MICROWAVE STERILIZER

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MICROWAVE STERILIZER

by

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LIST OF ABBREVIATIONS

CFU	Colony Forming Unit
GUI	Graphical User Interface
IR	Infrared
OFT	Optical Fiber Thermometer

PENSTERIL GELOMBANG MIKRO

ABSTRAK

Kajian ke atas kesan penyinaran gelombang mikro pada kesan biologi dan sifat kimia telah banyak dijalankan selama ini. Keberkesanan pensterilan gelombang mikro adalah salah satu kajian yang telah berlangsung selama bertahun-tahun. Walau bagaimanapun, kebanyakan kajian dan penyelidikan melibatkan penggunaan ketuhar gelombang mikro konvensyen yang tidak mesra untuk pengajian. Projek ini melibatkan pembangunan pensteril gelombang mikro dan antara muka komputer pengguna grafik (GUI). Sebuah ketuhar gelombang mikro konvensyen telah diubah suai dengan Arduino Uno sebagai pengawal untuk mencapai tetapan tempoh rawatan yang fleksibel dan pemantauan suhu. Penderia thermopile inframerah disepadukan kepada sistem tersebut untuk memantau suhu sampel dalam kebuk gemlombang mikro. Projek ini juga mengkaji keberkesanan pensterilan gelombang mikro pada air nira nipah dengan menggunakan sistem pensterilan gelombang mikro yang dibangunkan. Teknik “spread plate” digunakan untuk mengira unit pembentukan koloni (CFU) dan membandingkan keputusan untuk mengesahkan keberkesanan. Sistem pensteril gelombang mikro dibangunkan mempunyai GUI yang mesra pengguna untuk mengawal tempoh rawatan dan pemantauan suhu. Sistem ini mampu menjana profil haba untuk sampel dan ambang suhu boleh ditetapkan untuk rawatan. Kajian telah menunjukkan bahawa gelombang mikro adalah berkesan dalam pensterilan air nira. Sistem pensteril gelombang mikro dibangunkan terbukti membantu sepanjang kajian tersebut.

MICROWAVE STERILIZER

ABSTRACT

The studies of the effect of microwave irradiation on biological effects and chemicals properties have been widely conducted over the years. The viability of microwave sterilization is one of the study that has been going on for years. However, most of the studies and researches involve the use of a conventional microwave oven which do not provide appropriate features to aid them in their studies. Development of a microwave sterilizer system with a computer graphical user interface (GUI) are involved in this project. A conventional microwave oven is modified with Arduino Uno as the controller to achieve flexible treatment duration settings and temperature monitoring. An infrared (IR) thermopile sensor is integrated to the system to monitor the temperature of the sample within the microwave chamber. The effectiveness of microwave sterilization on nipa palm sap is studied in this project as well using the developed microwave sterilization system. Spread plate technique is used to calculate the colony forming unit (CFU) and the results are compared to verify the effectiveness of microwave sterilization. The microwave sterilizer system developed has a user-friendly GUI to control the treatment duration and temperature monitoring. The system is capable of generating a thermal profile for the treated sample and threshold temperature can be set for the treatment. The experiment has shown that microwave radiation is effective and viable in the sterilization of sap of Nypa Fruticans. The microwave sterilization system developed is proved to be helpful throughout the experiment.

CHAPTER 1

INTRODUCTION

In this chapter, a brief introduction is given regarding the background of microwave sterilization and microwave sterilizer. Problem statement is presented together with the objectives of this research. Followed by the scope and limitations of this research and the organization of the entire thesis.

1.1 Background

Microwave sterilization is a process that destroys or eliminates all forms of microbial life or microorganism with the use of microwave (Rutala & Weber, 2008). The sterilization process is occurred through the conversion of microwave energy into heat energy which known as microwave heating. In comparison to other convention heating methods, microwave heating has a faster, more effective heating, shorter process time, imply less changes in physical chemical properties of the product and effective destruction effect on microorganisms have made microwave radiation a promising sterilization method (Regier & Schubert, 2001).

In comparison to other sterilizing methods such as incineration, incinerators can emit significant quantities of pollutants to the atmosphere which include particulate matter, metals, acid gases, oxides of nitrogen, carbon monoxide, organics, and various other materials present in medical wastes (Prüss, Giroult & Rushbrook, 1995). This is where microwave sterilizer shows its advantage, it has good disinfection efficiency under appropriate operating conditions, drastic reduction in waste volume and most importantly it is environmentally sound. Therefore, microwave sterilization technology should be further studied and developed to be applied and to replace less efficient sterilization technology.

Studies have shown that sterilization using a convention magnetron of microwave can be achieved. (Wu, 1996; Dunsmuir & Gallacher, 2003; Mima et al, 2008). However, in most of the studies conducted, conventional microwaves are used. Conventional microwaves are designed for food heating or cooking; they are not suitable to work as a sterilizer. Lack of appropriate features such as flexible and precise treatment duration control, continuous temperature monitoring and a friendly user interface for the purpose of sterilization failed to provide convenience and aid the researchers in their studies.

Hence, this project is aimed to develop a microwave sterilizer through the modification of a conventional microwave oven. Appropriate features and implementations are discussed and developed throughout the project.

1.2 Problem Statement

The problems of using a conventional microwave oven for sterilization and related researches are lack of user friendly interface, non-accurate and flexible treatment duration control and lack of ability to monitor the temperature of the sample within the chamber continuously.

The interface of conventional microwave oven might be user friendly for food cooking but it is not appropriate for sterilization process. Most conventional microwave oven comes with either analog or digital timer control. Analog control is not accurate and rather unreliable when comes to the studies and researchers where precise timing is crucial and critical. Whereas for most of the microwave oven that comes with a digital timer control, the durations are preset as the user will not have much flexibility to choose the duration they wanted. The researcher will require a more precise control of the microwave oven in terms of treatment duration and overall control of the microwave oven. Therefore, modifying a conventional microwave and developing a graphical user interface (GUI) were proposed to enable the user to control the microwave sterilizer conveniently to aid them in the sterilization process and research.

Continuous monitoring of temperature within the microwave chamber has been a challenge due to the radiation of high power microwave. Convention thermometers will be damaged and its operation can be affected greatly under the influence of high power microwave radiation. Therefore, plausible and appropriate implementations are explored and developed throughout this project.

Therefore, the statement can be described in the following research questions. How can a conventional microwave oven be modified to provide accurate treatment duration control, continuous temperature monitoring and comes with a user-friendly GUI to take control of the oven itself? What is the efficiency of microwave sterilization on nipa palm sap and how can we test it?

1.3 Objectives

The objectives of this research are:

1) To develop a microwave sterilizer by modifying a conventional microwave oven with appropriate features such as precise treatment duration control, user friendly GUI and continuous temperature monitoring.
2) To verify the efficiency of microwave sterilization using the developed microwave sterilizer on sap of Nypa Fruticans with spread plate technique.

1.4 Scope of the Research

This work was focusing mainly on development of microwave sterilizer by modifying a conventional microwave oven. A computer GUI is developed for the user to control the microwave sterilizer with ease using Visual Studio. An Arduino Uno is used as the controller for the microwave sterilizer and a thermopile IR sensor is integrated to the system to continuously monitor the temperature of the sample accurately within the chamber. The thermopile IR sensor is calibrated with the use of MATLAB. The system is capable of generating thermal profile in the form of an Excel file for the sample under treatment. Thermal profile can be useful for the researches to better understand the effect of microwave on the particular sample and its heating pattern. The door switch that comes with the microwave oven is used and integrated to the system to provide certain degree of safety. The oven will be switched off whenever the door of the oven is opened.

Furthermore, this project also studied the efficiency of microwave sterilization using the developed microwave sterilizer. Sap of nypa fruticans or nira palm sap is used as the sample in this study. Spread plate technique is used to examine the efficiency of microwave sterilization on the sample by comparing the CFU of each sample.

1.5 Organization of Thesis

This thesis contains in total of 5 main chapters that cover from the introduction to the conclusion of this research. Chapter 1 is an introductory chapter that describes the background, problem statement, objectives and the scope of this research. Chapter 2 condenses the literature review done in the process of conducting this research. The chapter discusses some of the previous works on the effect of microwave sterilization and modification of microwave oven. It also provides theoretical information on microwave heating, effect of microwave sterilization, properties of nipa palm sap and structure of microwave oven. Chapter 3 presents the methodology employed in this project. It includes the procedures and methods taken in the development of microwave sterilizer system and the verification of the effectiveness of microwave sterilization. The features of the microwave sterilizer developed and the result of spread plate technique on the sterilization of nipa palm sap are presented in Chapter 4. Chapter 5 concludes the whole project and recommendations for future projects are presented.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

In this chapter, a brief introduction of microwave is given is Section 2.2 followed by the description of microwave heating in Section 2.3 where the mechanism of dielectric heating will be discussed in detail. Within this section, the mechanism of microwave sterilization will be briefly explained and review of the effectiveness of sterilization and disinfection based on previous researches and experiments will be discussed in Section 2.4. Different sterilization techniques are discussed and compared to microwave sterilization technique in Section 2.5. The structure and properties of High Voltage Section of the microwave oven is studied in Section 2.6. In Section 2.7, the properties of sap of nipa palm (Nypa Fruticans) that worth studying before we use it as a sample for the testing purpose of the microwave sterilizer. Previous work on the modification of conventional microwave ovens are presented and comments are given in Section 2.8. Overall summary of this chapter is given in Section 2.9.

2.2 Microwave

Microwave is a form of electromagnetic radiation with frequencies ranging between 3GHz to 300GHz and wavelength ranging between 10cm and 1mm, respectively. It located in the electromagnetic spectrum as shown in Figure 2.1 below. All the electromagnetic radiation including microwaves travel in the speed of light which is $3.0 \times 10^{8}\ ms^{-1}$ in a vacuum condition. The relationship between wave length, speed and frequency of an electromagnetic wave can be seen in Equation 2.1 below:

$$\lambda = \frac{c}{f} \tag{2.1}$$

where λ = wavelength (m)

c = speed of light (m/s)

f = wave frequency (Hz)

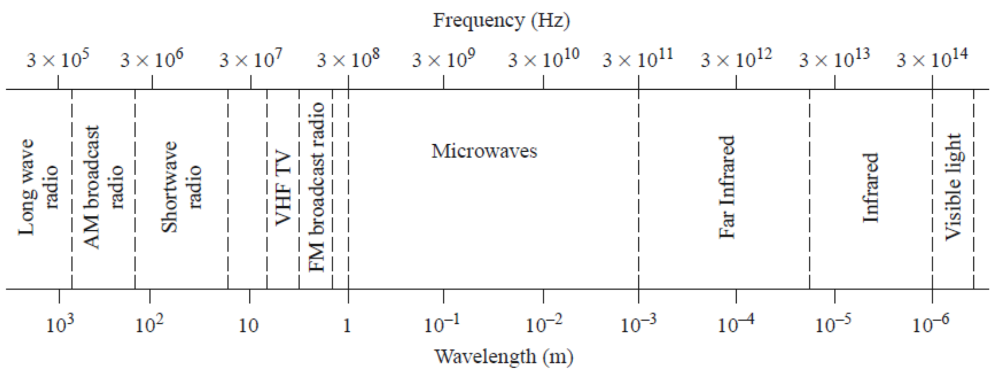

Figure 2.1: Electromagnetic spectrum

The magnetron of this project will be producing microwave at 2450 MHz or 2.45 GHz and its wavelength is 12.24 cm under vacuum condition. Microwave operating at this frequency is common since most of the conventional microwave ovens and household microwave ovens are operating at this frequency. Aside from 2.45 GHz, 915 MHz has been chosen and widely used in industrial heating for microwave heating applications to avoid interference with the already existed telecommunication devices as microwave band is widely used in telecommunications long before it is being used in heating (Menéndez, 2010; Meredith, 2007). This no not because they are the most suitable ones for the purpose but the fact that experiments and very little background information are not available for other microwave frequencies (Bengtsson & Ohlsson, 1974).

2.3 Microwave Heating

Microwave heating is the process where the electromagnetic energy converts to thermal energy within a substance. Its mechanism is different from convention heating which only involves heat transfer. Microwave heating is often known as dielectric heating. It refers to heating by high-frequency electromagnetic radiation which is microwave in our case. As electromagnetic field is make up of two components which are electric field component and the magnetic field component. The electric field component of microwave is the one that contributes to dielectric heating.

2.3.1 Microwave Electric Field Heating

Dielectric heating is result of two primary mechanisms which are dipolar polarization and ionic conduction. In dipolar polarization mechanism, when microwave is radiated towards a dielectric material, the dipolar components of molecules within will be couple electrostatically to the incoming electric field of the microwave. It causes both permanent and induced dipoles to try to align themselves with the incoming electric field which is alternating in time. However, under high frequency microwave (2.45 GHz in this project), the dipoles will align themselves up to 2450 million times per second. This molecular movement generates friction and collision among the rotating molecules which power is dissipated in the form of heat. This mechanism occurs to polar materials such as water that present within the microorganism that we intended to sterilize. Ionic conduction mechanism on the other hand, the electric field of the radiated microwave will influence any mobile charge carriers (electrons, ions, etc.) to oscillate back and forth through the material. This result in a current being induced and heat will be generated as it passed through any electrical resistance caused by the collisions of charged species with neighboring molecules or atoms within the sample (Sun, Wang & Yue, 2016; Menéndez, 2010; Meredith, 2007).

The power loss per unit volume for dielectric heating can be represented in equation 2.2 below:

$$P = \omega .\ \varepsilon''_{eff} .\ \varepsilon_{0} .\ E^{2}_{rms} \tag{2.2}$$

Where P = power density in the material (W/m^2) at the position (x, y, z)

$\omega = 2\pi f$ (Hz), f = frequency of the incident microwaves (Hz)

ε''_{eff} = effective dielectric loss factor

ε_0 = permittivity of free space ($\varepsilon_0 = 8.854 \times 10^{-12}$ F/m)

E^2_{rms} = square of local value of electric field strength (V/m) at the position (x, y, z)

Based on the equations, it describes how non-magnetic materials interact with electromagnetic radiation. The dielectric constant or permittivity, ε'_{eff} describes the ability of the material to absorb, transmit and reflect energy from the electric field of the incident microwave whereas the effective dielectric loss factor, ε''_{eff} describes the ability to convert this energy into heat. Both properties of ε' and ε'' are associated to the intensity of heating of the material under dielectric heating and can be related in equation 2.3.

$$tan\ \delta = \frac{\varepsilon'}{\varepsilon''} \tag{2.3}$$

The $tan\ \delta$ is known as the dielectric loss which describes the ability of a material to convert dielectric energy into heat. The dielectric properties or the value of $tan\ \delta$ of a material depend on several factors: frequency of the electromagnetic waves, temperature, physical state of the material and the composition of the mixture (Galema, 1997; Yaghmaee & Durance, 2005; Menéndez, 2009).

2.3.2 Microwave Magnetic Field Heating

The effect of heating by microwave magnetic field has some superior advantages compared to heating by microwave electric field. Peng et al (2012) found that the magnetic loss value can be up to 4 times greater than the dielectric loss in the heating ferrites (BaFe12O19, SrFe12O19 etc.) with microwave of 2.45 GHz. However, Vela and Wu (1978) and Jeng et al (1987) found that without the presence of water (dielectric material) the sterilization process using microwave is not significant. Therefore, we can say that microwave sterilization is achieved by electric field of microwave.

2.4 Microwave Disinfection and Sterilization

This section discusses the effectiveness of microwave irradiation on microorganisms based on previous works conducted over the years. The thermal and non-thermal effect caused by microwave radiation will also be discussed.

2.4.1 Effect of Microwave Irradiation on Microorganism

When living organisms such as microorganisms are exposed to microwave radiation, there are two types of effects: thermal and non-thermal effect (athermal effect). The former is caused by the absorption of microwave energy which transfer to heat which has been discussed in the microwave heating section. The idea of non-thermal effect was studied when experiments showed that microwave induced heating destroyed more bacterial cultures compared to other heating methods under the same working temperature. However, the effect of non-thermal effect still could not be fully understood (Banik Bandyopadhyay & Ganguly, 2003; Michaelson, 1974).

According to guidelines provided by WHO (Prüss et al, 1999), most microorganisms are destroyed with the exposure of microwave radiation with frequency of 2450 MHz but with the presence of water is crucial. The microorganisms and infectious components are destroyed by the conduction of heat. However, a bacteriological test using Bacillus Subtilis (a type of biological indicator) is recommended to demonstrate a 99.99% reduction of viable spores through treatment with microwave radiation.

Mima et al (2008) conducted a research on the effects of different exposure times on microwave irradiation on the disinfection of a hard chairside reline resin which infected with various type of microorganisms including Bacillus Subtilis are exposed to microwave radiation of different power and exposure time. They found that microwave radiation does have a significant effect on the growth of microbial cultures and they suggested that 3 minutes of microwave irradiation can be used for acrylic resin sterilization. However, the effects vary from killing the microorganisms with high frequency and high energy microwaves to enhancement of their growth with low frequency microwaves. In the case of bacteria indicator, Bacillus Subtilis, it was killed with microwave radiation of power 650W with exposure time of 2 to 5 minutes.

Wu, Deng and Wei (1994) also studied the effect of microwave radiation on several typical bacterial indicators include Bacillus subtilis, Bacillus Stearotherphilus etc. They found that the killing effect of microwave radiation on all bacteria depends on time, type of items involved, microwave power as well as the type of bacteria. However, they proved that under the same condition, if Bacillus subtilis is killed, all other type of bacteria will be killed as well. Therefore, Bacillus subtilis can be considered as an optimum bacteria indicator for disinfection or sterilization by microwave energy which is also recommend by WHO. Wu (1996) did a similar research and similar conclusion were made.

Dunsmuir and Gallacher (2003) used microwave to sterilize femoral head allografts which were decontaminated with S. aureus and Bacillus Subtilis. They found microwave sterilization of bone allografts is effective for sterilization of contaminated femoral head allografts as results showed that the growth of the microorganisms is halted after being treated for 2 minutes or longer.

Jonković, Milosev and Novakovic. (2014) studied the effects of microwave radiation on microbial cultures and summarized a table on effects of microwaves on microbial cultures depending on the frequency, power (or delivered energy) and microbial species which can be seen Table 2.1 below. They made a conclusion that microwave radiation has significant effects on microbial cultures however the result heavily dependent on the microwave frequency and the total energy absorbed by the microorganisms.

Table 2.1: Effects of microwaves on microbial cultures depending on the frequency, power (or delivered energy) and microbial species (Jonković et al 2014)

Delivered Energy	Frequency of microwaves				
	800 – 1900 MHz	2450 MHz	18 GHz	41.640 – 41.835 GHz	99 GHz
Not reported				Saccharomyces cerevisiae, INCREASED/ DECREASED GROWTH	
1 – 2 W; 30, 60, 120 and 180 minutes	E. coli, Klebsiella pneumoniae, ENHANCED GROWTH				
550 W; 5 – 30 seconds		P. aeruginosa, P. acidovorans, S. aureus and S. epidermidis, ENHANCED GROWTH	S. aureus, E. coli, INACTIVATION		
600 W; 2 – 4 minutes		E. coli and spores of Bacillus cereus, KILLED			
650 W; 2 – 5 minutes		P. aeruginosa, S. aureus, Candida albicans, and B. subtilis, KILLED			
800 W; 1 minute		S. aureus, Salmonella enteritidis, E. coli and B. cereus, KILLED			
10 and 60 mW/cm^2; 5-60 minutes		Aspergillus versicolor and Penicillium brevicompactum) and actinomycetal (Thermoactinomyces vulgaris and Streptomyces albus) spores, VIABILITY OF FUNGI DECREASED, VIABILITY OF ACTINOMYCETES INCREASED			
1500 kW/m^2			E. coli, OPENINGS OF PORES in the cell membrane		

Table 2.1: continued

2000 W; 2 minutes		Bacillus licheniformis spores, CORTEX HYDROLYSIS and Bacillus subtilis, AGGREGATION OF CYTOPLASMIC PROTEINS			
2000 W; 19 hours					E. coli, INCREASE IN PROLIFERATION

2.4.2 Role of Nonthermal Effect

Vela and Wu (1978) did research on mechanism of lethal action of 2450 MHz radiation on microorganisms under the presence and absence of water during treatment of microorganisms. They found that the microorganisms were inactivated only when in the presence of water and no significant effect with the absence of water. The data proved that the microorganisms are killed only by thermal effect as under the absence of water, the specimen do not absorb sufficient energy to kill microbial cells showed that the nonthermal effect is not significant in lethal action of microwave radiation towards microorganisms. Jeng et al (1987) also found that microwave sterilization was caused solely by thermal effects as nonthermal effects were not significant in a dry microwave sterilization process.

2.5 Comparison between Sterilization Techniques

This section will discuss three other sterilization techniques such as incineration, chemical disinfection and wet thermal steam treatment. These are the most popular sterilization techniques being conducted. Comparison between these techniques and microwave sterilization are made to show the advantages of microwave sterilization technique.

Incineration is a sterilization technique which used high temperature dry oxidation process to reduce organic and combustible waste to inorganic, incombustible matter and greatly reduce the volume and weight of the waste. However, incineration is viable and affordable only if the "heating value" of the waste reaches at least 2000kcal/kg and 4000 kcal/kg for infectious waste.

There are three basic types of incineration technologies are available such as double-chamber pyrolytic incinerators, single-chamber furnaces with static grate and rotary kilns operating at high temperature. Different incineration technology is suitable for the incineration of different waste type depending on the characteristic.

However, incineration technology which involves the combustion of organic compounds will produces mainly gaseous emissions including steam, carbon dioxide, nitrogen oxides and certain toxic substances such as metals and halogenic acids. Moreover, particulate matter (PM) and solid residues will be produced in the form of ashes. If the conditions of the combustion of certain waste are not fulfilled, toxic carbon monoxide will be produced and the ash or wastewater produced by the process will also contain toxic compounds. Extra cost will be incurred in order to treat the residues produced to avoid adverse effects on health and the environment.

Chemical disinfection is the use of chemicals to kill or inactivate the pathogens contained within the waste. Chemicals are added to the waste in order to conduct the treatment. Chemical disinfection is most suitable for treating liquid waste while the treatment of solid waste will have limitations.

One of the limitation of the use of chemical in disinfection process is the contact times. In comparison to microwave sterilization technique which has a lower treatment duration, the contact times of chemical sterilants range from 3 hours to 12 hours. Besides, studies have suggested that the efficiency of chemical sterilants may not convey the same sterility assurance level as sterilization achieved using thermal or physical methods. In comparison to sterilization achieved through heat such as microwave and steam techniques, heat can penetrate barriers such as biofilm, tissue and blood in order to kill or eliminate the organisms. Whereas liquid chemical sterilants do not show the same penetration level to the sterilization achieved using heat. Therefore, the effectiveness of chemical sterilent is less desired in comparison to other sterilization technique and its application is restricted due to the limitations inherent of using liquid chemical sterilants.

Wet thermal of steam disinfection is conducted by exposing the infectious waste to high-temperature, high-pressure steam which is similar to autoclave sterilization process. It can inactivate most types of microorganisms under the sufficient conditions.

Wet thermal treatment is capable of achieving 99.99% inactivation of microorganisms while autoclave sterilization can achieve 99.9999% inactivation of microorganisms. These treatment techniques have good sterilization efficiency but treatment of anatomical waste, animal carcasses, chemical or pharmaceutical wastes are not feasible and not appropriate. The types of waste can be treated are limited in comparison to other sterilization technique. Besides, the efficiency of disinfection is very sensitive to the operational conditions such as temperature, pressure and exposing time.

In comparison to the stated sterilization techniques discussed, microwave sterilization technique has the following advantages. Microwave sterilization technique which do not involve combustion is more environment friendly in comparison to incineration technique as it will not produce particulate matter and other toxic substances. Besides, microwave sterilization has better and more desired disinfection efficiency under appropriate operating conditions compared to chemical disinfection. Less limitations on types of waste that can be treated using microwave in comparison to wet thermal or autoclave treatment. Hence, microwave sterilization is extremely capable and has the potential to become the major sterilization technique. Therefore, it should be further studied and improved further (Prüss et al, 1999; Rutala et al, 2008).

2.6 High Voltage Section of Microwave Oven

One of the most important circuit of a microwave oven is high voltage section. This is the part that will power up the magnetron to produce microwave. Hence, this particular part of the circuit has to be studied before the modification of the microwave oven can take place.

Electrical sockets (outlets) in Malaysia usually supply electricity between 220 V to 240 V operating at AC at 50Hz. However, this voltage level is too low to power up a magnetron to produce microwaves. In this project, the magnetron being used is 2M210-M1 by Panasonic which required 4000V. Therefore, a half-wave voltage doubler circuit is applied in the microwave oven as shown in Figure 2.2. The doubler circuit can double the 2000V voltage which has been stepped up by the transformer from the 240VAC source to approximately 4000V. However, the 4000V will be supplied in terms of pulse with frequency of 50Hz. During the first positive half-cycle of AC current, it will charge the capicator and no voltage to the magnetron. During the second negative half-cycle of AC current, the voltage of 2000V will be add up to the discharging 2000V voltage from the capacitor to provide 4000V of voltage to the magnetron cathode. The capacitor being used in our project is MWC100 by Panasonic with 1.00 μC and voltage of 2100V. According to Figure 2.2, there is another part of the transformer that step down the voltage to 3.15V to supply voltage to the filament of magnetron (Gallawa, 1989).

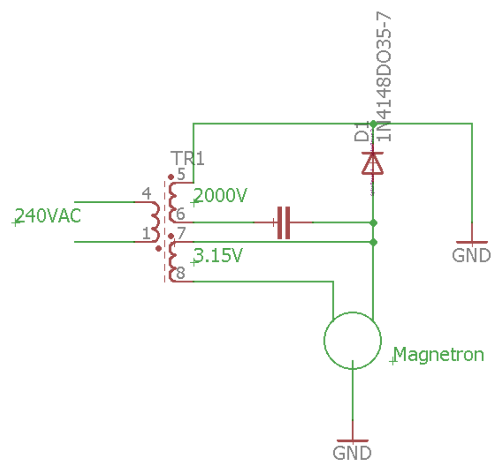

Figure 2.2: High voltage section of microwave oven (Gallawa 1989)

2.7 Sap of Nipa Palm (Nypa Fruticans)

Nipa sap or air nira is a type of sweet natural beverage collected from a type of palm tree known as nipa palm (Nypa fruticans). The nipa palm has been widely distributed over Malaysia with approximately of 20 000 ha are found in Malaysia. (Jabatan Pehutanan Semenanjung Malaysia, 2009)

Fresh palm sap or being called air nira in Malaysia is a traditional beverage that has been consumed by local community in Malaysia. Nipa sap should be consumed fresh due to the presence of natural existed microorganisms. On the other hand, fermented nipa sap is being called palm wine or toddy and being consumed by the non-Muslim community in Malaysia.

Aside from being consumed as beverage, nipa palm sap has a potential as feedstock for ethanol production due to the presence of rich yield in sucrose, glucose and fructose which are suitable to be fermented into ethanol (Tamunaidu et al 2013). Per a study by Amoa-Awua, Sampson and Tano-Debrah (2007) on the growth of microorganisms in palm wire, they found that fresh sap obtained in the first day of tapping were very sugary and did not contain substantial concentrations of alcohol. However, the growth of yeast dominated by S.cerevisiae started immediately after the tapping began and alcohol concentrations became substantial on the third day. They found that the sap is a suitable medium for the growth of various types of micro-organisms and identified a great number of yeasts, aerobic mesophiles, lactic acid bacteria and acetic acid bacteria within the palm sap. Similar results on the type of microorganisms isolated and identified by Santiago-Urbina and Ruiz-Teran (2014). These studies showed that palm sap is suitable to be used as a testing sample for sterilization process due to the presence of high number of microorganisms. The effect of microwave sterilization can be observed easily.

2.8 Previous Works on Modification of Conventional Microwave Oven

This section will discuss 3 works on the modification of conventional microwave for research purpose in different fields and comments will be given before the end of this section.

The first work is conducted by Horikoshi, Hidaka and Serpone (2003) on the modification of a convention microwave oven that incorporates an UV-Vis lamp and an optical fiber thermometer is used to measure the temperature. The aim of the modification is to photodegrade environmental pollutants in aqueous media. The field of study might be different but the integration of fiber optic thermometer to measure temperature is worth studying for this project. A fiber optic thermometer is used in this particular work due to their immunity to electromagnetic wave. A hole is drilled on top of the chamber to install the fiber optic thermometer. The thermometer is soaked directly to the sample in order to measure the temperature. However, the turntable of the microwave oven has to be removed to prevent rotation to avoid damage to the thermometer and other components.

The second work is conducted by Pagnotta, Nolan and Kim (1992) on the modification of a convention microwave oven for improved temperature control. A thermistor probe is used and connected to an independent temperature monitor to measure the temperature. The excess heat generated by the microwaves can be removed by installing inlet and outlet ports for circulating water. The circulation of chilled cooling water at a rate of 8-10 L/min allows the removal of excess heat generated to improve the accuracy of temperature measurement.

The third work is conducted by Goedeken, Tong and Lentz (1991) on using IR imaging to measure temperature continuously in microwave cavity. The top section of the microwave cavity is replaced by square hardware cloth which allow direct thermal imaging of the sample by the sensor and able to block the microwave from leaking at the same time. The study found that the actual temperature and the temperature sensed by the IR camera is different due to the combination of the temperature of the sample and temperature of the screen are both sensed. The temperature of the screen is believed to be heated by the heat released by the heated sample and the cavity. Therefore, a multivariable regression is done to relate the actual temperature to the IR and screen temperature. The project has successfully designed a system which can measure the temperature of the surface continuously and accurately.

In the first work, fiber optic thermometer is used and is one of the easiest implementation. But the turntable has to be removed in the same time which might reduce the even distribution of radiation of microwave onto the sample. In comparison to other implementations, the use of fiber optic thermometer is most costly due to the higher price of fiber optic. In the second work, the water circulation system can effectively remove excess heat that might disrupt the accuracy of temperature measurement. But the implementation would be much complex to implement a water circulating system. In the third work, the use of IR camera to measure the temperature proved to be very effective and accurate after the work of calibration.

However, most of the work do not involve the design of a customized control for the modified microwave oven where the original control is still being used. The overall control of the oven is still very limited and less flexible. A friendly user interface should be designed to replace the existing control panel of the microwave oven. Besides, the microwave ovens modified in the works do not have the ability to record the temperature of the sample as the whole systems are not connected. The temperature measurement devices are separated from the microwave oven itself. The works also have very limited space to be upgraded or improved. The oven should be modified in a way that the upgradability is available. The user should able to upgrade the device whenever there is a need in performance or application. For example, using Arduino as the controller for the oven will have a great flexibility and upgradability.

2.9 Summary

Based on the literature review above, microwave sterilization is viable and effective under the suitable condition. However, the effect of sterilization is solely due to thermal heating where the presence suitable amount of dielectric material such as water is crucial. The works on modification of microwave oven are discussed and are considered and implemented in this project.

CHAPTER 3

METHODOLOGY

3.1 Introduction

This chapter is to discuss overall methodology used in the development of microwave sterilizer. The development of the project is based on both hardware and software. A general flowchart for the overall flow of methodology is presented in Figure 3.1 below. Section 3.2 explains the modification process of a conventional microwave while Section 3.3 describes the implementation of ZTP-115M thermopile IR sensor for the modified microwave oven. The development of Graphical User Interface (GUI) using Visual Studio 2015 is discussed in Section 3.4. Section 3.5 explains the procedures taken in the treatment of nipa palm sap and Section 3.6 explains the methods used in determining the efficiency of microwave sterilization on the treated nipa palm sap. The summary of this chapter is given in Section 3.7.

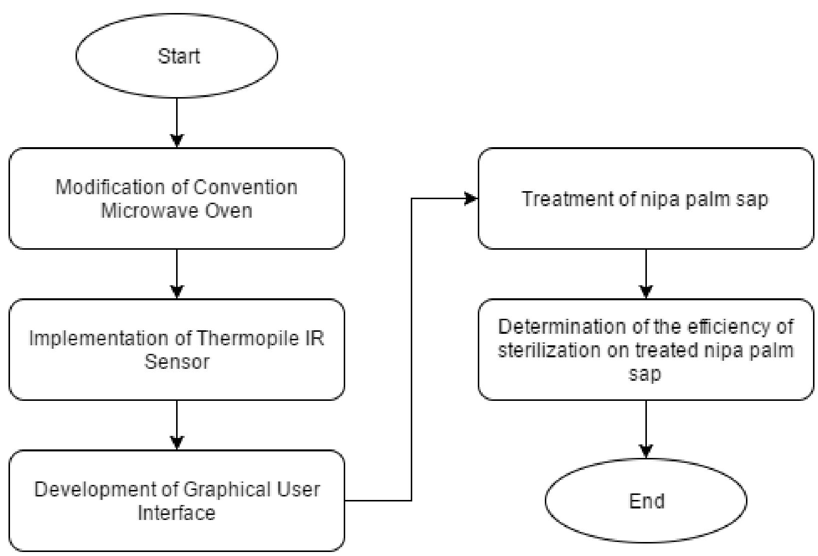

Figure 3.1: Overall flow of methodology

3.2 Modification of Microwave Oven

Modification of a conventional microwave oven is the first step of the project. In this Section, the use of an Arduino Uno microcontroller to replace the existing controller for the microwave oven will be discussed. The model of the microwave oven used for modification is National NN-MX20WF with power output of 850W. The overall block diagram of the microwave sterilizer is presented in Figure 3.2 below:

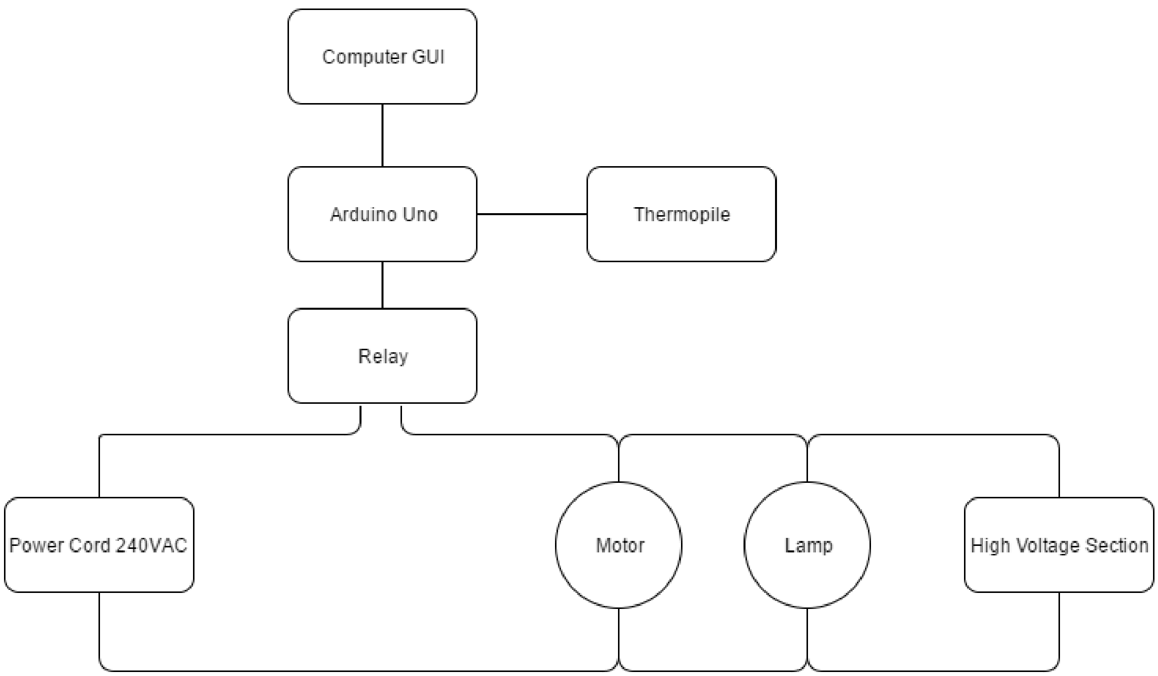

Figure 3.2: Overall circuit diagram of the microwave sterilizer

The microwave oven will be modified and developed into microwave sterilization system according to the configuration shown in Figure 3.2. A GUI will be developed which enables a computer to communicate with the Arduino Uno in the microwave sterilizer with USB connect through serial communication. A thermopile IR sensor is connected to the Ar-