CHAPTER 1

INTRODUCTION

1.1 Research Background

Hydrogenation process is widely used commercially to increase the melting point and to improve the consistency of oils and fats. Hydrogenation also reduces colour and odour, improves thermal stability and resistance to oxidation of fats and oils (Yap *et al*., 1989; Busfield *et al*., 1990; Smidovnik *et al*., 1992; Choo *et al*., 2001; Karabulut *et al.*, 2003). In the hydrogenation process, part of double bonds are eliminated while a significant proportion of the remaining bonds are isomerized through cis/trans conversion on positional shifted in the fatty acid chain. Herein, the isomerization contribute to the selectivity of a hydrogenation process. A fatty acid chain with higher selectivity is claimed to have higher trans isomers compare to the cis isomers (Swern *et al*., 1979; Jovanovic et al., 1998; Karabulut *et al*., 2003). Composition and properties of the final product depend on various operating factors, including catalyst type and concentration, agitation, hydrogen pressure and temperature (Busfield *et al*., 1990; Jovanovic et al., 1998; Choo *et al*., 2001; Salmi *et al*., 2002; Krabulut *et al.*, 2003).

Various means exist to create the physical conditions in bringing together oil, hydrogen and catalyst, namely, circulation system, dead-end system and both circulation and dead-end system. Using the above mentioned systems, hydrogenation is done either in batch or continuous process. However, due to the variation in raw materials and desired end products, application of continuous hydrogenation remains limited;

therefore, most hydrogenation is done in batch autoclaves (Patterson, 1983; van Dierendonck *et al*., 1998). A batch autoclave or a conventional Continuous Stirred-Tank Reactor (CSTR) is commonly utilized in the hydrogenation process. It is also one of the most commonly used devices in industry for mixing (Yoon *et al*., 2001). Nevertheless, proper design of turbine-stirred-tank reactor on an industrial scale can still be difficult to make (Dohi *et al*., 2002; Yoon *et al*., 2001). On the large scale, the removal of heat may become a limiting factor. Installation of additional cooling coils into the reactor vessel makes the design problems even more complex (van Dierendonck *et al*., 1998).

Therefore, a Jet Loop Reactor (JLR) is claimed to retrofit well the CSTR and represent a very attractive alternative technology for hydrogenation process. Due to the increasing demands of effective hydrogenation process system, nowadays, many researchers have involved themselves in many projects to study the feasibility of alternative Jet Loop Reactor (JLR) to replace the present conventional Continuous Stirred-Tank Reactor (CSTR) in their systems (Havelka *et al*., 1997; Van Dierendonck *et al*., 1998; Stefoglo *et al*., 1999; Cramers *et al*., 2001; Broekhuis *et al*., 2001). A typical Jet Loop Reactor (JLR) consists of a vessel, an ejector and a circulation loop equipped with a pump. The benefit of this reactor is its efficiency in gas-liquid mass transfer, which is accomplished by means of the ejector. Typically, no mechanical agitation is required, and heat transfer problem is solved by using an external heat exchanger (Van Dierendonck *et al*., 1998; Lehtonen et al., 1999; Broekhuis *et al*., 2001). Hence, undesired problem areas are solved and series of advantageous are offered to the users.

1.2 Objectives

The main purpose of this research was to study the feasibility of retrofitting the conventional Jet Loop Reactor (JLR) with Continuous Stirred-Tank Reactor (CSTR) system by performing a comparative study on Jet Loop Reactor (JLR) and Continuous Stirred-Tank Reactor (CSTR) in the selective hydrogenation of palm olein I.V. of 64.

In the selective hydrogenation, it is aimed to reach to a certain iodine number and also polyunsaturated acids are converted to monounsaturated acids (Karabulut *et al.*, 2003). Herein, an Iodine Value (I.V.) drop of 10 is aimed in the study. Besides that, a selective hydrogenation which requires less plentiful of hydrogen is chosen as the critical comparison in the research. The selective hydrogenation is commonly well performed using Continuous Stirred-Tank Reactor (CSTR) as it contributes a less plentiful of hydrogen. Jet Loop Reactor (JLR), on the other hand, is well suited for a non-selective hydrogenation (fewer mass transfer limitation).

Hence, it is the objective of the research to study whether the Jet Loop Reactor (JLR) is suitable for both selective and non-selective hydrogenation. Both the Jet Loop Reactor (JLR) and Continuous Stirred-Tank Reactor (CSTR) used in the research were presented by a pilot plant system with a maximum capacity of 250 litres for JLR and a full laboratory system with a maximum capacity of 1.5 litres for CSTR. Both systems used here were the down scaled version of the industrial scale system. Same type of operating conditions and raw materials were used in the hydrogenation process. The systems were scaled to a comparative capacity before the results were analyzed in the research study.

1.3 Scopes of Study

In order to achieve the objective of the study, the following research steps were taken. The research consisted of several important parts. Summary of the research scope was shown in Figure 1.1. The mentioned parts involved were:

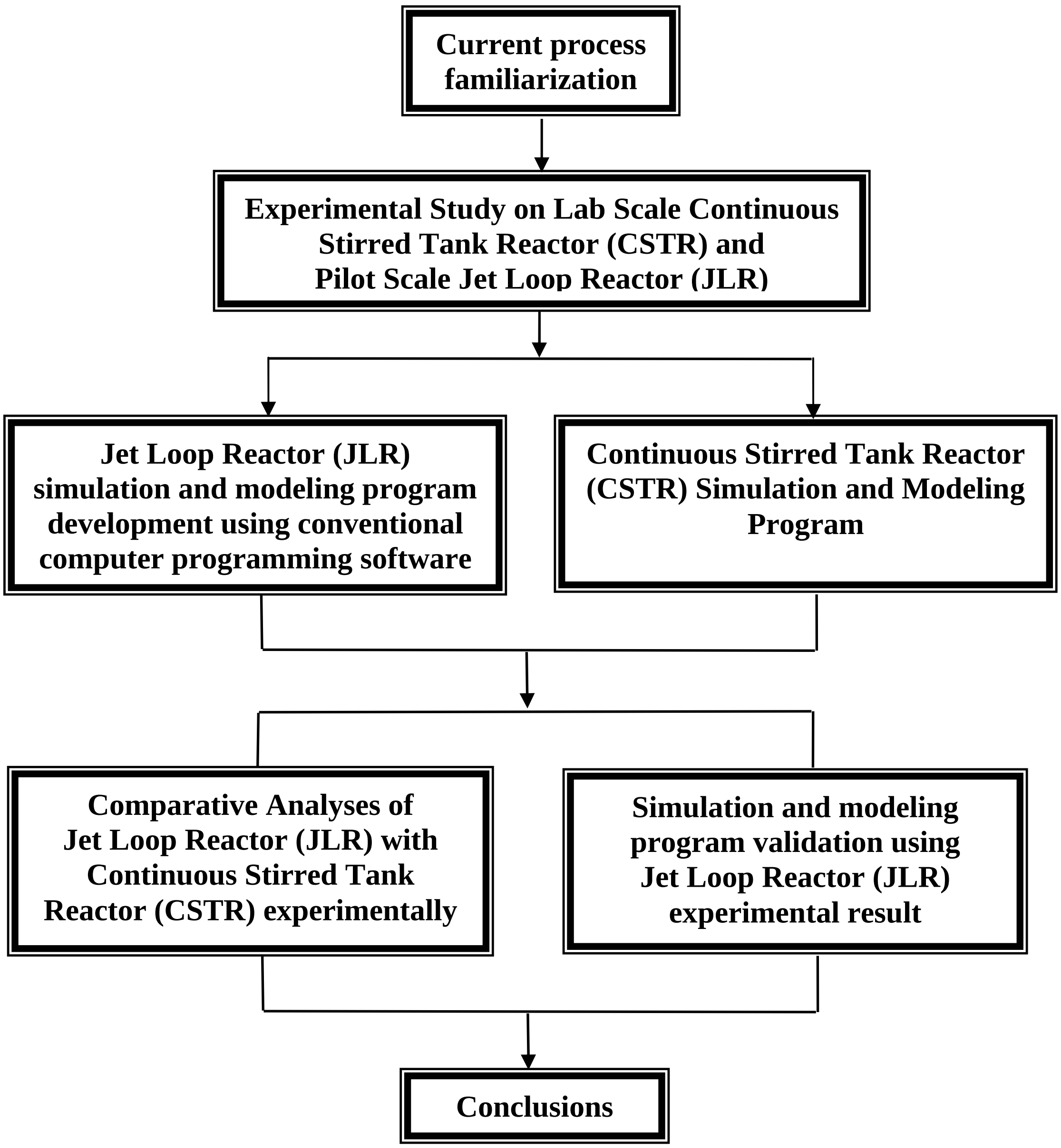

Figure 1.1: Research methodology flow chart

1.3.1 Experimental Study on Lab Scale Hydrogenation Process

Experiments were conducted using palm olein as raw material of lab scale CSTR hydrogenation process. Data were collected from the system and analyses were done on the acquired data.

1.3.2 Experimental Study on Pilot Scale Hydrogenation Process

Experiments were conducted using palm olein as raw material of pilot scale JLR hydrogenation process. Data were collected from the system and analyses were done on the acquired data.

1.3.3 Conventional Programming, Modeling and Simulation of JLR and CSTR

The data received from the experiments were used as the default values of modeling and simulation. A mathematical modeling of Jet Loop Reactor (JLR) was developed followed by numerical solution of the resultant model. Both mathematical and numerical solutions were applied in the conventional programming software, Microsoft Excel and Visual Basic Application to model the real system of Jet Loop Reactor (JLR). The resultant system was verified using data collected from the experimental study.

1.3.4 Analyses and Comparative Study of JLR and CSTR

Both systems were analyzed and compared. Discussions were made on the ability to retrofit the Jet Loop Reactor (JLR) in place of the Continuous Stirred-Tank

Reactor (CSTR) by means of experimental study and validity test using Jet Loop Reactor (JLR) simulation and modeling. Suggestions for further improvement in the future were done after the conclusions of the research were made.

1.4 Research Overview

According to the scopes of the study, the research was divided into two major parts:

(a) Data Collection and Parameters determination.
(b) Computer modeling and simulation.

1.4.1 Data Collection and Parameters Determination

Two sets of experiments were done in this project in order to collect required data and were used to determine the parameters required. For Continuous Stirred-Tank Reactor (CSTR), a set of experiments using lab scale equipment was done in SOCTEK (M) Edible Oil Sdn. Bhd. Data and parameters influencing the hydrogenation of palm olein using Continuous Stirred-Tank Reactor (CSTR) were collected and identified. Similar experiments were done with the same parameters but using Jet Loop Reactor (JLR). Same type of raw material such as palm olein, nickel catalyst and operating conditions were utilized in this project.

1.4.2 Computer Modeling and Simulation

A mathematical modeling was done on Jet Loop Reactor (JLR). The JLR was divided into three essential parts, namely reaction vessel, ejector and loop part. Each part of the JLR was modeled using gas and liquid mass balances. Tanks in series and dynamic axial dispersion model was used to model JLR. Analytical methods algorithm were used to solve the mathematical model.

Conventional programming language, Visual Basic Application together with Microsoft Excel was used to present the data obtained from modeling within spreadsheet environment. The model obtained was further verified with experimental results. Further on, the model developed were used to develop as similar as possible to the conventional simulator being used.

1.5 Importance of the Study

A few contributions and importance of the study were notified from the study, namely:

a) To give a general view of the pilot plant hydrogenation of palm olein I.V. 64.
b) To give information on the possibility of retrofitting the CSTR with JLR.
c) To introduce new software, this can be utilized as a modeling and simulation program of CSTR and JLR.