FABRIC FOR BIOMEDICAL APPLICATION

SYAZWANI BINTI ABD JAMIL

A thesis submitted in fulfillment of the requirements for the award of the degree of Master of Engineering (Biomedical)

Faculty of Biosciences and Medical Engineering
Universiti Teknologi Malaysia

AUGUST 2014
Specially dedicated to my beloved;

To my late father Haji Abdul Jamil Bin Selamat,

To my late mother Zaiton binti Mohd Yusoff,

My beloved husband Mohd Firdaus Bin Samah,

My beloved sister Zuriyal Hanim Binti Haji Abdul Jamil,

My beloved sister Nurzahirah Binti Haji Abdul Jamil,

My beloved brother Mohd Asyraf Bin Haji Abdul Jamil,

My beloved brother Mohd Haziq Bin Haji Abdul Jamil,

My beloved sister Zarifah Binti Haji Abdul Jamil
ACKNOWLEDGEMENT

*Bismillahirrahmanirrahim.* Alhamdulillah. I am very grateful to ALLAH, The Most Compassionate, The Most Gracious and The Most Merciful for granting me a strong heart and soul throughout this project.

I would like to express my deepest and sincere gratitude to my project supervisors, Dr. Dedy Hermawan Bagus Wicaksono and PM Dr Fadzilah Adibah Abdul Majid, whose encouragement, guidance and support from the initial to the final level enabled me to develop an understanding of the project.

I would like to thank our Ministry of Sciences, Technology and Innovations, Malaysia for funding this project through an eScience Funds Grant (Vot 01H65). My thanks and gratitude also goes to MEDITEG group members for all their support and valuable discussion that hold great value during this project.

I am grateful to my beloved husband, Mohd Firdhaus Bin Samah who stood beside me and encouraged me constantly and continuously, my thanks also goes to my beloved brothers and sisters for giving me happiness and joy. I would also fond to offer my gratitude to all my friends and relatives that had assist me in one way or another in completing this project.
Lastly, I would like to offer my regards and blessings to all of those who had supported me in any aspect during the completion of this study.
ABSTRACT

In this study, cotton fabric was used as a main material in creating two devices designed for cell proliferation and cell based assay application. The first device, low cost wax-impregnated cotton fabric platform was created to resemble a commercially available 96 well plates. The usage of cotton fabric platform was investigated through the proliferation of cell HSF 1184 on the designed platform. Surface property of cotton fabric platform was analyzed through FTIR (Fourier Transform Infrared) whereas biocompatibility of the platform was investigated through MTT (3-(4,5-Dimethylthiazol-2-yl)-2,5-diphenyltetrazolium bromide) assay. HSF 1184 proliferation on cotton fabric platform was observed through LVSEM (Low Vacuum Scanning Electron Microscope) and Confocal Microscope. Second device, known as cotton fabric based cell assay device are comprise of a microfluidic pattern surrounded by a hydrophobic background on the surface of cotton fabric. Capillary force exerting on the interstitial spaces between woven threads and spun fibers on the surface of cotton fabric are utilize as a natural pump to draw media bearing a suspended cell. Two types of suspended cells are used in this study; (HSF Fibroblast 1184; size: >5µm) and (Hybridoma; size: 2-5µm). Weave structures of cotton fabric are utilized as a natural filter to isolate cells based on size difference. Suspended cell were stained and wicking movement of cells drawn by the capillary wicking of the media in the hydrophilic channel was observed. To conclude, in this study, the usage of cotton fabric as a raw material for biomedical application was described in device designed for cell culture and cell based assay application.
Dalam kajian ini, kain kapas telah digunakan sebagai bahan utama dalam membuat dua alat yang digunakan untuk tujuan proliferasi sel dan alat kajian berasaskan sel. Alat yang pertama, platform kain kapas berlapikkan lilin yang berkos rendah telah direka untuk menyerupai 96 mikrowel yang boleh didapati secara komersial. Kegunaan kain kapas telah dikaji melalui proliferasi sel HSF 1184 di atas alat. Sifat permukaan kain kapas telah dikaji melalui ujian FTIR (Fourier Transform Infrared) manakala kesesuaian platform telah dikaji melalui ujian MTT (3-(4,5-Dimethylthiazol-2-yl)-2,5-diphenyltetrazolium bromide). Proliferasi HSF 1184 di atas platform kain kapas telah dilihat melalui LVSEM (Low Vacuum Scanning Electron Microscope) dan Confocal Microscope. Alat yang kedua, dikenali sebagai alat kajian berasaskan sel adalah terdiri daripada corak mikrofluidik yang dikelilingi latar belakang hidropobik di atas permukaan kain kapas. Daya kapilari di antara ruang celahan antara benang tenunan dan serat yang diputar di atas permukaan kain kapas telah digunakan sebagai pam semula jadi untuk menarik media yang mengandungi sel yang terapung. Dua jenis sel terapund telah digunakan dalam kajian ini; HSF 1184; saiz>5 µm dan Hybridoma; saiz 2-5 µm. Struktur tenunan kain kapas telah digunakan sebagai penapis semula jadi untuk mengasingkan sel berasaskan perbezaan saiz sel. Sel terapung telah di ditanda dan pergerakan sel melalui penyerapan media di dalam saluran hidropilik telah dilihat. Sebagai kesimpulan, di dalam kajian ini, kegunaan kain kapas dalam aplikasi biomedikal telah dihurstakan melalui alat yang dicipta untuk proliferasi sel dan juga alat kajian berasaskan sel.

ABSTRAK
# TABLE OF CONTENTS

<table>
<thead>
<tr>
<th>CHAPTER</th>
<th>TITLES</th>
<th>PAGE</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>DECLARATION OF ORIGINALITY</td>
<td>v</td>
</tr>
<tr>
<td></td>
<td>DEDICATION</td>
<td>vi</td>
</tr>
<tr>
<td></td>
<td>ACKNOWLEDGEMENT</td>
<td>vii</td>
</tr>
<tr>
<td></td>
<td>ABSTRACT</td>
<td>ix</td>
</tr>
<tr>
<td></td>
<td>ABSTRAK</td>
<td>x</td>
</tr>
<tr>
<td></td>
<td>TABLE OF CONTENTS</td>
<td>xi</td>
</tr>
<tr>
<td></td>
<td>LIST OF TABLES</td>
<td>xiv</td>
</tr>
<tr>
<td></td>
<td>LIST OF FIGURES</td>
<td>xvi</td>
</tr>
<tr>
<td></td>
<td>LIST OF ABBREVIATION</td>
<td>xxiii</td>
</tr>
</tbody>
</table>

## 1 INTRODUCTION

1.1 Preface  
1.2 Problem Statement  
1.3 Hypothesis  
1.4 Objective  
1.5 Scopes  
1.6 Research Methodology

## 2 LITERATURE REVIEW

2.1 Introduction  
2.2 Biomedical Device  
2.3 Biomedical Application  
2.4 Cotton
2.5 Cell Culture 11
2.6 Microwell Plate 14
2.7 Fabric based-assay 16
2.8 Cell based-assay 17
2.9 Microfluidic 18
2.10 Cell based-micrfluidic 23
2.11 Mechanical manipulation in cell based-microfluidic 31

3 MATERIAL and METHOD
3.1 Introduction 38
3.2 Low cost wax-impregnated cotton fabric 39
   3.2.1 Materials 39
   3.2.2 Wax paper preparation 39
   3.2.3 Wax ratios 39
   3.2.4 Human skin fibroblast (HSF 1184) 41
3.2.5 Methods 41
   3.2.5.1 Scouring treatment of cotton fabric 41
   3.2.5.2 ACAD schematic of low cost wax-
       Impregnated cotton fabric 42
   3.2.5.3 Low cost wax-impregnated cotton fabric 42
   3.2.5.4 Schematic illustration of low cost wax-
       Impregnated cotton fabric platform fabrication
       Process 44
3.3 Cotton fabric based-cell assay device 45
   3.3.1 Materials 45
   3.3.2 Wax paper preparation 45
   3.3.3 Human skin fibroblast (HSF 1184) 45
   3.3.4 Trypsinization 46
   3.3.5 AO (Acridine orange) staining 46
   3.3.6 Hybridoma 46
   3.3.7 Cell counting 47
### 3.3.8 Methods

<table>
<thead>
<tr>
<th>Subsection</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>3.3.8.1 Scouring treatment of cotton fabric</td>
<td>47</td>
</tr>
<tr>
<td>3.3.8.2 ACAD schematic illustration of cotton fabric based-cell assay</td>
<td>47</td>
</tr>
<tr>
<td>device</td>
<td></td>
</tr>
<tr>
<td>3.3.8.3 Cotton fabric based-cell assay device fabrication process</td>
<td>48</td>
</tr>
<tr>
<td>3.3.8.4 Schematic illustration of cotton fabric based-cell assay device</td>
<td>49</td>
</tr>
<tr>
<td>fabrication process</td>
<td></td>
</tr>
<tr>
<td>3.3.8.5 Preliminary analysis (dye wicking) on cotton fabric based-cell</td>
<td>50</td>
</tr>
<tr>
<td>assay device</td>
<td></td>
</tr>
<tr>
<td>3.3.8.6 AO (Acridine orange) staining</td>
<td>50</td>
</tr>
<tr>
<td>3.3.8.7 Cell wicking on cotton fabric based-cell assay device</td>
<td>50</td>
</tr>
</tbody>
</table>

### 4 RESULT and DISCUSSION

<table>
<thead>
<tr>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>4.1 Introduction</td>
<td>52</td>
</tr>
<tr>
<td>4.2 Low cost wax-impregnated cotton fabric platform</td>
<td>53</td>
</tr>
<tr>
<td>4.2.1 Low vacuum scanning electron microscope (LVSEM)</td>
<td>53</td>
</tr>
<tr>
<td>4.2.2 Fluorescence staining (Multiple staining for F-actin, cell membrane and nucleic acid of HSF 1184)</td>
<td>55</td>
</tr>
<tr>
<td>4.2.3 Cell survival assay (MTT assay) device</td>
<td>57</td>
</tr>
<tr>
<td>4.3 Cotton fabric based-cell assay device</td>
<td>59</td>
</tr>
<tr>
<td>4.3.1 Optical observation of cotton fabric structure</td>
<td>59</td>
</tr>
<tr>
<td>4.3.2 Preliminary analysis (dye wicking) on cotton Fabric based-cell assay device</td>
<td>61</td>
</tr>
<tr>
<td>4.3.3 Cell wicking on cotton fabric based-cell assay device</td>
<td>63</td>
</tr>
</tbody>
</table>
5 CONCLUSION

5.1 Introduction 69
5.2 Problem 71
5.3 Recommendations 71

REFERENCE 72
LIST OF TABLES

<table>
<thead>
<tr>
<th>TABLE NO.</th>
<th>TITLES</th>
<th>PAGE</th>
</tr>
</thead>
<tbody>
<tr>
<td>2.1</td>
<td>Material properties for fabrication of microfluidic.</td>
<td>21</td>
</tr>
<tr>
<td>2.2</td>
<td>(a) Latest achievements of cell manipulation techniques in microfluidic system.</td>
<td>25</td>
</tr>
<tr>
<td>2.2</td>
<td>(b) Latest achievements of cell manipulation techniques in microfluidic system.</td>
<td>26</td>
</tr>
<tr>
<td>2.3</td>
<td>Summary of micro fabricated fluidic systems for fluorescence-activated sorting.</td>
<td>28</td>
</tr>
<tr>
<td>3.1</td>
<td>Four different wax ratios used to create four different cotton fabric platforms.</td>
<td>40</td>
</tr>
<tr>
<td>3.2</td>
<td>Four different temperatures (°C) used in preparing four different wax ratios.</td>
<td>40</td>
</tr>
<tr>
<td>3.3</td>
<td>Different dimension used in preparing cotton fabric based-cell assay devices.</td>
<td>48</td>
</tr>
</tbody>
</table>
# LIST OF FIGURES

<table>
<thead>
<tr>
<th>FIGURES NO.</th>
<th>TITLES</th>
<th>PAGE</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.1</td>
<td>Research Design: Low cost wax-impregnated cotton fabric platform.</td>
<td>7</td>
</tr>
<tr>
<td>1.2</td>
<td>Research Design: Cotton fabric based-cell assay device</td>
<td>8</td>
</tr>
<tr>
<td>2.1</td>
<td>Types of cell.</td>
<td>13</td>
</tr>
<tr>
<td>2.2</td>
<td>Design and structure of a microfluidic device for 3-D cell culture.</td>
<td>14</td>
</tr>
<tr>
<td>2.3</td>
<td>(a) Functional (pH sensitive, acidic, and neutral) textile-based microfluidic chip (a) pH 9, (b) pH 6.7, and (c) pH 2. (b) Direct immunoassay on the fabric chip, (C) regions are signaling a positive result for 500 ng of antibody (polyclonal Goat Anti-Rabbit-Rabbit IgG) at the capture zones.</td>
<td>17</td>
</tr>
<tr>
<td>2.4</td>
<td>Fabrication steps of Poly (dimethylsiloxane) (PDMS) microfluidic device.</td>
<td>20</td>
</tr>
<tr>
<td>2.5</td>
<td>A timeline showing the evolution of microfluidic technology</td>
<td>21</td>
</tr>
<tr>
<td>2.6</td>
<td>(a) Microfluidic paper-based analytical devices (μPADs) (b) Diagram outlining fabrication of μPADs via photolithography.</td>
<td>22</td>
</tr>
<tr>
<td>2.7</td>
<td>Steps in cell manipulation techniques in a microfluidic system.</td>
<td>24</td>
</tr>
<tr>
<td>2.8</td>
<td>Schematics illustrative of various applications in cell manipulation techniques using an optical force.</td>
<td>27</td>
</tr>
</tbody>
</table>
2.9 Schematics illustration of the magnetic force separation technique; cells are forced to move along the magnetic wire by a high magnetic field gradient at the edge of each wire. Each wire will deploy force on the superparamagnetic beads at the angle of the hydrodynamic force.

2.10 Schematics illustration of microfluidic dielectrophoresis trap system (a) a metallic DEP trap made of microfabricated wires on top of a substrate. Wires are either free-floating or connected to a voltage source. (B) An electrodeless DEP trap made of dielectric constrictions.

2.11 (Left) Schematics illustration of a microfluidic electrofusion technique combined with DEP for selective cell pairing and fusion at the single-cell level. (Right) An electrofusion of a P3X myeloma cell and a B cell blast in a DEP field cage according to the process time Processing steps for finite element analysis.

2.12 Schematic illustration of different types of cell filtration devices. (a) Weir-type filters, (b) pillar, (c) cross-flow and (d) membrane.

2.13 Schematic illustration of the overlapped aligned porous membrane fabrication process. Different PDMS membranes are labeled with different colours.

2.14 Schematic illustration of the diffusive filter for size based continuous flow fractionation of erythrocytes from whole blood.

2.15 Schematics illustrative of separation of small particles (green dotted line) from a large particle (red dotted line) through a lateral displacement mechanism.
2.16 Schematic illustration of the operating process of a traditional flow cytometer. Mechanism: Adjacent sheath flow with a higher velocity will hydrodynamically squeeze the central sample flow into a narrow stream. Cell, usually labeled with fluorescent dye are optically sorted by a subsequent.

2.17 (a) Schematic illustration of sample detection whereby cells are injected into the core of a sheath flow and confined to a narrow single-file stream by hydrodynamic focusing. (b) A fluorescence-activated sorting in conventional flow cytometry.

2.18 Schematic diagram of the microfabricated automatic flow cytometry chip and organ.


3.2 Schematic diagram of the fabrication of wax-impregnated cotton fabric platform. The design in (a) was illustrated using ACAD 2006. The design in (a) was immersed in wax to create wax impregnated paper such as in (b). Design on wax paper was transferred simultaneously on cotton fabric through simple wax patterning method (c). Circle was punched out from the wax-impregnated cotton fabric manually as such in (d). Layer of cotton fabric covered with wax was folded and was pressed together to form one stack of wax impregnated cotton cloth as such in (e). Stack of
wax-impregnated cotton fabric was dipped again in a mixture of wax and was pressed slightly on smooth surface. In (f), a wax-impregnated cotton fabric platform is shown in (f).

3.3 Schematic illustration of cotton fabric based-cell assay device.

3.4 Schematic diagram of the fabrication of cotton fabrics based-cell assay device. The design in (a) was illustrated using ACAD 2006. The design in (A) was immersed in wax to create wax impregnated paper such as in (b). Design was printed onto wax-impregnated paper and hydrophilic region were cut off using computer aided printer. Design on wax paper was transferred simultaneously on cotton fabric through simple wax patterning method (c). Layer of cotton fabric was folded and was pressed together to create a cotton fabrics-based cell assay device (d). Device was then sealed with adhesive tape as in (e).

4.1 Scanning Electron Microscope (SEM) images of cultured HSF 1184 on R1 ratio of cotton fabrics platform after 24 hour of cultivation. (a) taken inside the well, magnifications ×500, scale bar = 50µm. (b) taken inside the well, magnifications ×5000, scale bar = 5µm.

4.2 Scanning Electron Microscope (SEM) images of cultured HSF 1184 cells on R1 ratio of cotton fabrics platform after 24 hour of cultivation. (a) taken at the edge of the well, magnifications ×500, scale bar = 50µm. (b) taken at the edge of the well, magnifications ×50000, scale bar = 5µm.
4.3 Scanning Electron Microscope (SEM) images of cultured HSF 1184 cells on R1 ratio of cotton fabrics platform after 48 hour of cultivation. (a) taken inside the well, magnifications ×500, scale bar = 50µm. (b) taken inside the well, magnifications ×5000, scale bar = 5µm.

4.4 Scanning Electron Microscope images of cultured HSF 1184 cells on R1 ratio of cotton fabrics platform after 48 hour of cultivation. (a) taken at the edge of the well, magnifications ×500, scale bar = 50µm. (b) taken at the edge of the well, magnifications ×50000, scale bar = 5µm.

4.5 Confocal microscope images of 24 hour cultured HSF 1184 cells, stained with Hoechst 33342 trihydrochloride, tryhydrate (H3570) for staining the nucleic acid (blue), Alexa Flour ® 488 phalloidin for staining filamentous actin (green), and Wheat Germs Agglutinin, Alexa Flour ® 555 conjugate for staining cell membrane (red). (a) Cells cultured on a cotton fabrics platform with the wax ratio of R1. Scale bar = 10µm.

4.6 MTT measurements of viability of cultured HSF 1184 cell on cotton fabrics platforms with different wax ratios for 24h. n = 4. ** indicates statistical significance (Students t test, P<0.01). Analysis was done in Ibnu Sina, Universiti Teknologi Malaysia. Analysis is courtesy of Norsamsiah Binti M. Wahab, Faculty Chemistry, Universiti Teknologi Malaysia.


4.7 (d) Microscope images of wax barrier on cotton fabric. Observation under Auto Digital Microscope DSX 500, observation method: BF, zoom: 1.2 X.

4.8 a) Microscope images of wax paper; (diameter: 2 cm, length of hydrophilic channel: 3cm, width of hydrophilic channel: 0.5 cm). Observation were done under Digital Microscope KH-8700, resolution: 5.4 µm.

4.8 b) Microscope images of cotton fabric-based cell assay device after 2µl of food dye (red) was dropped; (diameter: 2 cm, length of hydrophilic channel: 3 cm, width of hydrophilic channel: 0.5 cm). Observation under Digital Microscope KH-8700, resolution: 5.4.

4.9 Microscope images of cotton fabric-based cell assay device after 2µl of food dye (red) was dropped; (diameter: 2 cm, length of hydrophilic channel: 3 cm, width of hydrophilic channel: 0.4 cm). Observation under Digital Microscope KH-8700, resolution: 5.4 µm.
4.10 Microscope images of cotton fabric-based cell assay device. Dark image represents the hydrophilic channels and a clearer image represents the background of wax on the surface of cotton fabric-based cell assay device. Observation were done under Digital Fluorescence Microscope DX 50, Objective lens: 10x.

4.11 Microscope images of cotton fabric-based cell assay device. Dark image represents the hydrophilic channels and a clearer image represents the background of wax on the surface of cotton fabric-based cell assay device. Observation were done under Digital Fluorescence Microscope DX 50, Objective lens: 10x.

4.12 Microscope images of media (2µl) containing suspended HSF 1184 spreading on cotton fabric-based cell assay device. (b) HSF 1184: cell density of 2.5 x 10^5 cells/µl located on the surface of cotton fabric-based cell assay device. Red dot is a dead cell while green dot is a live cell. Observation was made under Digital Fluorescence Microscope DX 50, Objective lens: 10x.

4.13 (a) Fluorescence Microscope images of media (2µl) of suspended cell (Hybridoma); density: 2.5 x 10^5 cells/µl spreading on the inlet. (b) Spreading movement of suspension cell (Hybridoma) is covering the area of the inlet. (c) Spreading movement of suspension cell (Hybridoma) reaches hydrophilic channel. (d) Spreading movement of cell ceased. The spreading continues until it actually ceased at one point as seen in figure 4.14 (d).

4.14 Series of Confocal Microscope images of media (2µl) of suspended cell of Hybridoma; density: 2.5 x 10^5 cells/µl spreading on the hydrophilic pattern of device.
**LIST OF ABBREVIATIONS**

<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>ELISA</td>
<td>Enzyme-linked immunosorbent assay</td>
</tr>
<tr>
<td>PDMS</td>
<td>Poly (dimethylsiloxane)</td>
</tr>
<tr>
<td>HSF</td>
<td>Human Skin Fibroblast</td>
</tr>
<tr>
<td>FACS</td>
<td>Fluorescence activated cell sorter</td>
</tr>
<tr>
<td>DEP</td>
<td>Dielectrophoresis</td>
</tr>
<tr>
<td>WBC</td>
<td>White blood cell</td>
</tr>
<tr>
<td>DLD</td>
<td>Deterministic Lateral Displacement</td>
</tr>
<tr>
<td>µFACS</td>
<td>Microfabricated fluorescence activated cell sorter</td>
</tr>
</tbody>
</table>
Chapter 1

Introduction

1.1 Preface

Fabric is referring to any material that has been processed through weaving, knitting, spreading, crocheting or bonding. Cotton is considered as one of the textile material that is commonly used, especially for daily clothes. Cotton has also been a major focus for researchers around the world, especially in the low-cost analysis tools [39]. In addition, a number of advantages such as low cost, widely available and lightweight are among the reason of cotton fabrics usage in this study.

Microwell has recently been recognized as a tool that is often used in cell culture, particularly in 2D cell culture to replace a conventional Petri dish. The ability to perform high-throughput screening has made microwell as a standard tool in analytical research and clinical diagnostic test laboratories. Enzyme linked immunosorbent assay (ELISA), which is known as the basis of modern diagnostic testing in human and animals is commonly performed using microwell [15]. Fabrication processes of microwell such as photolithography, soft lithography and etching were effective in a large-scale production; however these fabrication procedures require an additional equipment to be implemented. As a result, additional costs are required during fabrication process and thus are not favorable especially in a limited resource region. Therefore, a simpler and low cost fabrication process to create microwell was formulated in this study.
Cell based-assay is recently applicable to a wider range of biological research topic especially relating to a cellular response of a various physiological and pathological stimuli [11]. This is cause by the capability of cell based-assay of monitoring the biochemical activity of a target bimolecular in a cellular context. Over the year, microfluidic has been seen to be integrating into a cell-based assay application due to several advantages such as a high surface area to volume ratio and a slow diffusion of secreted molecules necessary in a normal function. Generally, cell-based screening is often automated in order to reduce the time and the cost of fabrication. Most of these automation systems are thus expensive to be developed especially in a developing country [11].

To perform real biological sample detection, the cell must be sorted and separated in order to obtain a single cell from a complex sample. Since then, numerous approaches are developed to create a miniaturized particle-sorting on the microfluidic platform [52]. Generally, cell sorting on microfluidic platform is performed using optical, magnetic, electrical and mechanical manipulation [27]. Cell sorting based on size is the most commonly approach in a microfluidic sorting methods. In this study, a simpler and low cost fabrication process was investigated to create a cell based-assay to separate cells based on size differences.
1.2 Problem Statement

Low cost wax-impregnated cotton fabric platform:

Common fabrication process for microwell fabrication such photolithography, soft lithography and etching was proven effective but still require an extensive equipment to be implemented. These fabrication processes was costly especially in a limited resource region. A simpler fabrication method utilizing a low cost cotton fabric as raw material for cotton fabric platform was investigated in this study.

Cotton fabric based-cell assay device:

Cell based-assay device is capable of monitoring the biochemical activity of target bimolecular in the context of the cell without purification steps such as antibody-based enzyme assay or conventional enzyme-or antibody-based assay. However, most of the applied cell based screening was automated to reduce bearing cost and time which is still costly especially in a developing country. A low cost cotton fabric is used to fabricate a simpler cell based-assay device using a simpler fabrication process was investigated in this study.
1.3 Hypothesis

In order to fulfil the aforementioned problems statement, hypotheses are proposed;

Low cost wax-impregnated cotton fabric platform:

i. Wax ratios were used to improve the surface biocompatibility of cotton fabric for the proliferation of HSF Fibroblast 1184.

ii. Cotton fabrics are used as main material in cotton fabric platform fabrication process due to its advantages such as low cost, lightweight and commercially available.

ii. Wax patterning method was used as a fabrication process in order to create a low cost cotton fabric platform resembling a commercially available 96 microwell.

Cotton fabric based-cell assay device:

i. Cotton fabric and wax patterning method are used to create a low cost and simpler cell based assay by forming a microfluidic pattern on the surface of cotton fabrics-based cell assay.

ii. Cell isolation are perform based on size differences by utilizing cotton fabric woven structure as a filter.

iii. Capillary forces between interstitial spaces of fiber and spun yarn were used as a natural pump to draw media containing suspended cells.
1.4 Objectives

The objectives of this research project are stated as follow:

Low cost wax-impregnated cotton fabric platform:

i. To create cotton fabric platform resembling a commercially available 96 microwell for the proliferation of HSF Fibroblast 1184.

ii. To formulate wax ratios required for the development of a low cost wax-impregnated cotton fabric platform for the proliferation of HSF Fibroblast 1184.

iii. To assess the proliferation of HSF Fibroblast 1184 (cells) on a low cost wax-impregnated cotton fabric for 24 hour.

iv. To discuss the future possibility of cotton fabric platform resembling a commercially available 96 microwell in a cell culture application.

Cotton fabric based-cell assay device:

i. To fabricate a simpler and low cost cotton fabrics-based cell assay device by utilizing a low cost cotton fabric as a main material and a simple wax patterning method as a fabrication method.

ii. To observe wicking movement of suspension cell (HSF Fibroblast 1184, Hybridoma) on cotton fabrics-based cell assay device.

iii. To assess the wicking movement of suspension cell (HSF Fibroblast 1184, Hybridoma) on cotton fabrics-based cell assay device.

iv. To discuss the future possibility of cotton fabric-based cell assay device in isolating suspended cells based on size differences.
1.5 Research scopes

The scopes for this research were:

Low cost wax-impregnated cotton fabric platform:

i. Draft a design (ACAD) for the fabrication of a low cost wax-impregnated cotton fabric platform
ii. Formulate a wax ratios used in layering cotton fabric for the fabrication of a low cost wax-impregnated cotton fabric platform
iii. Analyze the proliferation of cell (HSF Fibroblast 1184) on low cost wax-impregnated cotton fabric platform.

Cotton fabric based-cell assay device:

i. Draft a design (ACAD) for the fabrication of a cotton fabric based-cell assay device.
ii. Manipulating the length of hydrophilic pattern on the surface of cotton fabric based on limitation occur in fabrication method.
iii. Analyze the wicking movement of suspended cell (HSF Fibroblast 1184, Hybridoma) through capillarity on the hydrophilic pattern on the surface of cotton fabric based-assay device.
iv. Accessing the future possibility of cotton fabric based-cell assay device by suspended cells isolation based on size differences.
1.6 Research Methodology

The summary of overall research approaches in this study was illustrated in figure 1.1 and figure 1.2

Figure 1.1: Research design

Low cost wax-impregnated cotton fabric platform
Cotton fabric based-cell assay device

- **Cotton fabric**
  - Scouring treatment
    - Boiling with distilled water
      - 20mg ml$^{-1}$ sodium carbonate (Na$_2$CO$_3$) was added for 15 minutes
    - Scoured cotton were rinse thoroughly
    - Scoured cotton were reimmerse in distilled water for 15 minutes
    - Scoured cotton was dried in an ambient temperature

- **ACAD design**
  - Channel (width-cm)
    - 0.5
  - Channel (length-cm)
    - 3.0
    - 4.0
  - Inlet (width-cm)
    - 2.0
  - Wax paper ratios
    - 3 Beeswax (JB): 1 Candelilla wax (SA)

- **Wicking**
  - Food dye (Red)
  - Optical microscope
  - Fluorescence microscope
  - Confocal microscope

- **Wicking**
  - Suspension cell
  - Hybridoma
  - Fibroblast

- **Wax paper**
  - Beeswax (Jadi Batek) was melted at 80°C
  - Plain A4 paper was dipped into the melted wax
  - Wax paper was left to dry

**Figure 1.2:** Research design
Cotton fabric based-cell assay device
REFERENCES


44. Sabine, D., Necessity is the mother of invention. GIT Labor-Fachzeitschrift, 2004.


52. Wei, H., Chapter 4; Microfluidic Device with Integrated Porous Membrane for Cell Sorting and Separation. Springer Theses, DOI 10.1007/978-3-642-32359-1 4, 2013.


