CHAPTER 1

INTRODUCTION

1.1 Introduction

Rice industry is one of the most important food industries in the world. Three billion people across the world consume rice, as the main product of the industry. This chapter provides an outlook of the global and local rice industry, followed by an introduction of the research background and problem statement. Next, the research objectives and the scope of this work related to the development of new systematic techniques to design an integrated, resource-efficient (IRE) rice mill complex are described. Finally, this chapter highlights five key contributions of this thesis that relevant to the research field and the rice industry.

1.2 Rice Outlook

According to FAOSTAT (2010), the global rice industry produces 672.0 million tonnes of paddy (unmilled rice) in year 2010, as presented in Table 1.1. Asia region alone contributes over 90% with China and India contributing some 29.3% and 17.9% shares of the total global output, respectively. In South East Asia region, Vietnam is the main producer, as it produces 6% of global rice output.

Rice demand is expected to remain strong in the next few decades due to the economic and population growths in many countries across Africa and Asia.
According to Timmer et al. (2010), the total rice consumption will be 450 million tonnes (milled basis) by year 2020, a 6.6% growth as compared to 422 million tonnes in 2007.

Table 1.1: Production quantity of paddy of year (FAOSTAT, 2009)

<table>
<thead>
<tr>
<th>Regions</th>
<th>Harvested Quantity (million t)</th>
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</thead>
<tbody>
<tr>
<td>Africa</td>
<td>22.86</td>
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<tr>
<td>Americas</td>
<td>37.17</td>
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<tr>
<td>Asia</td>
<td>607.33</td>
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<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>China: 197.21</td>
</tr>
<tr>
<td></td>
<td>India: 120.62</td>
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<tr>
<td></td>
<td>Indonesia: 66.41</td>
</tr>
<tr>
<td></td>
<td>Bangladesh: 49.36</td>
</tr>
<tr>
<td></td>
<td>Vietnam: 39.99</td>
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<tr>
<td></td>
<td>Myanmar: 33.20</td>
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<tr>
<td></td>
<td>Thailand: 31.60</td>
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<tr>
<td></td>
<td>Malaysia: 2.55</td>
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<tr>
<td></td>
<td>Europe: 4.44</td>
</tr>
<tr>
<td></td>
<td>Oceania: 0.22</td>
</tr>
<tr>
<td>World</td>
<td>672.01</td>
</tr>
</tbody>
</table>

In Malaysia, 2.55 million tonnes of paddy is harvested from planting area of 673,745 hectares in year 2010 (FAOSTAT, 2010). However, in 2011, considering the damages caused by the flood due to the occurrence of “La Nina”, the harvested area has been forecasted to decline to 667,000 hectares. Subsequently, the milled rice production is anticipated to decrease to 1.6 million tonnes. Notwithstanding, the demand for rice is expected to remain strong. Experts predict that the annual rice consumption will increase by 4.2% to 2.7 million tonnes in year 2011, due to the influx of foreign workers and population growth, whose main staple food is also rice.
To address the demand increase in rice, the Malaysian government has highlighted this issue in Eighth Malaysian Plan (2001-2005) and the Ninth Malaysia Plan (2006-2010). In these plans, Malaysia aimed to achieve 72% and 90% of rice self-sufficiency level (SSL) by 2005 and 2010, respectively (Yeong-Sheng et al., 2009). However, in the Tenth Malaysia Plan (2011-2015), the target has been revised to 70% of rice SSL by 2015 (Ho, 2011). With that, several measures have been taken by the government to stabilise the rice supply, for instance, by maintaining the rice stockpile at 292,000 tonnes or sustained consumption for 45 days. Also, the government will establish a long-term contract with countries to import rice, with the agreements to export palm oil or oil products to the corresponded countries. Note that no new paddy cultivation area will be assigned, with government aim to maintain or improve the rice production rate by upgrading the infrastructure of the existing planting areas.

1.3 Rice Supply Chain in Malaysia

The rice supply chain in Malaysia can be divided into the upstream and downstream industries. Figure 1.1 shows the rice supply chain in Malaysia. The activities of upstream industry consists of paddy harvesting, drying, rice milling and packaging plant, whilst the downstream industry involves value-process industry, for instance, vermicelli plant, rice flour mill, animal feed mill, rice bran oil plant. These products will be delivered to the wholesalers, before reaching the retailers or consumers.

For the upstream industry, Wong et al. (2010) reported some important figures in the year 2007, including:

a) 10 seed centres are in operation to supply seed to approximately 138,000 farmers, based on the subsidy figure.

b) The paddy harvested by the farmer was sold to 226 mills.

c) The products from these mills were purchased by 1239 wholesalers.

d) Local and imported rice were supplied to 44,637 retail outlets.
e) These rice products were then sold to 27.17 million of consumers.

Note that the rice mills produce a significant quantity of by-products such as broken rice, rice bran and rice husk. In the current practice, the rice milling company only utilises a small portion of these by-products at full economic potential. Rice husk is utilised as fuel for generating thermal energy that are required by the drying facilities. However, most of the by-products will be sold directly to the downstream industries at a subsistent price.

1.4 Problem Background

Up until now, most researchers, government agencies and rice companies have focused on research related to upstream rice-processing activities, for instance, paddy yield and soil fertility improvement. Yet in a newspaper article titled “Understanding the real causes of padi crisis”, Jegatheesan (2003) has stressed that the limited drying capacities of rice mills is the bottleneck of the rice industry. During the peak drying period, the delay in the drying of harvested paddy will cause the quality degradation that can adversely affect the yield and the productivity of rice mills. The loss of productivity will hamper the efforts of government in improving the upstream activities’ productivity. Besides, the existing by-products from rice mills are not fully utilised by the rice company (Wong et al., 2010). The aforementioned challenges, along with the continuous rise in the energy cost and stricter environment regulations, have combined to emphasise the growing importance of the optimal planning and synthesis of a resource-efficient network of processes for the rice industry, i.e., IRE rice mill complex.

The IRE rice mill complex can be defined as an optimum rice mill network design that enhances its profitability by efficiently utilising its existing by-products, to produce value-added products and energy products that includes heat and electricity. The IRE complex considers the trade-off between processes, utility system and logistic network.
To date, the concept of an IRE rice mill complex is relatively new for rice industry, although there have been extensive amount of research works on process integration and supply chain integration in the conventional integrated petrochemical industry, pulp and paper industry and the bio-refinery industry. The research works in this study represents the evolution of process engineering applications beyond the domain of traditional chemical processes, into the realm of the rice industry.

Analysis of the existing literature shows that there is only one study focusing on the rice supply chain modelling (Wong, 2004). The contributions of that study were twofold. The first is to identify the bottleneck for the drying and storage capacities for the rice industry. The second is to evaluate the economic performance of the different scenarios that involves the capacity adjustments of rice drying and milling. The study, however, has not considered by-product utilisation and the utility systems. In addition, the study has also assumed that the user has predefined the technology and the equipment capacity. Clearly there is a need for a systematic approach of planning and designing an IRE rice mill that integrates the efficient utilisation of resources utilisation that includes utility systems.

In this work, a new cost-screening framework that known as Resource Efficient Screening (RES) has been introduced to screen and select the product and technology involved in rice value chain with the objective of maximising the profit. Subsequently, the concept of an IRE rice mill complex is introduced and applied for the first time in this work, by deploying a IRE framework that analyse the trade-off between product revenue, capital expenditure and utility consumption. The model is further extended into a multisite integrated, resource-efficient (MSIRE) framework that considers the supply chain management aspects of rice mill complexes at multiple sites. Finally, a framework that designs the optimal logistic network of rice husk in a rice mill that considers the utility supply network has been developed.
Figure 1.1 The rice supply chain in Malaysia
1.5 Problem Statement

Given a number of resources (materials) and a number of processes, it is desired to synthesise a resource-efficient network of processes that can preferentially utilise by-products of a process to produce energy and value-added products. Given also are the yield of each process, and its supply (inlet) composition. The flowrate of each resource is unknown and is to be determined to maximise the profit.

The flowrate of resources are bounded by their availability in the process complex and may not exceed the specified limits. On the other hand, certain resources and utilities can be purchased from sources external to the rice mill complex. The flowrates of resources are to be determined by considering the overall profit of the resource-efficient process network.

1.6 Research Objective

The main objective of this research is to develop a new systematic framework for designing an IRE process complex for the rice industry. The sub-objectives include performing

1) Optimal resource allocation and profit targeting for a rice value chain
2) Synthesis of an integrated process-utility network for a single-site IRE rice mill complex
3) Design and resource allocation planning for an integrated process-utility-logistic network for a cluster of IRE rice mill complex (multiple sites)
4) Design and configuration of an integrated rice husk logistic and utility network of a rice mill
1.7 Scope of the Work

The scope of this research includes:

1) Analysing the state-of-the-art procedure on supply chain and process optimisation in rice industry, including its features, shortcomings and potential improvement.

2) Identifying the key technologies in processing the by-products.

3) Developing a systematic framework for targeting the maximum profit and resource utilization planning for a set of rice resources. The developed model is then solved using Generalised Algebraic Modelling System (GAMS).

4) Developing a systematic framework for targeting the maximum profit and synthesing the integrated process-utility network for an IRE rice mill complex. The developed model is then solved using Generalised Algebraic Modelling System (GAMS).

5) Developing a systematic framework for rice supply chain planning that caters for both private rice miller and rice enterprise using mixed integer linear programming (MILP). The developed model is then solved using Generalised Algebraic Modelling System (GAMS).

6) Developing a systematic framework for designed the integrated rice husk logistic-utility network for a rice mill that consist of cogeneration system and cyclonic husk furnace using mixed integer linear programming (MILP). The developed model is then solved using Generalised Algebraic Modelling System (GAMS).

7) Applying the optimisation models on industry case studies to demonstrate the effectiveness of the proposed framework in solving problems.

8) Comparing the economic performance of conventional rice mill and IRE rice mill complex.
1.8 Research Contributions

The key specific contributions of this work are summarised as follows:

1) A new optimisation model known as *Resource-Efficient Screening (RES) model* for synthesising the resource-efficient network for rice value chain.
   - A generic model has been developed to obtain optimal product portfolio and process selection, along with its resource allocation strategy while maximising the profit.

2) A new optimisation model known as *IRE model* to design IRE rice mill complex.
   - The concept of IRE rice mill complex is introduced. A multi-period generic model is able to solve the complex design problem that considers resource availability, shelf-life issue, and variation of heat and electricity demand across the periods, energy supply options, trade-off of by-product selling and further processing, supply and demand constraints to achieve maximum profit.

3) A new optimisation model known as *Multi-Site Integrated, Resource-Efficient (MSIRE) model* for designing IRE rice mill complexes at multiple sites.
   - A generic mixed integer linear programming (MILP) model that is capable of determining the design of IRE rice mill complex, resource allocation and logistic network at different process sites.

4) A new process network for an IRE rice mill complex
   - A process network that incorporates rice milling process with other value-added process.

5) A new optimisation model known as *Optimal Utility-Logistic (OUL) model* to design and configure rice husk logistic and utility network of a rice mill that includes a cogeneration system.
   - A MILP has been developed based on the superstructure of a rice mill that considers rice the husk logistic network and the
utility configuration to simultaneously design the cogeneration system and configure the logistic-utility network.

Appendix highlights all the publications and the corresponding key contributions of this thesis towards the new body of knowledge in designing and planning of an IRE rice mill.

This thesis consists of six chapters. Chapter 1 gives an overview of the rice industry issues, problem background, problem statement, objectives and scope of the research which aims to develop new systematic framework for designing an IRE rice mill complex using the mathematical approach. Chapter 2 of this thesis describes the fundamental theory and relevant literature related to the design of an IRE rice mill complex. Chapter 3 presents a detailed methodology of this study to achieve the targeted objectives. Chapter 4, 5, 6, 7 present the results and discussion from the application of new methods on the rice industry to showcase the effectiveness and advantages of the developed methodology. Finally, Chapter 8 summarises the key contributions of this research, prior to the recommendation of possible future work. Figure 1.2 shows the flow and linkage of the chapters.
Figure 1.2  Flow diagram illustrating the conceptual link among the chapters