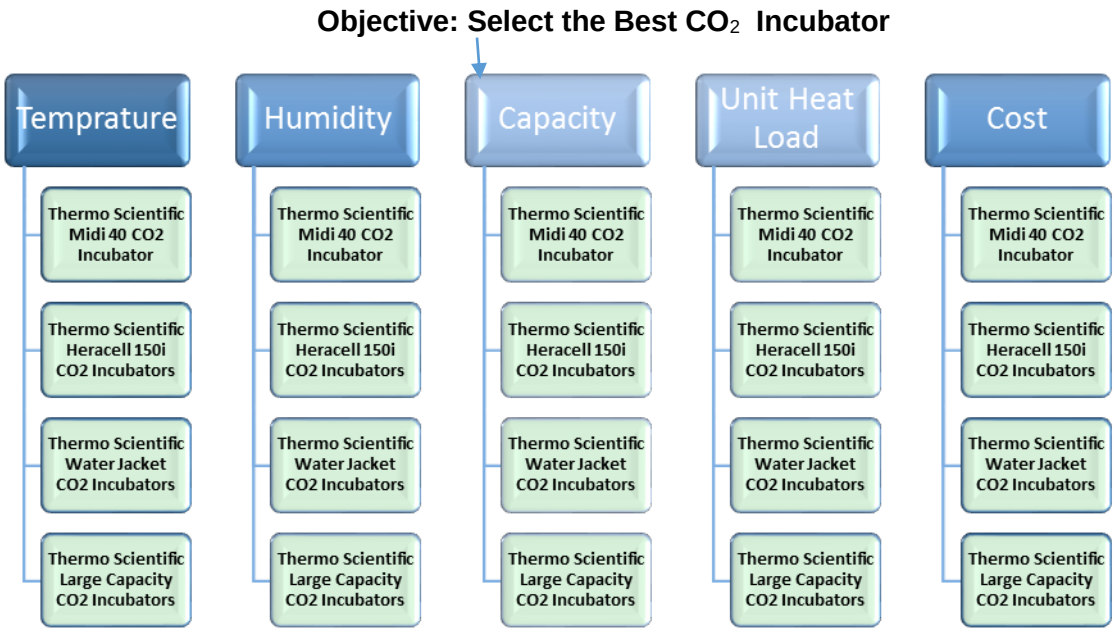

Table 2 Pairwise Comparison of Criteria

Priority Vector (Average)	Product	Ratio	CI	CR
0.10	0.60	5.88	0.11	0.10
0.06	0.34	5.18		
0.48	2.73	5.70		
0.03	0.18	5.14		

0.32	1.73	5.40		
1		5.46		

As seen from Table 2, the consistency ratio is 0.1 and hence it is consistent.

Table 3 Pairwise Comparison of Alternatives for Temperature

Priority Vector (Average)	Product	Ratio	CI	CR
0.30	1.23	4.05	0.008	0.009
0.06	0.22	4.02		
0.09	0.37	4.01		
0.55	2.21	4.03		
1		4.03		

Table 4 Pairwise Comparison of Alternatives for Humidity

Priority Vector (Average)	Product	Ratio	CI	CR
0.56	2.34	4.15	0.02	0.03
0.06	0.25	4.02		
0.11	0.43	4.02		
0.27	1.09	4.07		
1		4.06		

Table 5 Pairwise Comparison of Alternatives for Capacity

Priority Vector (Average)	Product	Ratio	CI	CR
0.33	1.43	4.29	0.08	0.08
0.06	0.24	4.07		
0.10	0.41	4.05		
0.50	2.27	4.50		
1		4.23		

Table 6 Pairwise Comparison of Alternatives for Unit Heat Load

Priority Vector (Average)	Product	Ratio	CI	CR
0.06	0.23	4.02	0.02	0.03
0.14	0.58	4.04		
0.25	1.01	4.08		
0.55	2.28	4.14		
1		4.07		

Table 7 Pairwise Comparison of Alternatives for Cost

Priority Vector (Average)	Product	Ratio	CI	CR
0.55	2.34	4.27	0.04	0.04
0.30	1.22	4.14		
0.10	0.40	4.03		
0.06	0.24	4.04		
1		4.12		

Table 8 Final Matrix

Thermo Scientific Midi 40 CO_2 Incubator	**0.41**
Thermo Scientific Heracell 150i CO_2 Incubators	0.14
Thermo Scientific Water Jacket CO_2 Incubators	0.11
Thermo Scientific Large Capacity CO_2 Incubators	0.35

Table 8 shows the aggregated weights of all the alternatives. Thermo Scientific Midi 40 CO_2 Incubator is the most preferred.

CONCLUSION

Thermo Scientific Midi 40 CO_2 Incubator is considered to be the best choice of incubator in tissue culturing. It provides an ideal environment along with being cost effective. Thermo Scientific Midi 40 CO_2 Incubator can be used for many applications such as cell culturing, tissue engineering, stem cell research and mammalian cell research. This incubator is a low maintenance direct heat incubator which has efficient operations.It is a space saving incubator which can be used for small to medium operations. Being cost effective, it can be incorporated in all the laboratories.

Appendix

Figure 3: Pairwise Comparison of Criteria Step1

Pairwise Comparison of 5 criteria					
	3	4	1	5	2
STEP 1	Temperature	Humidity	Capacity	Unit Heat Load	Cost
Temperature	1	3	1/7	5	1/5
Humidity	1/3	1	1/9	4	1/7
Capacity	7	9	1	9	2
Unit Heat Load	1/5	1/4	1/9	1	1/6
Cost	5	7	1/2	6	1

Figure 4: Pairwise Comparison of Temperature and alternatives

Step 1	Thermo Scientific Midi 40 CO2 Incubator	Thermo Scientific Heracell 150i CO2 Incubators	Thermo Scientific Water Jacket CO2 Incubators	Thermo Scientific Large Capacity CO2 Incubators
Thermo Scientific Midi 40 CO2 Incubator	1	5	4	1/2
Thermo Scientific Heracell 150i CO2 Incubators	1/5	1	1/2	1/9
Thermo Scientific Water Jacket CO2 Incubators	1/4	2	1	1/6
Thermo Scientific Large Capacity CO2 Incubators	2	9	6	1

Figure 5: Pairwise Comparison of Humidity and alternatives

Step 1	Thermo Scientific Midi 40 CO2 Incubator	Thermo Scientific Heracell 150i CO2 Incubators	Thermo Scientific Water Jacket CO2 Incubators	Thermo Scientific Large Capacity CO2 Incubators
Thermo Scientific Midi 40 CO2 Incubator	1	7	5	3
Thermo Scientific Heracell 150i CO2 Incubators	1/7	1	1/2	1/5
Thermo Scientific Water Jacket CO2 Incubators	1/5	2	1	1/3
Thermo Scientific Large Capacity CO2 Incubators	1/3	5	3	1

Figure 6: Pairwise Comparison of Capacity and alternatives

Step 1	Thermo Scientific Midi 40 CO2 Incubator	Thermo Scientific Heracell 150i CO2 Incubators	Thermo Scientific Water Jacket CO2 Incubators	Thermo Scientific Large Capacity CO2 Incubators
Thermo Scientific Midi 40 CO2 Incubator	1	7	5	1/3
Thermo Scientific Heracell 150i CO2 Incubators	1/7	1	1/2	1/6
Thermo Scientific Water Jacket CO2 Incubators	1/5	2	1	1/4
Thermo Scientific Large Capacity CO2 Incubators	3	6	4	1

Figure 7: Pairwise Comparison of Unit Heat Load and alternatives

Step 1	Thermo Scientific Midi 40 CO2 Incubator	Thermo Scientific Heracell 150i CO2 Incubators	Thermo Scientific Water Jacket CO2 Incubators	Thermo Scientific Large Capacity CO2 Incubators
Thermo Scientific Midi 40 CO2 Incubator	1	1/3	1/5	1/7
Thermo Scientific Heracell 150i CO2 Incubators	3	1	1/2	1/4
Thermo Scientific Water Jacket CO2 Incubators	5	2	1	1/3
Thermo Scientific Large Capacity CO2 Incubators	7	4	3	1

Figure 8: Pairwise Comparison of Cost and alternatives

Step 1	Thermo Scientific Midi 40 CO2 Incubator	Thermo Scientific Heracell 150i CO2 Incubators	Thermo Scientific Water Jacket CO2 Incubators	Thermo Scientific Large Capacity CO2 Incubators
Thermo Scientific Midi 40 CO2 Incubator	1	3	5	7
Thermo Scientific Heracell 150i CO2 Incubators	1/3	1	4	6
Thermo Scientific Water Jacket CO2 Incubators	1/5	1/4	1	2
Thermo Scientific Large Capacity CO2 Incubators	1/7	1/6	1/2	1

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