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Energy Analysis in White Rice and Par-Boiled Rice Mills for Cogeneration in Thailand

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ABSTRACT

This research is a part of a study entitled "Cogeneration Potential of Rice Mills in Thailand". Three types of rice mills are studied : the white rice mills that use only electricity, the white rice mills that use electricity and steam engines, and the par-boiled rice mills that use electricity and steam in the par-boiled process. The white rice mills and par- boiled rice mills use steam in the heating process for paddy drying. Electrical energy consumption in the milling process of white rice mill and par-boiled rice mill are approximately 110 MJ/ton paddy and 134 MJ/ton paddy, respectively. Electrical energy consumption of white rice mill spent in whitening and polishing process is 43%, 26% in screening and blowing process, 23% in bucket and conveyor process, and 8% in husking process. Similarly, 43% of electrical energy consumption in the milling process of par-boiled rice mill is spent in whitening and polishing process, 30% in screening, bucket and conveyor process, 23% in blowing process,and 4% in husking process . The thermal energy consumption for par-boiled rice process is 2410 MJ/ton paddy, of which 8% is for soaking process, 6 % for cooking process and 86% for paddy drying process.

The results of the analysis show that the total electrical energy consumption -- milling process, drying process, improving and packing process, office and boiler in the white rice mill -- is approximately 190 MJ/ton paddy and for par-boiled rice mill it is 234 MJ/ton paddy. Assuming that steam turbine cogeneration is used, the electrical power generated from 312 rice mills is therefore 217 MW, of which 123 MW is used within the rice mills and 94 MW is surplus. The thermal energy generated from the rice mills is 3.16 x 10^{10} MJ/year, of which 17% is used within the rice mills and 83% is surplus . However, optimization of cogeneration system may help reduce the amount of surplus steam.

1. INTRODUCTION

In 1994, there were approximately 40 000 rice mills in Thailand, of which 260 white rice mills and 52 par-boiled rice mills have production capacities over 100 ton paddy/day. Generally, there are two types of energy consumption in rice mills i.e. electricity and thermal. Usually the energy used for white rice mills is electricity or electricity and steam engine, where as for the par-boiled rice mills it is electricity and steam from steam boiler.

The paddy milling process produces either white rice or par-boiled rice. Par-boiled rice, mainly

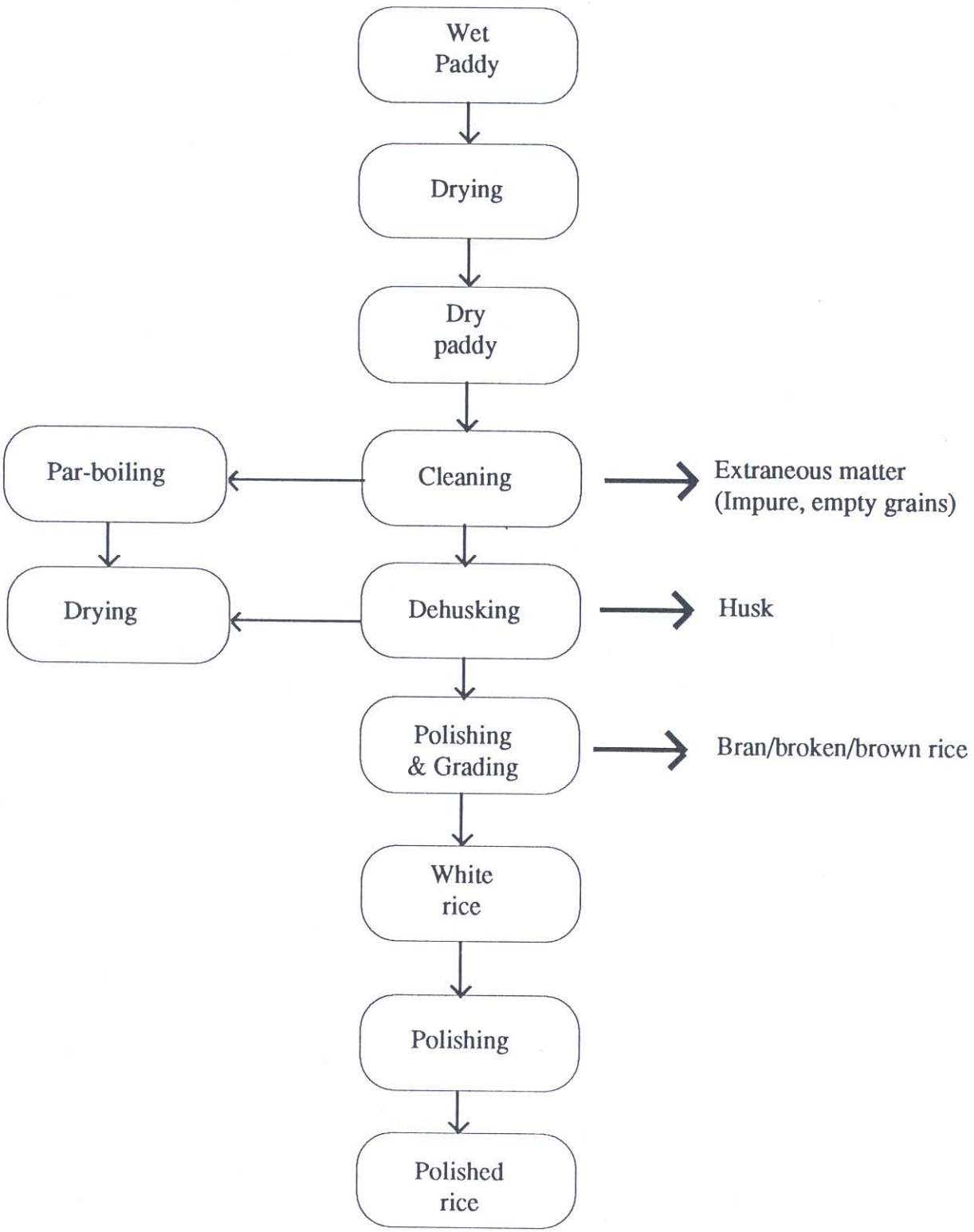


Fig. 1. Paddy milling process and residues production.

produced in Thailand, is defined as " pre-cooked rice ". Rice husk which is easily available at the mill site can be used as an energy source for both white rice and par-boiled rice processes. Fig. 1 illustrates the rice milling and residues production processes. The thermal energy consumption in steam produced from boiler is usually used in the processes of soaking, cooking and paddy drying in the par-boiled rice mills. The fuel used for the boiler is mainly from the rice husk found within the mill. The heating value of rice husk is approximately 15.7 MJ/kg of which 18.8% is carbon, 62.8% is volatile matters and 9.3% is moisture content.

The objective of this paper is to analyze the electrical and thermal energy in par-boiling process, drying process and milling process of white rice mill and par-boiled rice mill since the comparison of electrical and thermal energy in each process of white rice and par-boiled rice mills has not been studied in the past. The results of this analysis will be used to find out the potential of cogeneration system for rice mills in Thailand.

2. MATERIALS AND METHODS

The rice mill uses the electrical and thermal energy. Clip on is used for measuring power (kW), current (Amp), voltage (V) and power factor (cos θ). Thermal energy available from the drying process is estimated from the amount of condensate coming out from the equipment. Thermal energy available from the soaking process is estimated from the volume of hot water. A static-pitot tube is employed to measure the air velocity of the flue gas. The temperature of hot water and fuel gas are measured by a digital thermometer. The mass flow rate of rice husk fuel is measured by volume of container and time used. Time spent for the energy audit is approximately 4-5 days for each mill.

3. RESULTS AND DISCUSSION

3.1 Pattern of Energy Consumption in White Rice Mills

The study concerned two types of white rice mills. The big one with a capacity of 1000 ton paddy/day uses steam for drying paddy and electricity for milling. The small one,120 ton paddy/day, uses electricity and steam engines for milling without paddy drying process.

The first rice mill can produce approximately 320,000 tons paddy/year, working 24 hours/day. The electrical energy consumption is 110 MJ/ton paddy for milling process excluding that for the paddy drying process. The pattern of energy consumption for various processes is shown in Fig. 2. However, the actual amount of electrical energy consumption varies according to the type of paddy and quality of rice being produced. For example, producing rice for export consumes more energy than producing rice for domestic use since the quality of rice exported needs to be better than that of the domestic one.

There are two boilers in this big rice mill. The first boiler has a maximum production capacity of 35 tons/hour with an actual production of about 20-30 tons /hour at a pressure of 18-20 bars and a temperature of 360°C. The second boiler has a maximum production capacity of 20 tons/hour with an actual production of about 12-15 tons/hour at a pressure of 18-20 bars and a temperature of 360°C. The efficiencies of these two boilers according to the first law of thermodynamics is about 69%. The steam produced, about 90%, passes through the back pressure turbine to produce 1450 kW electricity from two generators.The 10% of the steam produced or about 4 ton steam/hour is used for distillation

process for producing extracted oil.

There are three dryers with total capacity of 100 tons/hour.The dryer is used when the moisture content of the paddy is over 14%.Usually, in each pass of the drying process, the moisture content can be reduced by 2% and it requires one day of tempering to reduce the stress of the paddy. For example, if the moisture content of the paddy is 24%, it requires 5 passes for the drying process to reduce the moisture content to 14%. In the past, the drying processes were done for two periods in each year, i.e. during December to March and during June to July . In 1993, 43% of the total paddy that had been bought needed to be dried in this rice mill.

For the drying process, it requires about 18 ton steam/hour to generate heat in the process. For this rice mill, 18 ton steam/hour is received from steam turbine for the drying process. Thermal energy used to evaporate water from the paddy is about 2000 MJ/ton paddy. This amount of heat being used is rather high compared to the average use of 440 MJ/ton paddy [1,5] because of improper design of the systems. Electrical energy used for the drying process is about 25 MJ/ton paddy.

The electrical power needed for this rice mill is about 2 MW. The details are given in Fig. 3.The total electrical energy consumption for the whole rice mill (milling and drying, oil extraction,improving and packing, office, boiler and warehouse) is 220 MJ/ton paddy or about 62 kWh/ton paddy. The total thermal energy consumption for the whole rice mill is 2000 MJ/ton paddy or about 556 kWh/ton paddy. The heat to power ratio is 9 which is rather high because of the heat used for drying processes and for producing extracted oil. If the oil extraction processes and warehouse are excluded, the electrical energy needed for this rice mill would be 190 MJ/ton paddy or 53 kWh/ton paddy. Therefore, the analysis is done based on this value.

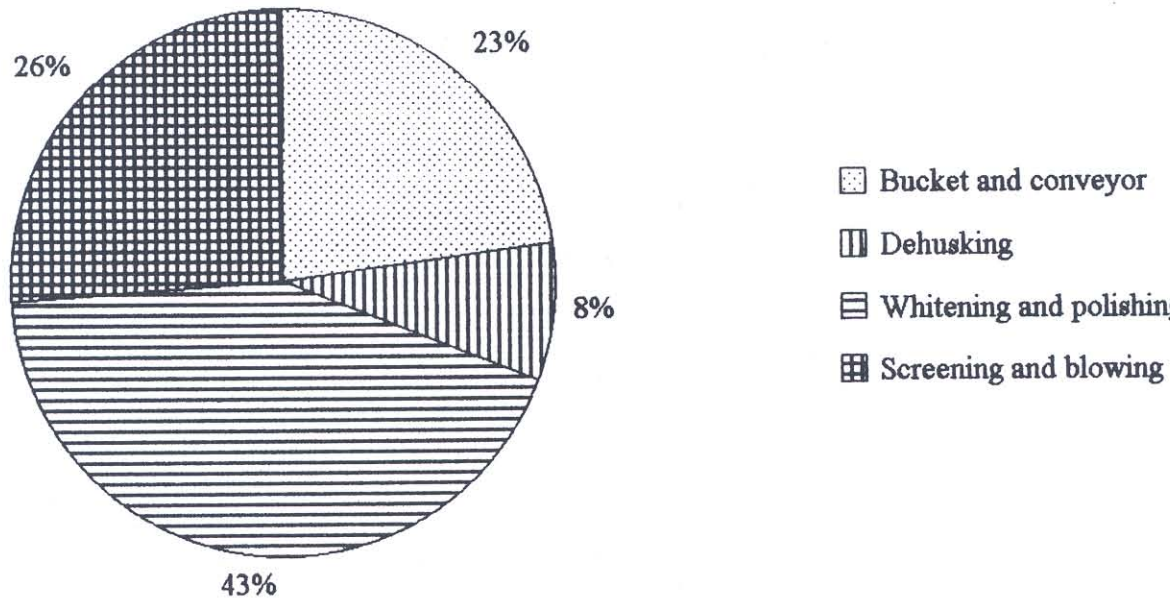
The second rice mill has a production capacity of 120 tons/day, working 24 hours/day. The energy used is electrical energy and energy from the steam engine. Electrical energy is used for the bucket process, screening process, whitening and polishing process and the blower. Energy from steam engine is used to drive the conveyor belt. If the efficiency of the steam engine is 15%, energy from steam engine would be equal to 103 kWh of electrical energy [1,2]. The details are given in Fig.4.

3.2 Pattern of Energy Consumption in Par-boiled Rice Mills.

The third and fourth are par-boiled rice mills with maximum capacity of 500 tons/day but work at an average capacity of 250 tons/day, operating for 24 hours daily, using electrical energy of 129 MJ/ton paddy and 138 MJ/ton paddy (as shown in Figs. 5 and 6.).The mills in this study have 5 boilers using rice husk as fuel at 54 % efficiency, producing 10-12 ton steam/hour at 10 bars and 180°C. The steam is used in the process of soaking, cooking and drying.

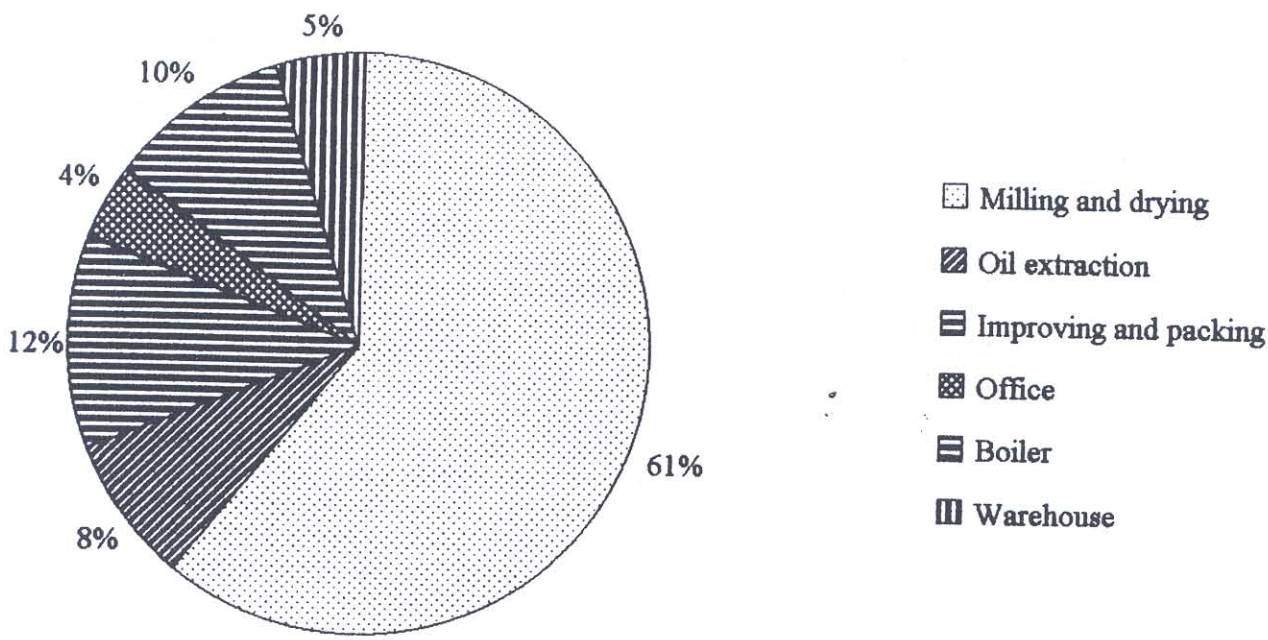
The steps of producing par-boiled rice are to soak paddy in the soaking unit, using hot water at temperature of 60°C - 65°C for 4-6 hours. The thermal energy used in soaking is approximately 196 MJ/ton paddy. Soaked paddy is then cooked by steam at a temperature of 100°C - 120°C for 30 minutes. The thermal energy used in cooking is 150 MJ/ton paddy. Part of the cooked paddy rice is to be dried in the sun. Drying by machine reduces moisture from 34% to 14% w.b. The thermal energy used to dry the paddy is produced by steam and flue gas from the boiler. The total energy used for drying is approximately 2062 MJ/ton paddy which consists of steam 1512 MJ/ton paddy and flue gas 550 MJ/ton paddy. The total thermal energy is 2412 MJ/ton paddy which is approximately the same for both par-boiled rice mills as shown in Fig. 7.

The electrical energy used in milling, soaking, cooking and drying processes of rice mills nos. 3 and 4 are about 238 MJ/ton paddy (66 kWh/ton paddy) and 230 MJ/ton paddy (64 kWh/ton paddy) respectively.The overall electrical power used in these two rice mills are 656 kW and 641 kW



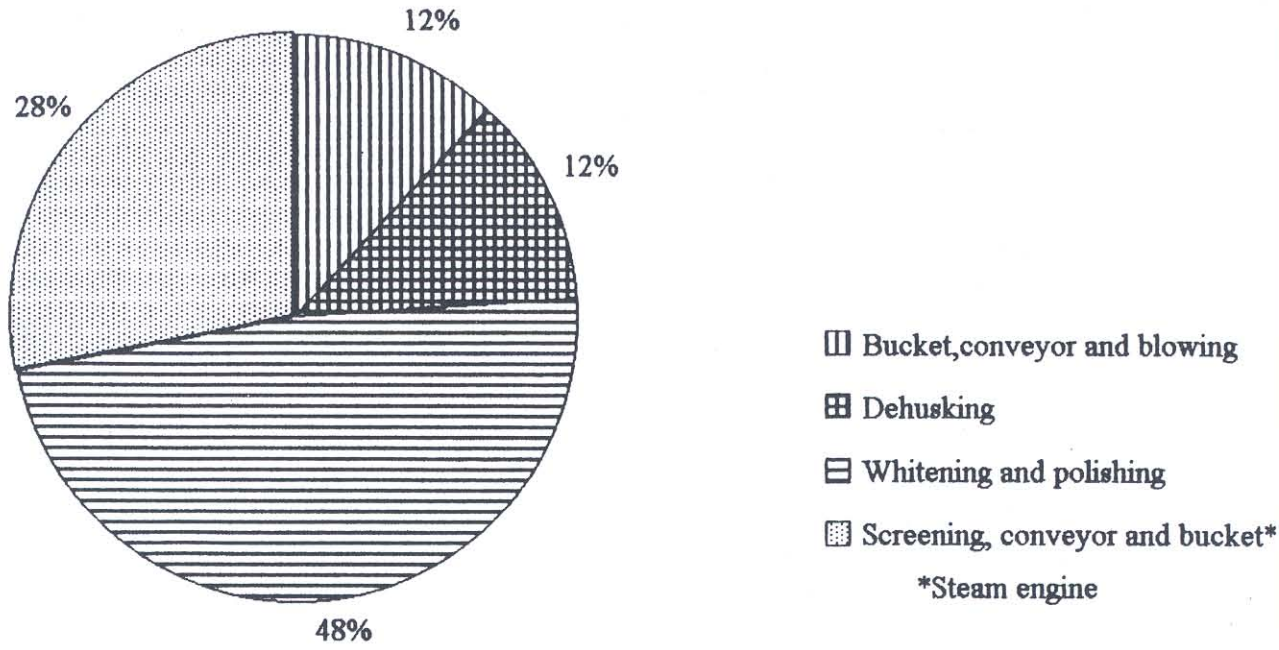
Total electrical energy consumption is 110 MJ/ton paddy excluding drying process.

Fig. 2. Percentage of electrical energy consumption in white rice milling process of white rice mill no. 1.



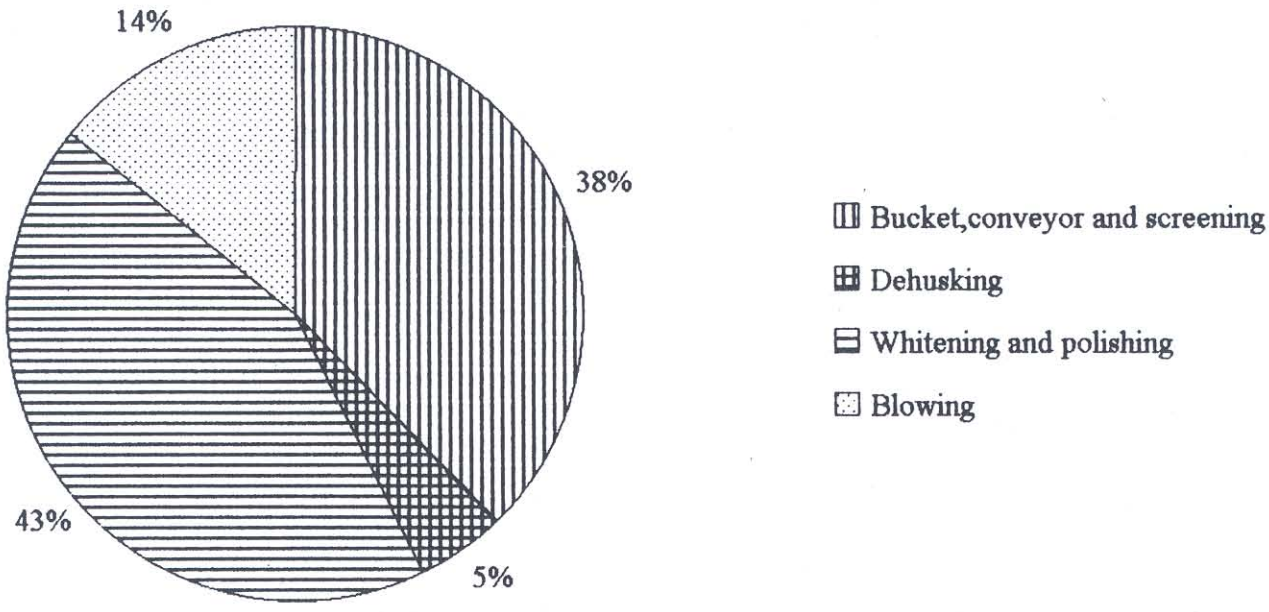
Total electrical power consumption is 1890 kW.

Fig. 3. Percentage of electrical power consumption in white rice mill no. 1.



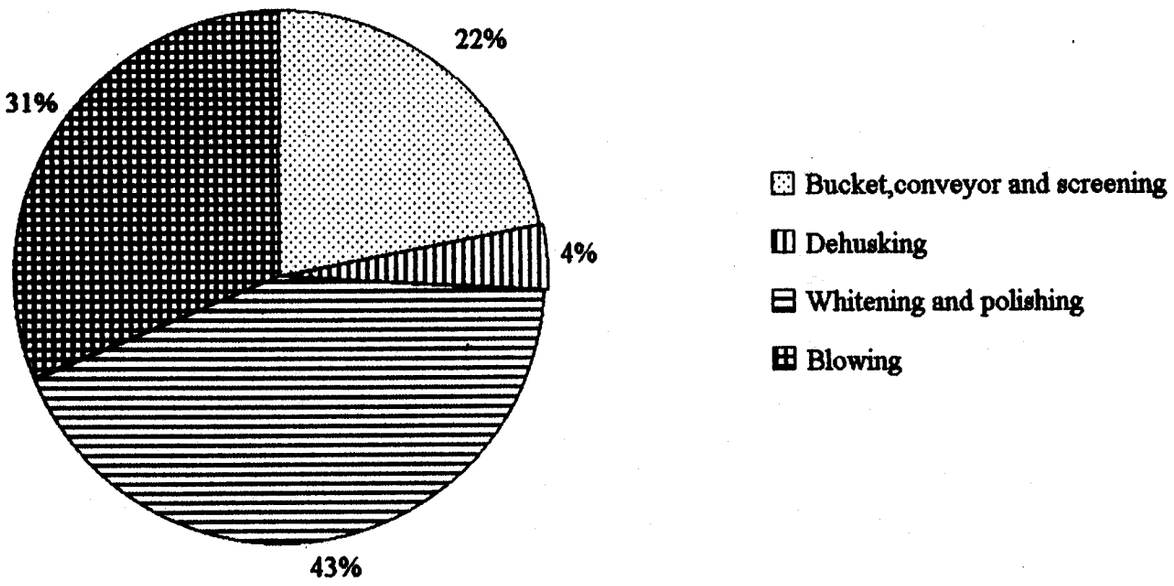
Total electrical energy consumption is 102 MJ/ton paddy excluding drying process.

Fig. 4. Percentage of electrical energy consumption in white rice milling process of white rice mill no. 2.



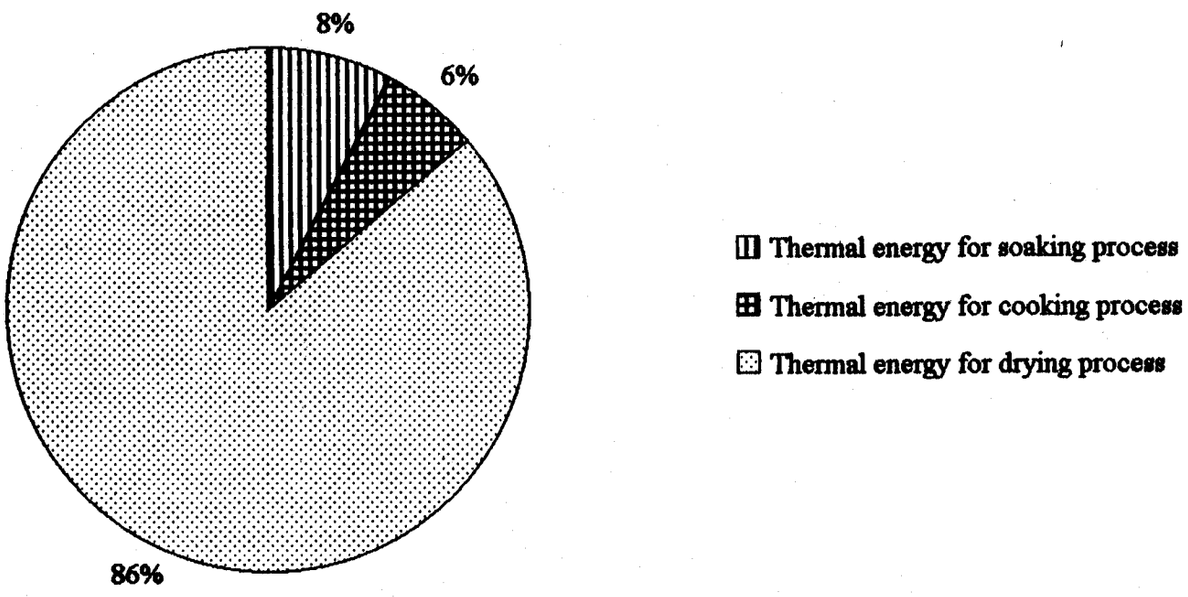
Total electrical energy consumption is 129 MJ/ton paddy excluding drying process.

Fig. 5. Percentage of electrical energy consumption in par-boiled rice milling process of par-boiled rice mill no. 3.



Total electrical energy consumption is 138 MJ/ton paddy excluding drying process.

Fig. 6. Percentage of electrical energy consumption in par-boiled rice milling process of par-boiled rice mill no. 2.



Total thermal energy consumption in par-boiled rice process is 2412 MJ/ton paddy.

Fig. 7. Percentage of thermal energy consumption in par-boiled rice milling process of par-boiled rice mill no. 3 and no. 4.

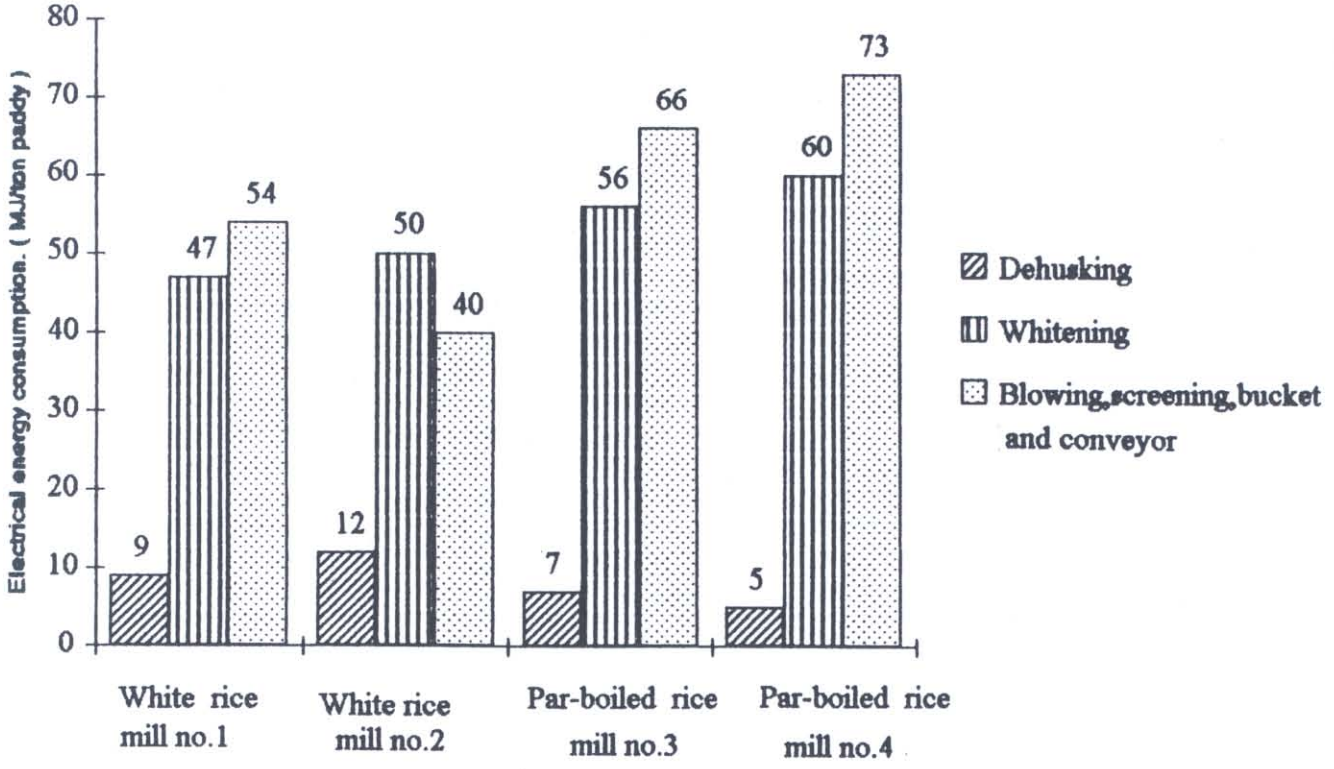


Fig. 8. Comparison of electrical energy consumption in rice milling process.

(including that used in office operation), respectively, or on an average 234 MJ/ton paddy (65 kWh/ ton paddy). For these rice mills, the heat to power ratio is 10 which is rather high due to the low efficiency of the drying machine.

3.3 Comparative Energy Consumption

From this study, it is found that electrical energy used for dehusking process of the par-boiled rice mill is less than that being used for the white rice mill, as shown in Fig. 8. The reason is that the paddy which has been soaked and cooked is much easier to mill. The energy used in all the processes are 5 MJ/ton paddy - 7 MJ/ton paddy for the par-boiled rice mills where as for the white rice mills the energy used are 9 MJ/ton paddy and 12 MJ/ton paddy, respectively. It is also found that electrical energy used for polishing in the par-boiled rice mill is more than that used in the white rice mill. The reason is that the rice from par-boiled rice mill is harder than that from the white rice mill.The amounts of electrical energy used for other processes such as bucket, belt, screen and blower depends on the design of the mill.

The thermal energy used in the rice mills in this study is too high in the drying process. The rice mill no. 1 uses about 2000 MJ/ton paddy . The rice mills nos. 3 and 4 use about 2412 MJ/ton paddy.

3.4 Energy Conservation for the Rice Mill

From the study, it is found that the highest electrical energy is used for the polishing process, the amount of electrical energy used depends on the percentage of the whiteness. The energy saving for this part can be achieved by choosing an equipment which is suitable for the quality of rice. Apart

from this, the bucket, belt and blower have to be properly designed.

The thermal energy used for the par-boiled rice mill such as soaking and boiling processes can also be saved by using an insulator. The thermal energy used for drying process for both the par-boiled rice mill and the white rice mill can be saved by proper design and operation of the equipment.

For the white rice mill and the par-boiled rice mill, if energy saving is done in the drying process, the thermal energy used will be only 240 MJ/ton paddy and 673 MJ/ton paddy [5], respectively. The heat to power ratio is found to be 1.3 and 4.4, respectively.

3.5 Analysis of Potential of Using Steam Turbine Cogeneration for the Rice Mills in Thailand

From this study, it can be concluded that electrical energy used are 190 MJ/ton paddy or 53 kWh/ton paddy and 234 MJ/ton paddy or 65 kWh/ton paddy for the white rice mill and the par-boiled rice mill, respectively.

From these data an assumption can be made that all the rice husk obtained from the rice mill is used as fuel for cogeneration system. The electricity generating process uses back pressure steam turbine-generator type with 65% efficiency at 50 bars and 450°C and 10.3 bars [3,4] and the steam boiler of 70% efficiency [3,4].

The electrical and thermal energy produced, used and unused were analyzed for 260 white rice mills as follows (assuming that annual production is 11.7×10^6 ton paddy or 293×10^4 ton husk and 270 days of operation):

- The electrical energy consumption of the white rice mills, 53 kWh/ton paddy, is used to analyze the necessary electrical energy required .The electrical power generated from 260 white rice mills by using steam turbines and rice husk as fuel is 177 MW, of which 54% is used within the rice mills and 46% is surplus.
- The energy conservation of thermal energy consumption for the white rice mills is 242 MJ/ton paddy. The thermal energy generated from 260 white rice mills by using steam after it leaves the steam turbine at 10.3 bars [4] is 2.58×10^{10} MJ/year, of which 11% is used within the rice mills and 89% is surplus.
- The analysis of electrical energy and thermal energy produced, used and unused for 52 par-boiled rice mill are analyzed as follows (assuming that annual production is 2.63×10^6 ton paddy or 66×10^4 ton husk and 270 days of operation).
- The electrical energy consumption for the par-boiled rice mills, 65 kWh/ton paddy, is used to analyze the necessary electrical energy required.The electrical power generated from 52 par-boiled rice mills by using steam turbines and rice husk as fuel is 40 MW, of which 68% is used within the rice mills and 32% is surplus.
- The energy conservation for thermal energy consumption of the par-boiled rice mills is 1019 MJ/ton paddy. The thermal energy generated from 52 par-boiled rice mills by using steam after it leaves the steam turbine at 10.3 bars [4] is 5.78×10^9 MJ /year of which 46% is used within the rice mills and 54% is surplus.

4. CONCLUSION

The study proves that the total electrical energy consumptions are 190 MJ/ton paddy (53 kWh/ton paddy) and 234 MJ/ton paddy (65 kWh/ton paddy) for the white rice mills and the par-

boiled rice mills, respectively. The thermal energy consumptions in the par-boiled rice mill are 196 MJ/ton paddy for the soaking process, 150 MJ/ ton paddy for the cooking process and 2062 MJ/ ton paddy for the drying process of paddy from 34% moisture content to 14 % w.b. The total thermal energy consumption is 2412 MJ/ton paddy.

The electrical power generated from 260 white rice mills is calculated to be 177 MW of which 54% is used within the rice mills and 46% is surplus. The electrical power consumption from 52 par-boiled rice mills is 40 MW of which 68% is used within the rice mills and 32% is surplus.

The thermal energy generated from the white rice mills is calculated to be 2.58×10^{10} MJ/ year of which 11% is used for the drying process of paddy which is reduced from 24% moisture content to 14% w.b. (assuming 240 MJ/ton paddy). The heat to power ratio is 1.3.

The thermal energy generated from the par-boiled rice mills is 5.78×10^{9} MJ/year of which 46% is used for the thermal process including soaking, cooking and drying processes of paddy which is reduced from 34% moisture content to 14% w.b. (assuming 673 MJ/ton paddy) . The heat to power ratio is 4.4.

This study found that the design of cogeneration system still has high thermal energy available. However, optimization of cogeneration system may help reduce the amount of surplus steam.

5. REFERENCES

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