# OPTIMIZATION CONDITION FOR PALM OIL FRUIT STERILIZATION PROCESS

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# OPTIMIZATION CONDITION FOR PALM OIL FRUIT STERILIZATION PROCESS

**TG FARHANA BT T KAMARULZAMAN**

A thesis submitted in fulfillment of the
requirements for the award of the degree of
Bachelor of Bachelor of Chemical Engineering

Faculty of Chemical and Natural Resources Engineering
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APRIL 2009

I declare that thesis entitled "Optimization Condition for Palm Oil Fruit Sterilization Process" is the result of my own research except as cited in references. The thesis has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

| | |
|---|---|
| Signature | :…………………. |
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| Date | : |

To my beloved mother and father

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# ABSTRACT

The research that been implement is about the optimization condition for palm oil fruit sterilization process. The parameters that have been focused throughout this experiment were pressure and process time of sterilization process. The experiment works has been done at factory of LKPP CORPORATION SDN. BHD. Both parameters have been tested during and after sterilization process and the oil losses are determined. The oil losses are determined at the condensate and empty fruit bunch. In this research, the experiment has been run with three different set of pressures which are 39 psig, 40 psig and 41 psig and process time of 80 minutes to 100 minutes for three (3) weeks. The value of free fatty acid (FFA), moisture and deterioration of bleachability index (DOBI) were also taken to determine the quality of the fresh fruit bunch (FFB) and to improve the quality of crude palm oil (CPO). The result shown, the oil losses are decreased at the 41 psig of pressure and 90 min of process time. The lower the oil losses will result to higher oil extraction rate (OER) ad hence higher oil production of Crude Palm Oil (CPO).

# ABSTRAK

Kajian yang dijalankan adalah mengenai keadaan optimum dalam proses pensterilan buah kelapa sawit. Dua parameter telah difokuskan sepanjang eksperimen ini iaitu tekanan dan tempoh masa dalam proses pensterilan. Proses pensterilan ini dijalankan di makmal kilang LKPP Corporation Sdn. Bhd. Kedua-dua parameter ini diuji semasa dan selepas proses pensterilan dijalankan dan kemudian kadar kehilangan minyak ini disukat. Kadar kehilangan minyak diperolehi melalui kolam perangkap minyak dan buah tandan kosong. Eksperimen dijalankan pada tekanan yang berbeza iaitu pada 39 psig, 40 psig dan 41 psig dan tempoh masa proses yang berbeza iaitu pada 80 minit hingga 100 minit untuk tiga minggu. Nilai asid lemak bebas, kandungan kelembapan dan kemerosotan kebolehan meluntur indeks juga diambil untuk menentukan kualiti buah dan untuk membaiki kualiti minyak mentah. Berdasarkan keputusan yang diperolehi, didapati bahawa kehilangn minyak berkurang pada tekanan 41 psig dan masa selama 90 minit. Kadar kehilangan minyak yang rendah akan secara langsung menyebabkan kadar perahan minyak tinggi. Oleh itu penghasilan mintak mentah akan meningkat.

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| | | |
|---|---|---|
| DOBI | - | Deterioration of Bleachability Index |
| FFA | - | Free Fatty Acid |
| CPO | - | Crude Palm Oil |
| USB | - | Unstripped Bunch |
| FFB | - | Fresh Fruits Bunch |
| OER | - | Oil extraction rate |

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# CHAPTER 1

# INTRODUCTION

## 1.1 Background of Study

Palm oil is the one of the most important vegetable oils in the world's oil and fats market [Hartley, C.N.S., 1988]. Oil palm tree *(Elaeins guineensis)* is the most productive oil producing plant in the world, with one hectare of oil palm producing between 10 and 35 tonnes of fresh fruits bunch (FFB) per year [Hartley, C.N.S., 1988, Ma, A.N., Y. Tajima, M. Asahi and J. Hannif, 1996]. The palm oil has a life of over 200 years, but economic life 20-25 years.

**Figure 1.1:** Fresh Fruit Bunch

Usually, the harvested part is the fruit "fruit bunch" whereby oil is obtained from the fleshy mesocarp or pulp of the fruit. Oil extraction from flesh amounts to at least 45-46% while kernel accounts for at least 40-50%. Crude palm oil contains fatty acid ester of glycerol commonly referred to as triglycerides, therefore, contributing to the worlds need of edible oil and fats. It is composed of approximately 50% saturated (primarily palmatic acid) and 40% unsaturated fats (principally linolenic and oleic acid) a unique composition if compared with other major fats [Usoro, E.J., 1974].

Under concerted programmed of agricultural diversification, Malaysian Government embarked on re-plantation of traditional rubber estates with oil palm 1960 and new land was offered for the cultivation of this wonder crop. Today, Oil Palm is the leading agricultural crop in Malaysia, covering over 2.5 million hectares of land which is over a third of the total cultivated area in the country.

Malaysia remains world's largest producer and exporter of Palm Oil with 11.8 million tan per annum production or around 50% of world production. With increasing population and growing oil demand Palm Oil appears to be the only option to meet the future requirements due to better yields comparing to other oil crops.

There are several stages of processing the extraction of palm oil fresh fruit bunches. These include sterilization, bunch stripping, digestion, oil extraction and finally clarification and purification; each process with its own various unit operation. In the conventional milling process, the bunch are loaded into cages and pushed into sterilizers, where they are cooked using steam at 40 psig. The process arrests oil quality deterioration due to enzymatic activity. It also facilitates the stripping of fruits from bunch stalks and the extraction of oil and kernel. The sterilization time and steam pressure required to achieve complete stripping of fruits from crushed bunches.

**Figure 1.2:** Fruit Palm Oil

Based on these problems the process at sterilization will study to produce the higher palm oil. The last result, oil extraction rate of palm oil can be determined by the oil losses after sterilization process. It has been shown that it is possible to get the optimum condition of the process. For the edible oil refining industry the most important quality criteria for crude oil are low content of free fatty acid which are costly to remove during oil refining, low content of products of oxidation and readily removed colors.

**Figure 1.3:** Sterilizer

## 1.2 Problem Statement

In order to maintain the position of producer of palm oil as a major player in the vegetable oil market, Malaysia is focusing her efforts on production of quality oil. For this strategy to be effective, we must be aware of the crude palm oil (CPO) quality and characteristics produced by other prominent producers. The quality of final palm oil products exported is determined by the quality of CPO produced and this is determined by the quality of palm fruits processed at the mills. Towards this end, Malaysia has to ensure that palm oil products exported are of consistent and high quality. The quality of oil has often been determined at the fruit or bunch level. (CPO) is normally traded bases on three main specifications, namely, free Fatty Acid (FFA), moisture and impurities content. The quality of oil has often been determined at the fruit or bunch level. Damage or over ripped fruits exhibit high FFA content and during the milling process these acid are incorporated into the CPO. Therefore, CPO with high FFA has detrimental effect in refining operation process. Moisture and impurities content of CPO also need to remove in physical refining process. Apart from direct loss to the refiners, high moisture and impurities adversely affect the vacuum, thus disturbing the whole operation. An indication of refined palm oil quality is reflected by the deterioration of bleachability index (DOBI) values of CPO. Lower DOBI values indicate poor bleachability. In this research, the optimum condition of sterilization process will determine by using two parameters that are pressure and process time to minimize oil losses after sterilization process. Therefore when oil losses are increased after sterilization process, the production of CPO also increased.

## 1.3 Research Objective

i. The main objective of this experiment is to optimize the oil extraction rate to produce the higher oil production in order to minimize the oil losses after sterilization process.

ii. Besides that, this experiment will focus on production of the quality of crude palm oil.

## 1.4 Research Scope

The list below is about my scope of the experiment:

i. Effect of oil losses on OER by using different pressure and process time during sterilization process.

ii. Effect of oil production during sterilization process to produce the highest palm oil fruit quality.

iii. Effect of FFA, moisture and DOBI value on quality of CPO.

# CHAPTER 2

# LITERATURE REVIEW

## 2.1 Stage in the Extraction

As mentioned earlier, there exists several processing stages in the extraction of crude palm oil from fresh fruits bunches. The first stage is sterilization. The fruit bunches brought to the mill to a high pressure steam (120 to 140°C at 40 psig). The next stage is called bunch stripping. This offers a means of separating the fruits from the bunch stalks by mechanical stripping. The separated and sterilized fruits thereafter undergo a process of digestion. This achieved by reheating the fruits using steam to a temperature of 80-90°C. This prepares the fruits for oil extraction by rupturing the oil bearing cell in the mesocarp or pulp and loosening the mesocarp from nuts. The extraction liquid and nuts are discharged from the screw press. However, the extracted oil contains varying amounts of water, solids and dissolved impurities that must be removed. The capacity of the proposed mill is based a number of factors:

i. availability of equipment
ii. production costs per liter (raw materials)
iii. anticipated impact on local economy; both positive and negative
iv. environmental impact
v. experience and expertise/skill labor or workers

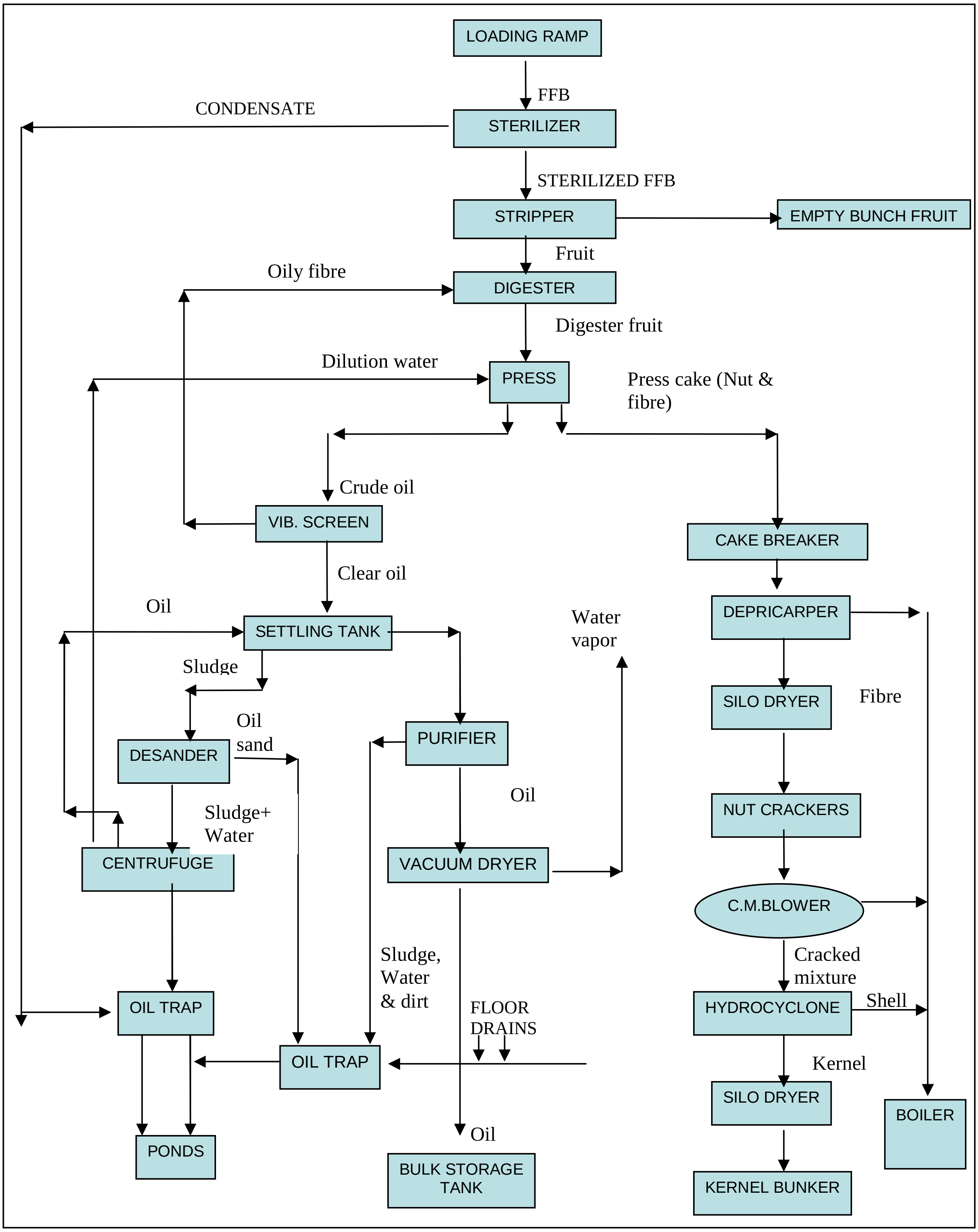


**Figure 2.1:** Process Flow Chart (Palm Oil Mill Kilang Sawit Lcsb, Lepar)

1. Transport the harvested bunches to the mill with minimum bruising for processing within 24 hours. This minimizes the fermentation of the oil, and makes it possible to produce a final product with low free fatty acids.

2. Sterilize/cook the bunches with steam under pressure (40 psi). The sterilization destroys the enzymes that cause the oil to ferment.

3. Strip the fruit from the bunches. This will likely be done with a mechanical bunch stripper.

4. Process the individual fruit-lets in a digester that releases the oil.

5. Press the oil out of the digested fruit in a mechanical screw press.

6. Remove water, dust, and fibers from the oil by filtering and boiling and/or using a centrifuge.

**Figure 2.2:** Processing Steps

Based on this research, the focusing is at the sterilizer. According from Encyclopedia by Wikipedia, sterilization or cooking means the use of high-temperature wet-heat treatment of loose the fruit. Cooking normally uses hot water; sterilization uses pressurized steam. When high-pressure steam is used for sterilization, the heat causes the moisture in the nuts to expand. When the pressure is reduced the contraction of the nut leads to detachment of the kernel from shall wall, thus loosening the kernel within their shells. From the foregoing, it is obvious that sterilization is one of the most important operations in oil processing.

## 2.2 The Sterilization Process

Sterilization is the first process step in extraction of oil and kernel from the oil palm fruit. If the fruit is adequately sterilized then the efficiency of the oil and kernel extraction processes will adversely affected. The current method of sterilization is batch process. This batch process has to supply the fruits needed to maintain subsequent extraction processes in continuous operation. Operations related to the batch sterilization process absorb much of the process labour in a typical mill. The introduction of the pollinating weevil, *Elaeidobius Kamerunicous,* in 1981 resulted in larger and heavier bunches with more closely packed fruitlets being delivered to palm oil mills [Basri, M. Halim, A. and Hitam A.,1983]. Difficulties encountered with the processing of these types of bunches highlighted the need to examined the design and operation of the sterilization process.

### 2.2.1 The Sterilizer

Sterilizer is carried out in horizontal steam auto-types of cylindrical shapes of approximately 1.83 m (6 ft) diameters. The length of the sterilizer is adapted to the number of fruit cages it should hold. Each fruit cage is approximately 3.05 m (10 ft) long and capable of holding up to 3.5 tonnes of fruit bunches. The sterilizer is normally made from mild steel, and may be provided with a single door or alternatively with a door at each end. The latter arrangement is preferred in larger capacity mills since it simplifies the movement of cages. The doors can be swung to a side to allow free access to the interior. Condensate is removed right from the bottom of vessel through a number of pipe connections. The steam usually enters the sterilizer through a single pipe at the top of the vessel. A spreader plate is fitted running practically the whole length of sterilizer. The purpose of this is to prevent the steam from over-cooking the bunches immediately below the inlet pipe and causing localized erosion due to the high speed of condensate droplets. It also spreads the steam so that the condition along the whole length of sterilizer is more or less even.

The following instruments are normally provided with manually operated sterilizer:

i. A pressure gauge to provide a readily visible indication of pressure reached within the sterilizer.

ii. A pressure recorder to enable the operator to follow the course of sterilization and to provide management with a permanent record for trouble shooting purposes.

### 2.2.2 The Sterilization Cycle

Figure 2.3 illustrates the desired pressure-time curve during a triple peak sterilization cycle. The cycle time is defined as the door-shut-to-shut time and can be computed as follows:

Cycle time= $t_1 + t_2 + t_3 + t_4 \ldots\ldots t_{10}$

The relationship between cycle time and sterilization throughput can be expressed as follows:

$$\text{Throughput} = \frac{\text{Total sterlization capacity}}{\text{Cycle time}}$$

For double peak sterilization cycle, $t_4$ and $t_5$ are set zero to zero. i.e. one peak omitted. For single peak sterilization cycle $t_2$, $t_3$, $t_4$ and $t_5$ are set zero, i.e. two peaks are omitted.

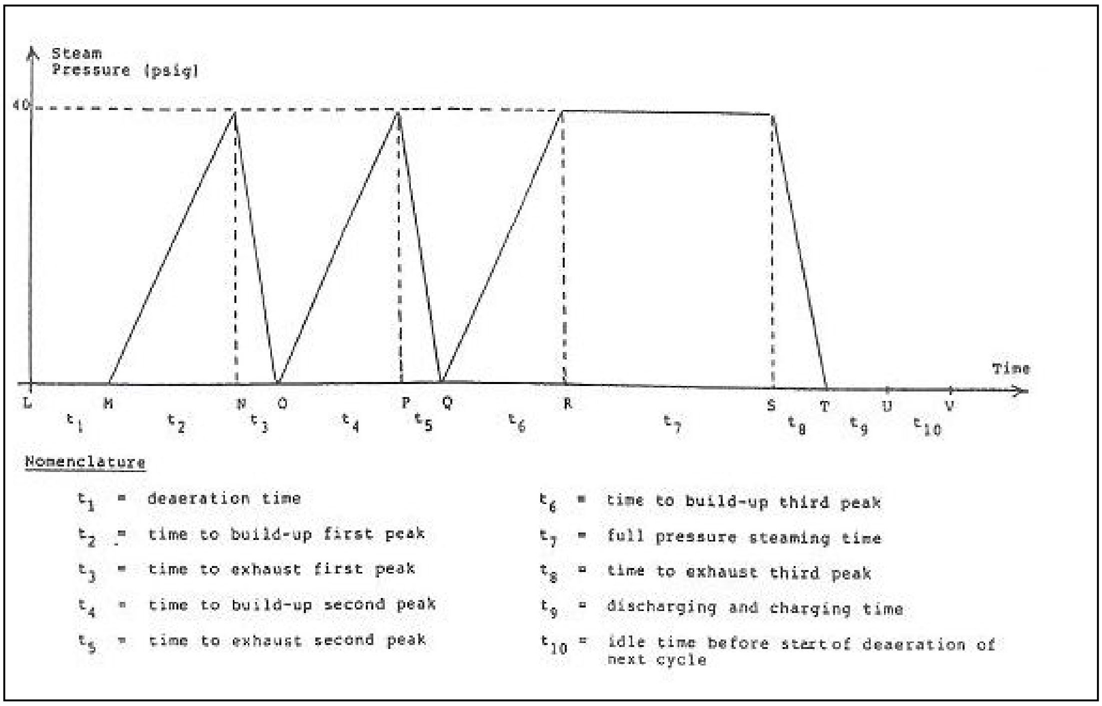


**Figure 2.3:** Ideal Pressure-Time Curve during Triple Peak Sterilization Cycle

### 2.2.3 Sequencing of Multiple Sterilizer

The task of sequencing multiple sterilizers involves coordinating valve movement of more than one sterilizer, especially during those periods in the sterilization cycle when there is build-up pressure in the sterilizers. This has an important effect on:

i. Total instantaneous steam demand for sterilization.

ii. Throughput of the sterilization station.

Figure 2.4 and Table 2.1 [Shafii, A.F., Sivasothy K. and Lim, N.B.H., 1985] show the overall steam distribution in a typical palm oil mill. It can be seen that sterilization consumes about 35 % of the total steam generated in the palm oil mill. If instantaneous steam demand is too great because of simulation build-up of pressure in too many sterilizers, then the rate of build-up of pressure in the sterilizer may be reduced. It may be affected because of the need to extend steaming time. Alternatively, the desired pressure may not be attained within the specified time interval. The aim of proper sequencing is to minimize the changes in steam demand. The loss of steam into the atmosphere would also be minimizing.

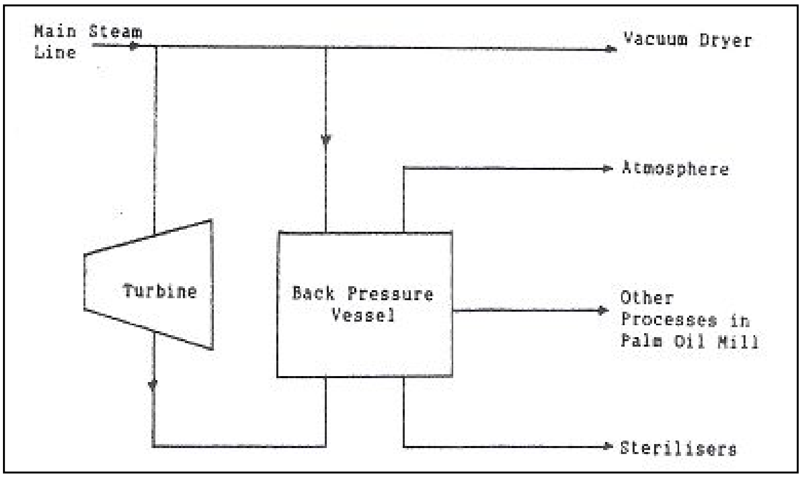


**Figure 2.4:** Steam Distribution in Typical Palm Oil Mill

| *Measurement* | *Steam flowrate* (kg/h) | *Percentage of boiler output* |
|---|---|---|
| Boiler steam output | 14 744 | 100 |
| Before back pressure vessel: | | |
| Turbine | 12 389 | 84 |
| Make-up | 1540 | 10 |
| Vacuum dryer | 1068 | 7 |
| After back pressure vessel: | | |
| Sterilisers | 5219 | 35 |
| Other processes | 3302 | 22 |
| Loss to atmosphere | 5433 | 37 |

**Table 2.1:** Analysis of Steam Distribution in 25 tonne/hr Palm Oil Mill

## 2.3 Assessment of Automation Needs

The sterilization process also can control based on the use of a personal computer and a programmable logic controller. The term process automation has been defined as the function of monitoring and regulating process operations non-manually or remotely to check or maintain the required process conditions and product quality.

### 2.3.1 For the Palm Oil Mill

The objective of any palm oil mill automation programmed consists of one or more of the following:

i. To provide improvements in process efficiency.
ii. To provide improvements in product quality.
iii. To provide improvements in productivity.
iv. To provide improvements in operating practices.
v. To facilitate introduction of new technology.
vi. To conserve energy resources.
vii. To control pollution.
viii. To provide safer or better worker conditions.

Careful consideration must be given during palm oil mill automation strategy to existing conditions in the mills. Because of this, there has been little effort put in the gearing the milling operation for automation. Some factors which at present act as deterrents to automation [Shafii, A.F., 1986 and Sivasothy K and Maycock, J.H., 1987] are:

i. Variability in amount, nature and quality of fresh fruit bunches processed.
ii. Processing discontinuities such as breakdowns and stoppages for cleaning or removing foreign material which prevent steady-state operation.
iii. The batch nature of the sterilization process introduces variability in the amount processed by the rest of the mill.
iv. Lack of skilled process control and maintenance personnel.
v. Scale of operation of most mills is quite small.
vi. Waste fibre and shell is available for use as boiler fuel in most mills.

Two of these above are other factors such as low labour cost and isolate location of most mills. This is initiative to reduce the cost of production and increase the profit-making capability of the mills. It is anticipated that some of the constraints mentioned above will be addressed and solutions found which will permit a greater role for automation in the future.

### 2.3.2 For the Sterilization Process

By the standards of most process control problems, control of process sterilization process is a relatively simple control problem. Since slight changes in process conditions will not markedly alter product losses or product quality. The practice of recycling partially stripped bunches for reprocessing helps to control losses due to poor sterilization.

There are benefits to be derived through automation [Southworth A, Lim, E.H. and Lee A.K., 1987]. Some of these are:

i. It compensates for operator carelessness and unreliability which can lead to poor sterilization or less than 100 % efficiency in recycling of partially stripped bunches for reprocessing. The sterilization cycle conditions can be set to minimize the effects of under and over sterilization.

ii. If there is significant change in fruit quality, the sterilization cycle can be quickly changed; therefore, allows for greater flexibility in controlling the sterilization process.

iii. The operator's task is made much simpler, allowing concentrating on other aspect of sterilizer operation, thereby improving the productivity.

iv. The use of control system overall steam management in the sterilizer will minimize process upsets which are directly on indirectly related to steam flow fluctuations. Such upsets will affect product losses and quality.

## 2.4 Requirement for Proper Sterilization

At the sterilizer, the requirement is important to maintain the product. It is also to ensure quality oil improvement.

### 2.4.1 Time and Temperature of Sterilization

Bunches must be allowed sufficient time to heat through thoroughly and became cooked. With satisfactory sterilization, the temperature reached in the centre of the stalk will be found to be at least 100 °C. The time required to reach 100 °C will depends on the size of the bunch and time period the bunch temperature has to maintained above 100 °C will de dependent on the ripeness of the bunch. The temperature is related to steam pressure in sterilizer vessel.

### 2.4.2 Deaeration

The presence of air limits the effectiveness of the sterilization process [The Mongana Report, 1955] in two respects. Firstly, it is limits the maximum temperature attained in the sterilizer, i.e. a mixture of steam and air will have a lower temperature than steam alone would have at that pressure. For example, if a mixture of three parts of steam and one part of air exerted an absolute pressure of 4 $kg/cm^2$ in a sterilizer, the partial pressure of steam would be 3 $kg/cm^2$ and temperature of the mixture would only be 132.9 °C instead of 142.9 °C which is temperature of pure steam at 4 kg/cm$^2$ absolute pressure.

Relatively complete air removal from the sterilizer not only gives a higher temperature at a given pressure but only improves the thermal conductivity since air is a very poor conductor of heat. At the start of the sterilization cycle, the sterilizer is full of air. The first stage of sterilization must therefore be concerned with the removal of air from the vessel. There are two practical methods of removing air from sterilizer, i.e. steam sweeping and diffusion followed by blow-off steam.

Steam sweeping is done during the initial phase of sterilizing and involves removing the air from the relatively easily accessible spaces in the sterilizer. The sweeping action should therefore be controlled so that there is as little turbulence as possible. No real advantage is gained by this; layering effect and time required for steam as fast as possible. Deaeration of the bunches take place only after they have been heated up for some time at high temperature. Steam will diffuse into the bunch and air will be displaced out.

The presence of air when heating at high temperature can increase the rate of oxidation of palm oil which is thought to be one of the main factors responsible for discoloration and poor bleaching characteristics.

### 2.4.3 Condensate Removal

A large amount of condensate is formed during sterilization, especially during the start of the sterilization cycle. There must be an effective system of condensate removal for the following reasons:

i. The condensate could flood the bearings of the wheels of fruit cages and destroy them.

ii. If the level of the condensate rises too high, oil will be washed out the bunches in excessive quantities.

iii. The condensate will pick up the surface oil from the bruised fruits which has a high free fatty acid content and therefore corrosive.

iv. At the end of sterilization cycle, free condensate in the vessel will flash off and tend to increase the blow off time of sterilizer. Also, adequate dehydration off the fruits may not take place.

### 2.4.4 Blow-off

The blow-off must be complete as quickly as possible to minimize the non-productive parts of the cycle and induce flashing action in the sterilizer which is responsible for dehydrating the fruits. If intermediately blow-off is used, it is important to ensure that the pressure in the sterilizer is brought down to almost atmospheric pressure to ensure effective deaeration.

## 2.5 A New System for Sterilization Process

For years, the palm oil industry has cherished a dream for a continuous sterilization process. The ability to achieve complete stripping of fruits with sterilization carried out using steam at low pressure. The problem of continuously transferring bunches to and from the sterilization can be more easily. Many different methods were explored for transferring bunches to and from the sterilizer as well as for conveying the bunch through the continuous sterilizer.

Ideally, the method used for conveying should ensure continuous and uninterrupted flow of the product and ensure consistent product retention time with little or no short-circulating. There should also be little probability of product accumulating inside the sterilizer as this is detrimental to oil and kernel quality. The system should de designed to minimize the steam loses from the feed and discharge opening. This requires that the feed and discharge openings be made as small as possible while ensuring continuous and uninterrupted flow of the product through the system.

In the proposed process, the bunches are pre-heated using steam that bleeds from continuous sterilization chamber. These facilitates heating the bunches immediately after they are crushed to above 60°C to deactivate the lipolytic enzymes responsible for the formation of free fatty acid (FFA). Pre-heating bunches also facilitates deaeration and minimizes the amount of air. An additional pre-heating step may be used if the delay between crushing and steam heating is significant enough to cause oil quality deterioration.

The bunches enter and leave the continuous sterilization chamber through one or more rotary valve, flap valves or gate valve to minimize the steam loss. The base of the need conveyor can also be filled with water to seal against steam loss. This water bath can be heated to above 60 °C to enable simultaneous deactivation of the lipolytic enzymes.

### 2.5.1 Pilot Plant

The continuous sterilization pilot plant set up (Figure 2.5) was specifically designed for heating using steam at atmospheric pressure. By making use of both the forward and return paths for conveying, it was possible to achieve a total conveyor length of only approximately 20 m. The crushing was carried using a double-roll bunch crusher with a fixed clearance of 15 mm between the rollers. The speed of rotation of the rollers was 22 rpm and 32 rpm. A steam-sealed inclined scraper conveyor was used for conveying the bunches to the continuous sterilization chamber. A simple double-flap door was used at the entrance of the continuous sterilization chamber to minimize steam loss. The hinged flpas were kept in the normally closed position by counterweights and opened by the impact of the bunches. The bunches were hand-fed to the crusher one at a time at 30 s to 60 s intervals. The steam that escaped through the inlet valve was used to pre-heat the bunches in the feed conveyor.

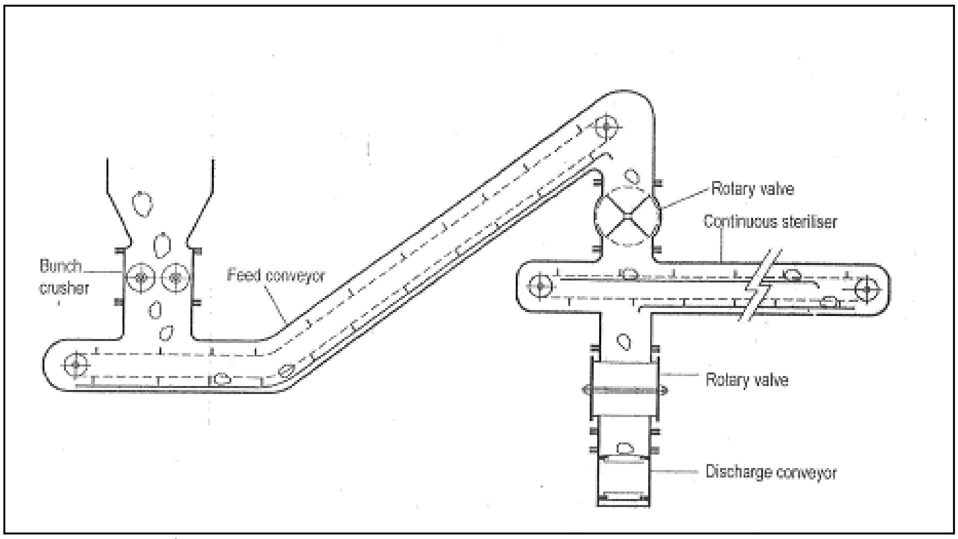


**Figure 2.5:** Proposed systems for Continuous Sterilization

The crushed bunches were pre-heated for 6min in the feed conveyor and then a further 56 minutes in the continuous sterilization chamber. Steam was introduced at a number of points at both decks. The rate at which steam was introduced was manually adjusted to minimize loss from the entrance and discharge ends. It was observed that the temperature in the continuous sterilization chamber could be quite easily maintained close to 100 °C. The continuous sterilization chamber was insulated to minimize heat loss and slightly tilted to facilitate condensate discharge. The bunches leaving the continuous sterilization chamber were held in a hopper and periodically discharge by hydraulically controlled sliding door.

### 2.5.2 Assessment of Cooking Effectiveness

Table 2.2 summarizes the results of comparative study of the cooking effectiveness of batch and continuous sterilization based on the ease of peeling off the mesocarp from the nuts. The mesocarp was peeled off by a simple squeezing action using our fingers without applying too much pressure. Although the mesocarp was soft enough to be quite easily peeled off by scraping for the purpose of this qualitative test, the peeling was achieved without the use scrapers. It can be observed from Table 4.1 that mesocarp could not be peeled off from 2.13 % of the fruits from batch sterilization. These fruit were mainly from the inner layers of the bunch and had a very thin mesocarp. On the other hand, mesocarp could no be peeled off from 24.10 % of the fruits from continuous sterilization.

| Source | Hard fruits (%) | Peeled mesocarp (%) |
|---|---|---|
| Batch sterilization (*i.e.* fruits from mill) | 2.13 | 45.47 |
| Continuous sterilization | 24.10 | 37.68 |

**Table 2.2:** Assessment of Cooking Effectiveness

From Table 2.3, the FFA content in the oil from the continuous sterilization was slightly lower than that in the oil from batch sterilization. This could be due to the fact that bunches used in continuous sterilization were generally fresher than the bunches processed by the mill. It also shows that the peroxide value was approximately the same both process, the DOBI value of the oil from continuous sterilization was higher by 0.5. This may have been due to reduced oxidation due to sterilization being carried out at lower temperature. The carotene content of the oil from continuous sterilization was lower by about 50 ppm. The oil and press cake were lighter colored in the case of continuous sterilization. There is probably a correlation between the cooking effectiveness and carotene content of the oil. The iron content of the oil from continuous sterilization was about 2 ppm higher than that from batch sterilization. It may be due increased contact with the metal surface during the conveying.

| Parameter | Batch sterilization | Continuous sterilization |
|---|---|---|
| FFA content (%) | 2.68 | 2.10 |
| Peroxide value (meq) | 0.30 | 0.29 |
| DOBI | 2.77 | 3.22 |
| Carotene content (ppm) | 598 | 546 |
| Iron content (ppm) | 4.24 | 6.18 |

**Table 2.3:** Effect of Sterilizer Process on Oil Quality

The pilot plant study has to demonstrated that the bunches can be heated using steam at atmospheric pressure without difficulty. It also shown that there should be no major problems integrating the proposed continuous sterilization process with the rest of the milling process in a conventional mill. Figure 2.6 and Figure 2.7 shows the sterilization process.

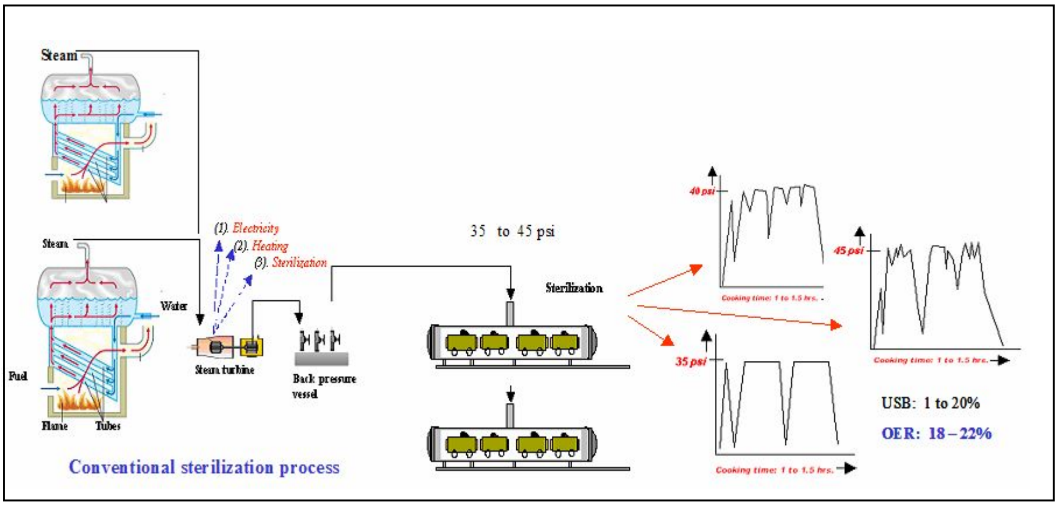


**Figure 2.6:** Conventional Sterilization Process

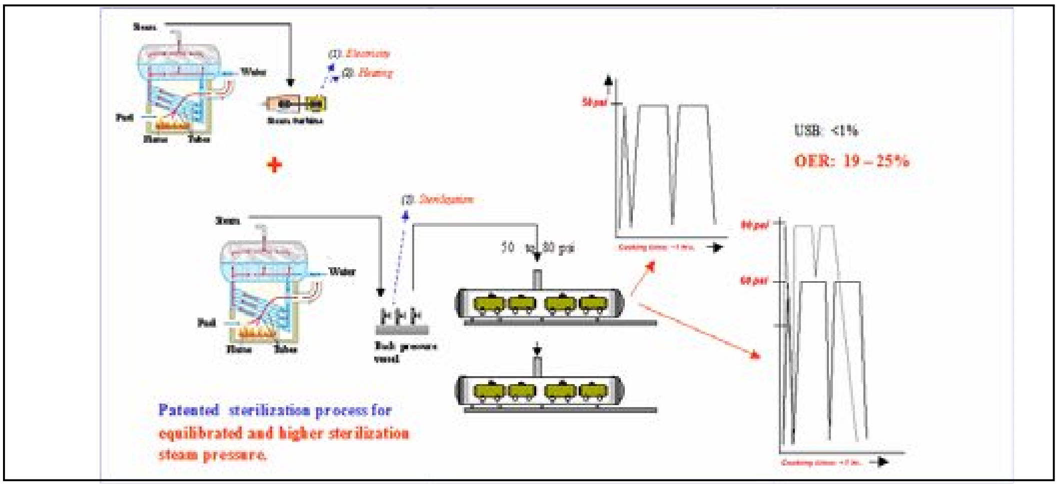


**Figure 2.7:** Sterilization Process for Equilibrated and Higher Sterilization Steam Pressure

# CHAPTER 3

# METHODOLOGY

## 3.1 Background

This experiment will be done at the LKPP CORPORATION SDN.BHD by using the different pressure and process time during sterilization process. Sterilization is the first process step in extraction of oil and kernel from the oil palm fruit. After the sterilization process, the percentage of losses at condensate and empty fruit bunch (hard bunch and unstripped bunch) are taken to get the higher quality oil production of CPO after sterilization process. Figure 3.1 shows the overall general methodology for this experiment.

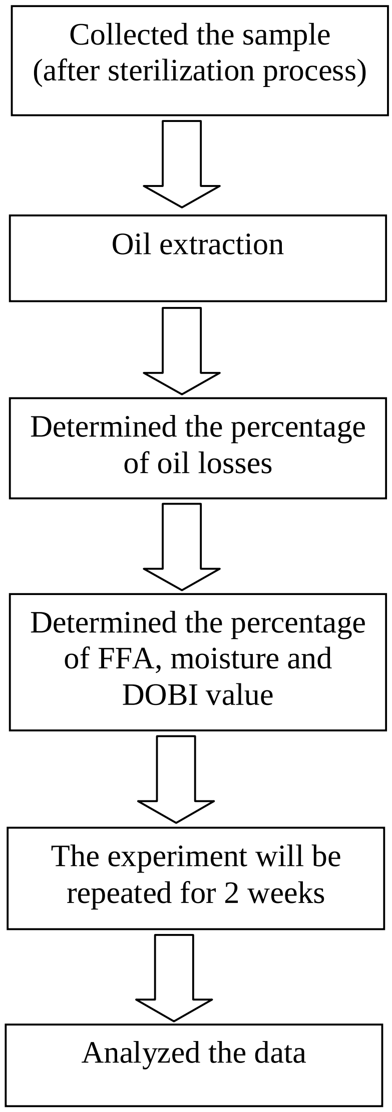


**Figure 3.1:** Overall General Methodology

## 3.2 Determination of Free Fatty Acid (FFA)

1. 5 kg sample of CPO was weighting in the conical flask.
2. 50 ml of ethanol have been neutralized with adding little drops of 0.1 N NaOH and phenolphthalein indicator.
3. The mixture heats up on the hot plate.
4. Then, the mixture was titrated with 0.1 N NaOH until the solution changed to red color.
5. The reading in the burette was taken.

Formula:

Percentage of FFA = $\frac{2.56 \times V}{W}$

Where,

V = Volume of 0.1 N NaOH

W = Weight of oil

## 3.3 Determination of Oil Losses Dry Basis (OLDB)

**Figure 3.2:** The Extraction Process

1. Sample (CPO) was shaking before used.

2. The crucible was weighting.

3. 30 gram sample was weighing and added in a crucible. Then it was weighting.

4. The sample was drying in an oven at 103 ℃ for 8-12 hours.

5. Then, the crucible was weighing after cooling.

6. Dried sample was added in a timble.

7. After that, the sample was extracted with n-hexane for 3 hours.

8. After extraction process, the timble was separated from the extraction equipment and then the excessive must be removed.

9. The oil content was heated in the oven at 103 ℃ for 1 hour.

10. The flask and the oil content was weighting after cooling.

### 3.4 Determination of the Moisture Content

1. Fibre filter are added in a gooch crucible and the weight is taken.

2. Oil was filtered with filter vacuum and rinsed with hexane.

3. Sample was dried up in an oven about 2 hours.

4. After that the sample was taken out and allowed it.

5. Then, it was weighting.

Formula:

Percentage of impurities = $\frac{W_2 - W_1}{\text{Weight of oil}} \times 100\%$

$W_1$ = weight of gooch crucible + filter

$W_2$ = weight of gooch crucible + filter + dirt

## 3.5 Determination of Deterioration of Bleachability Index (DOBI)

1. The crude palm (CPO) oil is weighing till 0.1 gram in a 25 ml volumetric flask.

2. N-hexane is added and agitated until the CPO dissolved.

3. Then, quartz cell was added in the UV-Visible with the light absorption at 269 nm and 446 nm.

Formula:

$$\text{DOBI} = \frac{\text{Absorption in 446 nm}}{\text{Absorption in 269 nm}}$$

# CHAPTER 4

# RESULT AND DISCUSSION

## 4.1 Result and Discussion

In this chapter, the results of the experiment and the discussion on the result obtained will be shown. The experiment had been done by varying the two parameters; that were pressure and process time during sterilization process to achieve the objective of the research.

## 4.2 The Effect of Free Fatty Acid (FFA) after Sterilization Process

One of the effects of sterilization is to inactivate the fruit enzyme. Once this enzyme has been inactivated the rise of the FFA is virtually stopped. The value of acid is a total sodium hydroxide (NaOH) is used to neutral the free acid in 1 g sample of Crude Palm Oil (CPO). The quality of oil has often been determined at the fruit or bunch level. Damage or over ripped fruits exhibit high FFA content and during the milling process these acid are incorporated into the CPO. Therefore, CPO with high FFA has detrimental effect in refining operation process. The data analysis of sample is shown as following:

**Table 4.1:** Data collection of FFA with different pressure

| Pressure,P (psig) | FFA (%) |
|---|---|
| 39 | 4.17 |
| 40 | 3.33 |
| 41 | 3.70 |

**Table 4.2:** Data collection of FFA with different process time

| Process Time,t (min) | FFA (%) |
|---|---|
| 80 | 5.51 |
| 90 | 3.57 |
| 100 | 2.84 |

## 4.3 The Effect of Moisture after Sterilization Process

The moisture has been taken to determine dirt in the oil content. Moisture and impurities content of CPO need to remove in physical refining process. Apart from direct loss to the refiners, higher moisture adversely affects the vacuum, thus disturbing the whole operation. The data analyses are shown in the Table 4.3 and Table 4.4.

**Table 4.3:** Data collection of moisture with different pressure

| Pressure,P (psig) | Moisture (%) |
|---|---|
| 39 | 0.14 |
| 40 | 0.11 |
| 41 | 0.13 |

**Table 4.4:** Data collection of moisture with different process time

| **Process Time,t (min)** | **Moisture (%)** |
|---|---|
| 80 | 0.13 |
| 90 | 0.12 |
| 100 | 0.13 |

## 4.4 The Effect of DOBI value after Sterilization Process

The Deterioration of Bleachability Index (DOBI) of the sample has been measured by using UV-Visible. Lower DOBI values indicate poor bleachability and it depends on the quality of FFB. The values are shown in the Table 4.5 and Table 4.6.

**Table 4.5:** Data collection of DOBI value with different pressure

| **Pressure,P (psig)** | **DOBI** |
|---|---|
| 39 | 2.23 |
| 40 | 2.35 |
| 41 | 2.40 |

**Table 4.6:** Data collection of DOBI value with different process time

| **Process Time,t (min)** | **DOBI** |
|---|---|
| 80 | 2.20 |
| 90 | 2.57 |
| 100 | 2.25 |

## 4.5 The Effect of Oil Extraction Rate (OER) after Sterilization Process

The oil extraction rate (OER) of the palm oil fruit was measured to control and improve the quality of CPO. However, if the oil losses were decreased, the value of the OER will be optimizing. The data analysis is shown as following:

### 4.5.1 Formula

$$OER = \frac{Weight\ of\ Oil\ Production}{Weight\ of\ FFB} \times 100\ \%$$

**Table 4.7:** Data collection of OER with different pressure

| Pressure,P (psig) | OER (%) |
|---|---|
| 39 | 18.95 |
| 40 | 19.24 |
| 41 | 20.48 |

**Table 4.8:** Data collection of OER with different process time

| Process Time,t (min) | OER (%) |
|---|---|
| 80 | 19.46 |
| 90 | 20.71 |
| 100 | 19.15 |

## 4.6 Data Collection of Oil Losses Dry Basis (OLDB)

In this experiment, the oil losses dry basis or extraction of the sample was implemented in order to get the percentage of oil losses at the condensate and empty fruits bunch. The percentage of oil losses was determined after sterilization process. The Figure 4.1 showed the oil losses content after doing the extraction process. The result of the oil losses of the sample is shown in the table below:

**Figure 4.1:** The Oil Content

**Table 4.9:** Data collection of oil losses with different pressure

| | **Oil Losses (%)** | |
|---|---|---|
| **Pressure(psig)** | **Condensate** | **Empty Bunch** |
| 39 | 0.19 | 1.985 |
| 40 | 0.33 | 0.71 |
| 41 | 0.45 | 0.48 |

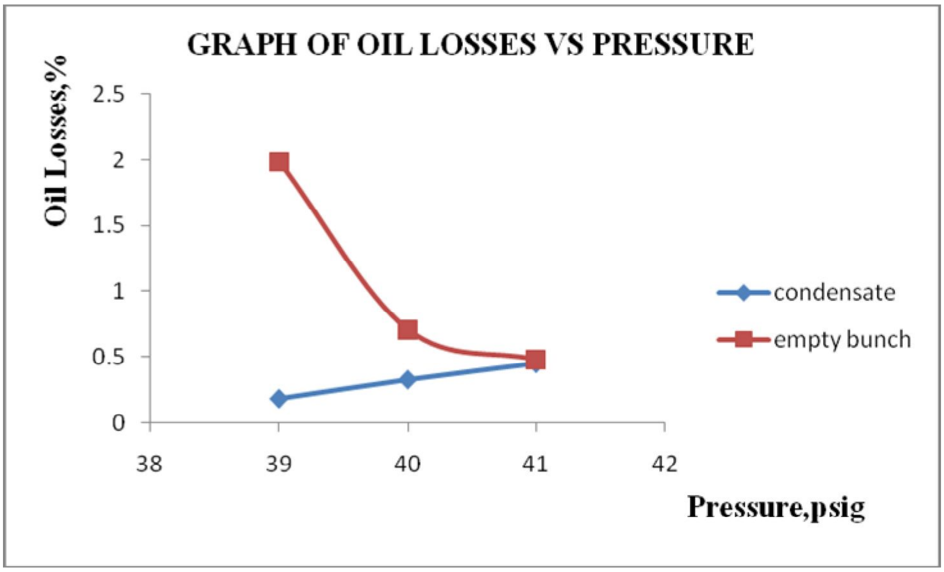


**Figure 4.2:** Relationship between Oil Losses at Condensate and Empty Fruit Bunch

Figure 4.2 shows the graph of oil losses at condensate and empty fruit bunch versus pressure. Based on the graph, at the pressure of 39 psig, percentage of oil losses at hard bunch and unstripped bunch (USB) is increased, while at the condensate the oil losses is decreased. At the pressure of 40 psig, the oil losses at condensate decreased as increased at the hard bunch and USB. While at the pressure of 41 psig, the oil losses at the hard bunch and USB decreased because the oil losses at the condensate are highest.

**Table 4.10:** Data collection of oil losses with different process time

| | **Oil Losses (%)** | |
|---|---|---|
| **Process time (min)** | **Condensate** | **Empty Bunch** |
| 80 | 0.8 | 3.66 |
| 90 | 0.45 | 0.81 |
| 100 | 3.37 | 0.08 |

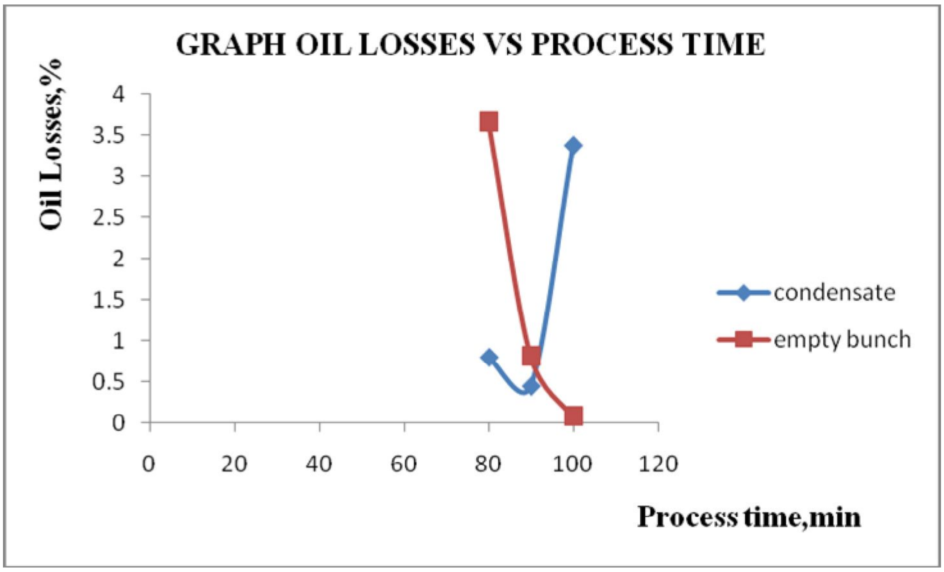


**Figure 4.3:** Relationship between Oil Losses at Condensate and Empty Fruit Bunch of Process Time

The graph in Figure 4.3 shows the oil losses at condensate and empty fruit bunch (hard bunch and unstripped bunch) versus process time. The graph is plotted using the different process time from the experiment. At the process time of 80 minutes, the oil losses at the condensate are low but at the empty fruit bunch oil losses were high. While at the process time of 100 minutes oil losses at the condensate was high but oil losses at the empty fruit bunch was low. The graph shows the ideal time for sterilization process is 90 minutes because the oil losses are lower than the process time of 80 minutes and 100 minutes.

## 4.7 Effect of Oil Losses after Sterilization Process

The total percentage of oil losses at condensate and empty bunch are calculated to plot a graph of oil losses versus pressure and process time. At the different pressure, the process time is constant and at the different process time, the pressure is constant. The data analysis is shown in Table 4.11 and Table 4.12.

**Table 4.11:** Effect of Oil Losses after Sterilization Process with different Pressure

| **Pressure** | **Oil Losses (%)** |
|---|---|
| Week 1 | |
| 39 | 2.175 |
| 40 | 1.04 |
| 41 | 0.93 |
| Week 2 | |
| 39 | 2.23 |
| 40 | 1.32 |
| 41 | 1.09 |
| Week 3 | |
| 39 | 2.15 |
| 40 | 1.24 |
| 41 | 0.97 |

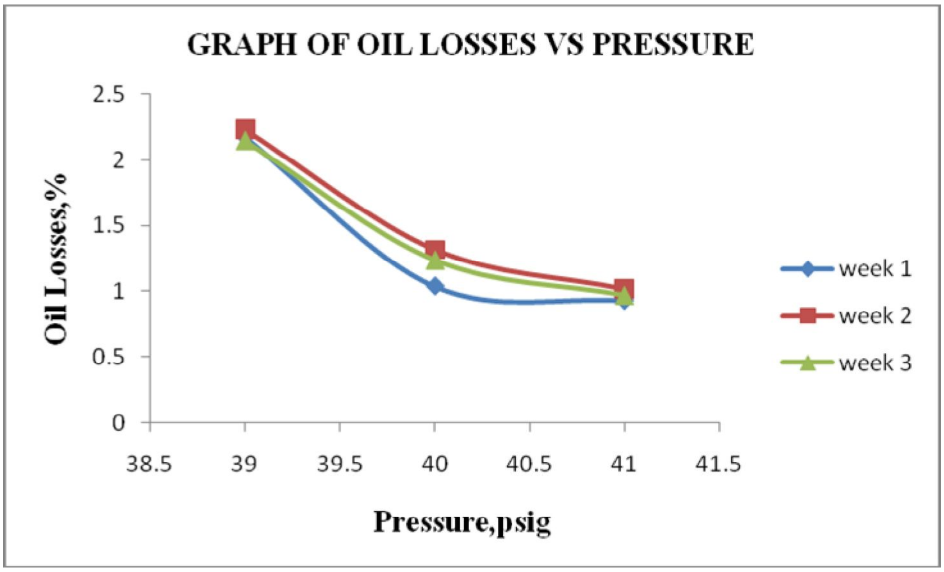


**Figure 4.4:** The Oil Losses versus Pressure

Figure 4.4 shows the graph of oil losses versus pressure. It was found that the percentage of oil losses was decreased to the pressure. The graph was plotted by using three different pressures for three weeks which are 39 psig, 40 psig and 41 psig.

The percentage of oil losses was higher at pressure of 39 psig because at this lower pressure, hard bunch and unstripped bunch (USB) was high. This means that the stripping of fruits from bunches during sterilization process was low and inefficient process of sterilizer. Practically when the hard bunch and USB high, oil content at the sterilizer condensate will decrease based on the Figure 4.2.

At the pressure of 41 psig, the percentage of oil losses was decreased because the sterilization process was efficient. So, the oil loses of hard bunch and USB were decreased, will result at the condensate are high due to the pressure that apply to the process. But the oil content in the condensate was recycled to the oil process. At the pressure of 40 psig, the percentage of oil losses still decreased but the ideal pressure of the sterilization process is at 41 psig.

The ideal condition to achieve complete stripping of fruits with sterilization process carried out using the pressure of 41 psig. The bunches should also be conveyed without subjected to very high forces or very low forces as the cooking progresses to oil being easily released from the cooked fruits and lost with the condensate and empty bunch stalks.

At the initial of the sterilization cycle, the sterilizer was full of air. The first stage of the sterilization must be concerned with the removal of air from the vessel. So at pressure of 41 psig the condition in sterilizer is efficient to remove air and to achieve complete stripping of fruits from the bunch due to decreased the oil losses and get the higher oil production of CPO.

**Table 4.12:** Effect of Oil Losses after Sterilization Process with different Process Time

| **Process Time (min)** | **Oil Losses (%)** |
|---|---|
| Week 1 | |
| 80 | 4.46 |
| 90 | 1.26 |
| 100 | 3.45 |
| Week 2 | |
| 80 | 3.34 |
| 90 | 1.45 |
| 100 | 2.23 |
| Week 3 | |
| 80 | 4.05 |
| 90 | 1.12 |
| 100 | 2.98 |

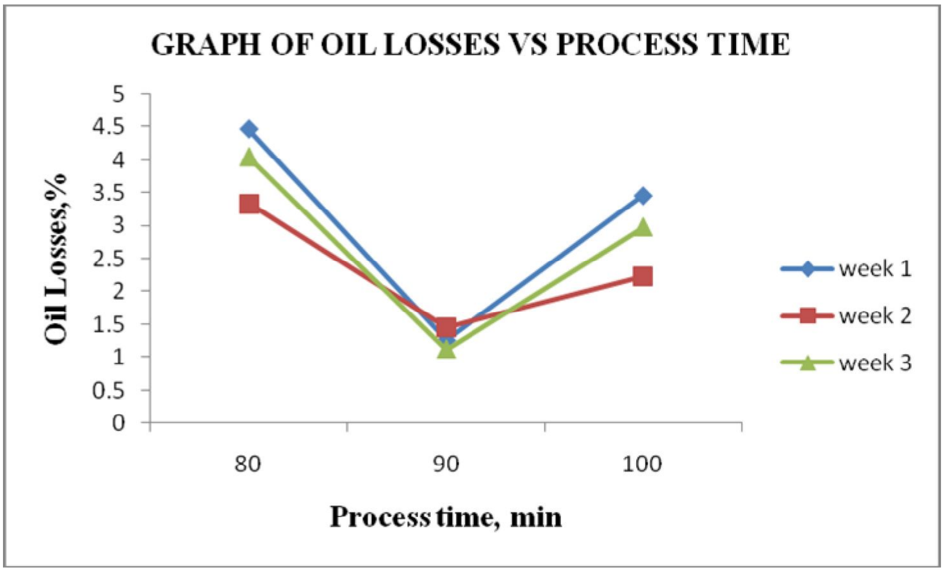


**Figure 4.5:** The Oil Losses versus Process time

From Figure 4.5, it was also found that the graph was plotted inconsistently. The graph was plotted by using three different process times for three weeks which are 80 minutes, 90 minutes and 100 minutes.

For the process time of 80 minutes percentage of oil losses was increased because the hard bunch and USB are high. So, the oil losses at the condensate were decreased.

Based on the graph, for the process time of 90 minutes the percentage of oil losses decreased but for 100 minutes the percentage of oil losses was increased. This is because at this process time, oil losses at condensate were higher than oil losses at the process time of 90 minutes. This process time is not relevant as throughput of 40 metric tonne because for one cycle of sterilizer, a total metric tonne that was process about 40-45 metric tonne per hour. If the process takes time more than 90 minutes, the process will delay and the throughput will decrease lower than 40 metric tonne per hour.

Fresh fruit bunches (FFB) must be sterilized in sufficient time to heat through thoroughly and become cooked. By utilize a satisfactory sterilization time, the temperature reached in the centre of the stalks will found to be at least 100°C. The time required to reach 100°C will depend on the time period of fruits to ripe from the bunch.

The ideal process time for sterilization process is 90 minutes because it was determined that percentage of oil losses in this process time was lower than the percentage of oil losses for the process time of 80 minutes and 100 minutes. Furthermore, it can be concluded that if the oil losses was decreased, the value of OER will increased, means that the higher oil production of CPO will be achieved.

# CHAPTER 5

# CONCLUSION AND RECOMMENDATION

## 5.1 Conclusion

In this research, the Optimization Condition for Palm Oil Fruit Sterilization Process has been completed successfully. The analysis is to determine the oil losses after sterilization process to get the high oil production of CPO. Thus, there are several conclusions that can be made:

i. The sterilization process time and pressure are required to achieved complete stripping of fruits from the crushed bunches to minimize the oil losses after sterilization process.

ii. The oil losses at the condensate and empty fruit bunch are decreased at the pressure of 41 psig and the process time of 90 minutes. This shows that the ideal conditions during sterilization process are at the pressure 41 psig and process time of 90 minutes.

iii. The minimum acceptable DOBI value is 2.3.Within this experiment, the actual result obtained was considered acceptable because the values were higher than

2.3. The values of FFA and moisture also acceptable because the maximum value is 5 % and 0.2 % respectively (Pathak M.P., 1988).

iv. Besides that, the factors that will affect the oil losses at the empty fruit bunch and condensate are depend on the quality of the fresh fruit bunch (FFB), sterilizer, and condition during sterilization process.

v. The OER is increased as decreased the oil losses, will result the highest oil production of CPO.

## 5.2 Recommendation

The study of sterilization process is to find the ideal condition to get the highest quality and the highest oil production of CPO. From the experiment that had been done, several important recommendations should be carried out in operating condition during sterilization process such as:

i. The oil losses at the condensate shall recuperate to the oil process. So it can be minimize the oil losses to the final effluent.

ii. From the observation, the quality of the FFB also must be analyzed prior to receive it in order to improve the quality of the CPO.

iii. FFA, moisture and DOBI was controlled by way of timely cutting of fruits bunch, safe storage and transportation to mill without damage to the fruits and quick processing at mills, are the main factors to improve the quality of CPO.

iv. For the plant to increase the workers awareness on safety aspect in work place for examples:

1. Face mask
2. Safety helmet
3. Safety boot
4. Proper signboard for caution of slippery for area

v. For further investigate the other parameters in the sterilization process for ideal condition such as:

1. Temperature
2. Weight of FFB for sterilize

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# APPENDIX A

## Data Collection for Oil Losses Dry Basis (OLDB)

Result of Oil Losses at 39 psig and 90 min

| | **EFB before** | **EFB after** | **Final Effluent** | **Sterilizer condensate** |
|---|---|---|---|---|
| Wt of dish & sample | 17.501 | 14.4267 | 107.7672 | 106.5696 |
| Wt of dish | 5.9625 | 6.2991 | 75.9116 | 73.3334 |
| Wt of sample | 11.5385 | 8.1276 | 31.8556 | 33.2362 |
| Wt of dish & dry sample | 10.0947 | 9.7665 | 76.3751 | 74.6612 |
| Wt of moisture loss | 7.4663 | 4.6602 | 31.3921 | 31.9084 |
| Wt of flask & oil | 98.6274 | 95.4489 | 103.9878 | 90.5556 |
| Wt of flask | 98.035 | 95.1316 | 103.9426 | 90.3687 |
| Wt of oil | 0.5924 | 0.3173 | 0.0452 | 0.1869 |
| Moisture | 64.19 | 57.34 | 98.54 | 96 |
| N.O.S | 30.68/35.81 | 38.76/42.66 | 1.32/1.46 | 3.44/4 |
| Oil content | 5.13 | 3.9 | 0.14 | 0.56 |
| Dry matter | 14.33 | 9.14 | 9.59 | 14 |

Result of Oil Losses at 40 psig and 90 min

| | **EFB before** | **EFB after** | **Final Effluent** | **Sterilizer condensate** |
|---|---|---|---|---|
| Wt of dish & sample | 26.9554 | 21.6529 | 110.3011 | 107.0405 |
| Wt of dish | 6.0123 | 6.2229 | 75.914 | 73.3338 |
| Wt of sample | 20.9431 | 15.43 | 34.3871 | 33.7067 |
| Wt of dish & dry sample | 13.9361 | 12.8468 | 77.0373 | 75.6323 |
| Wt of moisture loss | 13.0193 | 8.7061 | 33.2638 | 31.4082 |
| Wt of flask & oil | 99.9321 | 95.6765 | 104.224 | 90.8167 |
| Wt of flask | 98.0376 | 95.1313 | 103.8766 | 90.3665 |
| Wt of oil | 1.8945 | 0.5452 | 0.2444 | 0.4502 |
| Moisture | 62.17 | 56.42 | 96.73 | 93.18 |
| N.O.S | 28.78/37.83 | 40.05 | 2.559/3.27 | 5.09/6.82 |
| Oil content | 9.05 | 3.53 | 0.711 | 1.34 |
| Dry matter | 23.91 | 8.108 | 21.73 | 19.58 |

Result of Oil Losses at 41 psig and 90 min

| | **EFB before** | **EFB after** | **Final Effluent** | **Sterilizer condensate** |
|---|---|---|---|---|
| Wt of dish & sample | 20.4091 | 21.4974 | 131.9401 | 134.2064 |
| Wt of dish | 5.9137 | 6.037 | 103.3927 | 100.721 |
| Wt of sample | 14.4954 | 18.4604 | 28.5474 | 33.4854 |
| Wt of dish & dry sample | 11.8401 | 11.8549 | 104.3773 | 103.1752 |
| Wt of moisture loss | 8.569 | 9.6425 | 27.5628 | 31.0312 |
| Wt of flask & oil | 86.6401 | 91.4302 | 89.2748 | 91.3169 |
| Wt of flask | 85.2167 | 90.8642 | 89.0915 | 90.9838 |
| Wt of oil | 1.4234 | 0.566 | 0.1833 | 0.3331 |
| Moisture | 5912 | 52.23 | 96.55 | 92.67 |
| N.O.S | 31.06/40.88 | 44.7/47.77 | 2.808/3.45 | 6.335/7.33 |
| Oil content | 9.82 | 3.07 | 0.642 | 0.995 |
| Dry matter | 24.02 | 6.43 | 18.61 | 13.57 |

Result of Oil Losses at 40 psig and 80 min

| | **EFB before** | **EFB after** | **Final Effluent** | **Sterilizer condensate** |
|---|---|---|---|---|
| Wt of dish & sample | 23.0859 | 17.561 | 75.4998 | 81.8842 |
| Wt of dish | 5.8955 | 5.9942 | 51.7483 | 47.1311 |
| Wt of sample | 17.1904 | 11.5668 | 23.7515 | 34.7531 |
| Wt of dish & dry sample | 11.0913 | 10.8833 | 52.3767 | 51.4067 |
| Wt of moisture loss | 11.0913 | 6.6777 | 23.1231 | 30.4775 |
| Wt of flask & oil | 86.4459 | 91.1143 | 91.153 | 95.4926 |
| Wt of flask | 85.6838 | 90.8547 | 90.9969 | 92.1216 |
| Wt of oil | 0.7621 | 0.2596 | 0.1561 | 3.371 |
| Moisture | 64.52 | 57.73 | 97.35 | 87.7 |
| N.O.S | 29.13/35.48 | 40.02/42.27 | 1.2/2.65 | 2.6/12.3 |
| Oil content | 6.35 | 2.24 | 0.66 | 9.7 |
| Dry matter | 17.9 | 5.3 | 24.91 | 78.9 |

Result of Oil Losses at 40 psig and 90 min

| | **EFB before** | **EFB after** | **Final Effluent** | **Sterilizer condensate** |
|---|---|---|---|---|
| Wt of dish & sample | 29.0269 | 18.9896 | 107.9205 | 96.5633 |
| Wt of dish | 5.9643 | 6.2174 | 75.9086 | 73.3315 |
| Wt of sample | 23.0626 | 12.7722 | 32.049 | 23.2318 |
| Wt of dish & dry sample | 13.5341 | 11.0671 | 76.7114 | 75.1014 |
| Wt of moisture loss | 15.4927 | 7.9225 | 31.2091 | 21.4619 |
| Wt of flask & oil | 99.0464 | 96.069 | 104.1426 | 90.8119 |
| Wt of flask | 98.0329 | 95.1271 | 103.9362 | 90.3596 |
| Wt of oil | 1.0135 | 0.9419 | 0.2064 | 0.4523 |
| Moisture | 67.18 | 62.03 | 97.49 | 92.38 |
| N.O.S | 28.43/32.82 | 30.6/37.97 | 1.87/2.51 | 5.67/7.62 |
| Oil content | 4.39 | 7.37 | 0.64 | 1.95 |
| Dry matter | 13.38 | 19.41 | 25.5 | 25.59 |

Result of Oil Losses at 40 psig and 100 min

| | **EFB before** | **EFB after** | **Final Effluent** | **Sterilizer condensate** |
|---|---|---|---|---|
| Wt of dish & sample | 27.3806 | 19.5632 | 104.671 | 104.0367 |
| Wt of dish | 6.0026 | 6.2176 | 75.9109 | 73.3319 |
| Wt of sample | 21.378 | 13.3456 | 28.7601 | 30.7048 |
| Wt of dish & dry sample | 13.0591 | 11.3334 | 76.5844 | 76.2444 |
| Wt of moisture loss | 14.3215 | 8.2298 | 28.0866 | 27.7923 |
| Wt of flask & oil | 99.1678 | 95.2492 | 104.0964 | 91.2227 |
| Wt of flask | 98.0354 | 95.129 | 103.941 | 90.361 |
| Wt of oil | 1.1324 | 0.1202 | 0.1554 | 0.8617 |
| Moisture | 66.99 | 61.67 | 97.66 | 90.51 |
| N.O.S | 27.71/33.01 | 37.43/38.33 | 1.8/2.34 | 6.68/9.49 |
| Oil content | 5.3 | 0.9 | 0.54 | 2.81 |
| Dry matter | 16.06 | 2.34 | 23.08 | 29.61 |

# APPENDIX B

## Calculation of Oil Extraction Rate (OER)

**At 41 psig and 90 min**

OER = $\frac{154.23}{755} \times 100 = 20.43\%$

**At 40 psig and 90 min**

OER = $\frac{177.98}{925} \times 100 = 19.24\%$

**At 39 psig and 90 min**

OER = $\frac{151.61}{800} \times 100 = 18.95\%$

**At 40 psig and 100 min**

OER = $\frac{171.41}{895} \times 100 = 19.15\%$

**At 40 psig and 90 min**

OER = $\frac{198.78}{960} \times 100 = 20.71\%$

**At 40 psig and 80 min**

OER = $\frac{153.78}{790} \times 100 = 19.46\%$

# APPENDIX C

## Calculation of Free Fatty Acid (FFA)

**At 41 psig and 90 min**

| | |
|---|---|
| Weight of beaker | = 90.5610 g |
| Weight of CPO + beaker | = 93.5370 g |
| Weight of CPO | = 4.976 g |
| Volume of NaOH | = 7.2 ml |

$$\% FFA = \frac{2.56 \times 6.5}{4.986}$$

**= 3.70** %

**At 40 psig and 90 min**

| | |
|---|---|
| Weight of beaker | = 90.5610 g |
| Weight of CPO + beaker | = 95.5470 g |
| Weight of CPO | = 4.986 g |
| Volume of NaOH | = 6.5 ml |

$$\% FFA = \frac{2.56 \times 6.5}{4.986}$$

**= 3.33** %

**At 39 psig and 90 min**

| | |
|---|---|
| Weight of beaker | = 89.5468 g |
| Weight of CPO + beaker | = 94.3345 g |

Weight of CPO = 4.7877 g

Volume of NaOH = 7.8 ml

$$\% \, FFA = \frac{2.56 \times 7.8}{4.7877}$$

**= 4.17** %

**At 40 psig and 100 min**

Weight of beaker = 89.1210 g

Weight of CPO + beaker = 94.7150 g

Weight of CPO = 5.594 g

Volume of NaOH = 6.2 ml

$$\% \, FFA = \frac{2.56 \times 6.2}{4.986}$$

**= 2.84** %

**At 40 psig and 90 min**

Weight of beaker = 91.0768 g

Weight of CPO + beaker = 95.5270 g

Weight of CPO = 4.4502 g

Volume of NaOH = 6.2 ml

$$\% \, FFA = \frac{2.56 \times 6.2}{4.4502}$$

**= 3.57** %

**At 40 psig and 80 min**

Weight of beaker = 88.9620 g

Weight of CPO + beaker = 92.4470 g

Weight of CPO = 3.485 g

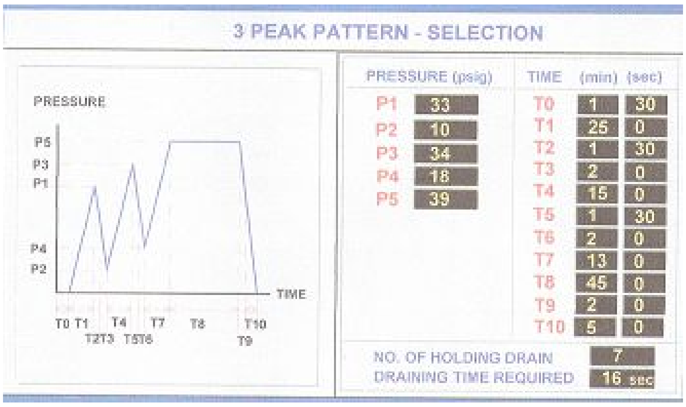
Volume of NaOH = 7.5 ml

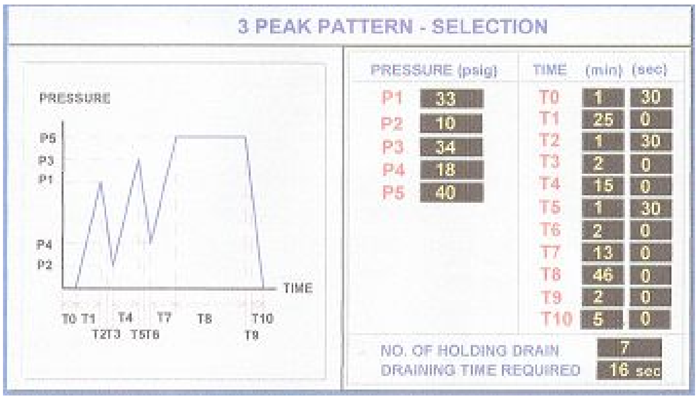
$$\% \, FFA = \frac{2.56 \times 7.5}{3.485}$$

**= 5.51** %

**APPENDIX D**

**Ideal pressure-time curve during triple peak sterilization cycle**



## APPENDIX E

### Gantt chart / Project Schedule

| PROJECT ACTIVITIES | M7 | M8 | M9 | M10 | M11 | M12 | M1 | M2 | M3 | M4 |
|---|---|---|---|---|---|---|---|---|---|---|
| 1. Visit factory | | | | | | | | | | |
| 2. Proposal writing | | | | | | | | | | |
| 3. Proposal presentation | | | | | | | | | | |
| 4. Literature review | | | | | | | | | | |
| 5. Detail research on methodology | | | | | | | | | | |
| i) Determine the oil losses | | | | | | | | | | |
| ii) Determine percentage of FFA and moisture & impurities | | | | | | | | | | |
| iii) Determine the DOBI value | | | | | | | | | | |
| 6. Preparation of the experiment | | | | | | | | | | |
| 7. Data analysis and report writing | | | | | | | | | | |
| 8. Correction and preparation of report writing | | | | | | | | | | |
| 9. Final presentation | | | | | | | | | | |
| 10. Compile and submit the report | | | | | | | | | | |