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Modelling of palm oil production using fuzzy expert system

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ABSTRACT

The production of crude palm oil and palm kernel is a complex problem due to the influence of processing variables and environmental factors. These processing variables influence the amount of crude palm oil and palm kernel losses during processing. Instead of mathematical model, fuzzy logic approach provides a simpler and easier mechanism to describe the relationships between the processing variables and the amount of crude palm oil and palm kernel losses. In this study, four fuzzy expert system models were developed for each palm oil processing station. An approximation of centre of gravity method for defuzzification is also proposed to enable the development of the model using Microsoft®Excel. For comparison purpose, the models were also developed using MATLAB®. Results obtained from the Excel model are found to be very close to the results from MATLAB.

1. Introduction

Palm oil is one of the main commodities in Malaysia and Indonesia that gives high significant contributions to their national incomes. Both two countries are the biggest producers and exporters of crude palm oil (CPO) in the world. Malaysia produces 15.9 million tonnes of CPO in 2006 (Malaysian Palm Oil Board., 2008), followed by Indonesia that produces 15.8 million tonnes in that year. The total exports of crude palm oil from Malaysia is around 14.42 million tonnes in 2006 and 13.74 million tonnes in 2007 (Malaysian Palm Oil Board, 2008). While, Indonesia exports 11.3 million tonnes of crude palm oil in 2006 (Siagian, 2008). Therefore, the importance of research related to how to increase palm oil production become major interest for government as well as palm oil producers in both two countries.

In a palm oil production, objectives that are of interest to the decision makers are to maximise crude palm oil and kernel production, to minimise palm oil and palm kernel losses during processing and to maintain production costs at the lowest possible level (Eng & Tat, 1985). Nevertheless, the production of crude palm oil and palm kernel is a complex problem due to the influence of processing variables and environmental factors. Existing problems in the processing of crude palm oil and palm kernel are the lack of processing efficiencies, the properties of the raw materials that cause them to deteriorate easily, delay in processing, etc. These factors may affect the quantity and quality of oil and kernel production as well as giving impact to the production costs.

One of the main concerns of palm oil mills is how to minimise the palm oil and palm kernel losses during processing. These losses occur almost in all processing station such as sterilising and threshing station, digesting and pressing station, clarification and kernel station. The relationship between the amount of palm oil and palm kernel losses and the processing variables that influences those losses in each station is very complex and difficult to describe through a mathematical model. Instead of using mathematical model, this relationship can also be constructed using fuzzy logic approach. As a qualitative approach, fuzzy logic provides a methodology to mimic human expert and allow the use of data and information from expert knowledge. Fuzzy logic also provides an easier and simpler mechanism in developing the model due to its nature that allow decision making process that involves a vague, imprecise, incomplete and ambiguous information.

The application of fuzzy logic expert system in the production process control and optimisation have been widely used since Mamdani and Assilian (1975) developed fuzzy inference fuzzy logic controller model for a steam engine. Mamdani fuzzy logic expert system has been applied in the area of production optimisation and control in the food processing industries as well as other industries. For example, application of fuzzy expert control for hydraulic forging machine (Lee & Kopp, 2001) and twin extruder machine (Lee, Hong, Han, Kang, & Kwon, 2002). Peres, Guerra, Alique and Ros (1999) also developed fuzzy control model for milling process optimisation and Vagelatos, Rigatos, and Tzafestas (2001) developed fuzzy control model for optimising the injection molding process. Other applications include optimisation of power distribution system operations that was developed by Sarfi and Solo (2002), food frying process (Rywotycki, 2003) and fuzzy expert control for oil and gas supplies (Neuroth, McConnell,

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Stronach, & Vamplew, 2000). Despite the wide application of fuzzy expert system, the technique has yet to be applied in the crude palm oil production.

In this study, fuzzy expert models are developed in the area of palm oil production to describe the relationship between palm oil and kernel losses and the processing variables that influence those losses during the processing. The fuzzy expert models use Mamdani approach and are developed based on knowledge of decision makers and experts in palm oil processing. Most of fuzzy expert system models are developed using Mamdani approach. Liao (2003) noted that compared to TSK (Takagi-Sugeno-Kang) model, the Mamdani approach is better for discovery of human understandable knowledge from real world problem.

2. Crude palm oil and palm kernel processing

Crude palm oil (CPO) and palm kernel are yielded from fresh fruit bunches of palm oil that undergo several stages of processing. After the fresh fruit bunches of palm oil are loaded into the loading ramp, the fresh fruit bunches are sterilised in a steriliser in order to separate fruit from the bunches. During the sterilising process, steam at a temperature 140 °C is used to produce the sterilised fruit bunches. The steam pressure and sterilising time are dependent on the amount of unripe fruits in the fresh fruit bunches. A higher percentage of unripe fruit means that the sterilising process needs a longer sterilising time and a higher pressure.

The sterilised fruit bunches are then conveyed into a thresher using a hoisting crane where the fruit is threshed in a stripper drum. Stripper drum consists of horizontal metal bars with sufficient space between them to allow the stripped fruit to fall through onto a conveyor which carries the fruit into a digester. The centrifugal force exerted on the bunches is sufficient to raise them to the top of the drum whence they fall to the bottom and scatter their fruit (Hartley, 1977). Fruits are then carried into a digester, while the empty bunches are conveyed to a hopper before they are brought out of the factory.

The fruits are then digested in a digester in order to separate nuts from the fruits. A digester is a steam-jacketed vertical vessel that has a vertical rotating shaft in the centre. Fruits are meshed by pairs of stirring arms attached to the shaft until the *pericarp* is broken and fruits are separated from the nuts. Digesting temperature must be controlled at 90–100 °C for 15–20 min. The level of fruits in the digester must be maintained at least three quarter of its volume.

After the digesting process, the fruits are then carried into a screw press by a feed screw conveyor. Because of screw press pressure, the mixture of fruits and nuts are pressed so that the crude oil is separated from fibre and nuts. Crude oil resulted from pressing is carried into a clarification station, while the press cake, which is a mixture of fibre and nuts, is transferred into the kernel station through a cake breaker conveyor.

In the clarification station, the crude oil consisting of oil, water and non oil solid (NOS) is separated using centrifugal force and heat. Crude oil from screw press flows into a sand trap tank and vibrating screen in order to separate sand, fibre and dirt before entering the crude oil tank. Then, the crude oil is pumped into a continuous settling tank (CST). Steam is given to maintain the CST temperature at around 90 °C. At this temperature, the difference in specific gravity between oil and water will increase causing oil to be separated from water. Oil will rise to the top of tank, while sludge (the mixture of water and dirt) is at the middle, and sand and other heavy particles will settle at the lower part. Crude oil at the upper layer is passed into the oil tank and then carried into a purifier, while sludge is pumped into the sludge tank. The crude oil is purified in a purifier using centrifugal force so that the remaining dirt and water that have a higher specific gravity than the oil can be separated. Oil is then passed into a vacuum dryer before it is stored in an oil storage tank.

Sludge from the continuous settling tank flows into a decanter or sludge separator in order to separate oil from water and NOS. The decanter temperature is maintained at around 90 °C to ensure specific gravity difference between oil and the mixture of water and NOS. Using centrifugal force, oil is separated from the sludge and fed back into the continuous settling tank. Wastes resulted from decanter consists of solid and liquid wastes.

Press cake from the screw press that consists of the mixture of fibre and nuts is carried into the kernel station by a cake breaker conveyor. There after, the fibre and nuts are separated in a depericarper and entered the nut silo in order to reduce the water content. Nuts are broken in a ripple mill to obtain the kernel. The mixture of kernel and shell is then separated using double stage light tension density separation (LTDS) which is a pneumatic winnowing system designed to give a separation velocity 8–14 m/s at the first separation column and followed by a separation velocity of 12–16 m/s at LTDS II. Based on specific gravity difference, the light particles such as shell can be removed and separated from the kernel. Finally, kernel is dried in a kernel dryer before it is stored.

3. Methods of study

Four fuzzy expert system models were developed using the Mamdani approach namely for sterilising and threshing station, digesting and pressing station, clarification station and kernel station. Each fuzzy expert system model is developed through three stages, ie. fuzzification, inference engine and defuzzification as depicted in Fig. 1.

The fuzzy expert system approach is proposed due to difficulties in developing mathematical models to describe those relationships. The models were developed based on interview with production personnel in two palm oil mills, ie. *PT. Perkebunan Nusantara VII (PTPN VII)* and *PT. Mitra Ogan* that are located in South Sumatra, Indonesia.

These four fuzzy expert system models were developed using Microsoft Excel spreadsheet. For comparison, the models were also developed using MATLAB® 6.5.1. The development of the model in Microsoft®Excel spreadsheet enables production optimisation to be modelled using a heuristic optimisation software such as NLI Gen® (a Genetic Algorithm software) and Visual Basic Editor in the Excel spreadsheet.

4. Development of fuzzy expert system model

4.1. Fuzzification

The fuzzy input and output variables in each station namely for sterilising and threshing, digesting and pressing, clarification and

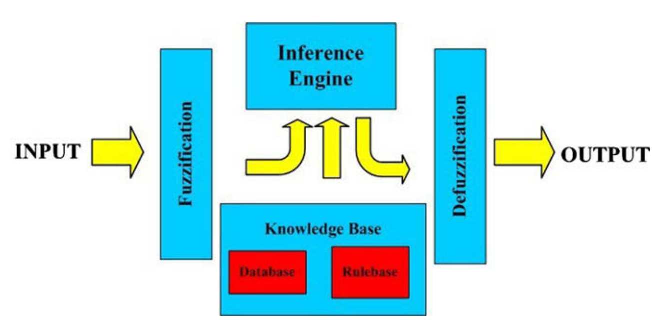

Fig. 1. Fuzzy expert system approach.