DRYING RASAMALA WITH COMBINED HEAT RELEASED FROM SOLAR ENERGY, FUEL-POWERED STOVE AND HEATER

(*Pengeringan Rasamala dengan Kombinasi Panas dari Tenaga Surya, Tungku Bahan Bakar dan Pemanas*)

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ABSTRAK

Pengeringan kayu rasamala dilakukan dalam 2 tahap. Pada tahap awal, pengeringan dilakukan dari kondisi basah hingga mencapai kadar air rata-rata 40% dengan hanya menggunakan panas surya. Pada tahap berikutnya, kayu rasamala dengan kadar air 40% dikeringkan hingga mencapai kering udara menggunakan kombinasi panas surya dan panas tungku pada siang hari dan panas heater untuk proses pada malam hari. Waktu pengeringan kayu rasamala pada tahap pertama berlangsung selama 16 hari dan pada tahap kedua hanya selama 5 hari. Selama proses pengeringan dengan kombinasi energi surya dan panas buatan (tungku bakar dan heater), penggunaan bahan bakar solar adalah 9,52 liter dan pemakaian listrik sekitar 592,2 kwh. Sebagian besar kayu rasamala yang dikeringkan memiliki kualitas yang baik. Analisa kelayakan finansial lebih lanjut menunjukkan bahwa pada tingkat suku bunga 15% dan dengan asumsi harga jual kayu rasamala kering adalah Rp 4.000.000 per m^3*diperoleh nilai NPV Rp 2.991.465 dan IRR 15,9%. Hal ini menunjukkan bahwa pada tingkat suku bunga 15%, pengeringan rasamala dalam bangunan pengeringan tenaga surya dengan teknik yang digunakan dalam penelitian ini layak diterapkan pada skala industri. Biaya investasi yang dikeluarkan kembali dalam jangka waktu 5,7 tahun, sedangkan titik impas produksi akan tercapai pada produksi kayu rasamala kering sebesar 43, 95* m^3*.*

Kata kunci : Rasamala, pengeringan tenaga surya, energi ,kelayakan finansial

ABSTRACT

The drying process of rasamala in solar kiln was carried out in two stages. At first stage, the green rasamala was dried with solar energy only until most boards reached average moisture content of 40%. The second stage used the combination between solar energy and heat from stove or heater to dry rasamala from average MC of 40% to dry condition. At this stage, the heat source for the drying process during the day was from the combination between solar energy and stove's heat, while the heat source for nighttime was from the heater. Total drying period in the first stage was around 16 days and in the second stage was around 5 days. During the second stage of the drying process, the amount of diesel fuel consumed was around 9.52 litres and the electricity used was around 592.2 Kwh. The quality of the dried rasamala was good. By assumming that the interest rate was 15% and sales price of dry timber was Rp 4,000,000 per m^3, the NPV value obtained was Rp 2,991,465 and IRR was 15.9%. This showed that at interest rate 15%, drying rasamala with the technique applied in a solar dryer was feasible for the industries to implement in large scale operation The payback period was achieved in 5.7 years, and break even point was reached at production level of 43.95 m^3 of dry rasamala.

Keywords: Rasamala, solar drying, energy, financial feasibility

I. INTRODUCTION

Rasamala (*Altingia excelsa* Noronha) timbers dried slowly and easily deformed during the drying process (Martawijaya *et al*, 2005). Air drying 1-3 cm-thick Rasamala boards took about 5 to 7 months to reach air-dry condition (moisture content was ± 15%) from green (Martawijaya *et al*., 2005).

One technique to fasten the drying process of Rasamala is by using solar dryer. In this dryer type, the heat from solar energy is collected and distributed inside the drying chamber (Basri, 2000). Improvement of dryer performance was done by installing other sources of heat such as biomass/fuel-powered stove and heater. This will allow continous supply of heat inside the solar dryer during the day and night, and optimize the drying process inside. Previous research showed that the application of combined heat released from solar energy and other sources could dry timbers in short period with good quality. For example, drying mangium with solar energy during the day with heat from the stove during night’s usage resulted in shorter drying period than the air drying time (about 40% lower) and good quality of dry boards (Basri, 2005a).

Based on the facts above, an experiment was carried out to investigate the drying performance of Rasamala with the combined heat from solar energy and stove for day’s use and heater for night’s use. Furthermore, to see whether the technique could be further adopted by the industries or not, the feasibility of the applied technique was also analysed.

II. METHODOLOGY

A. Materials and Equipment

The materials used were rasamala logs and diesel-oil. The equipments used were a 6 m^3-capacity solar dryer that was fully equipped with stove and heater, sawing equipment, balance, *thermohygrometer*, *moisture meter* (Figure 1), and oven.

Figure 1. Lignometer HT100-moisture meter used in the experiment
(*Gambar 1. Moisture meter tipe Lignometer HT100 yang digunakan dalam penelitian*)

B. Experiment Method

The rasamala logs were cut into 400-cm length boards with 2 different widths and thicknesses, i.e. (5 x 10) cm and (6 x 12) cm, respectively. The boards were stacked inside the solar dryer using ± 2-cm thickness sticker. Total volume of the boards stacked inside the solar dryer was ± 6 m^3.

The drying process was run using the drying schedule in Table 1. Nine (9) boards representing the top, middle and bottom parts of the stack were randomly selected for moisture content observation. The decrease of moisture content from these 9 boards was observed using Ligno HT100-moisture meter (Figure 1). For each selected board, the moisture content was observed twice, on the middle and edge part of the board, then the collected values were averaged.

Table 1. Basic drying schedule used for Rasamala wood

Tabel 1. Bagan pengeringan dasar kayu Rasamala

Moisture content/*Kadar Air* (%)	**Temperature/ *Suhu* (^{0}C)**	**Humidity/*Kelembaban* (%)**
Green (*basah*)-40	40	91
40-30	42	88
30-25	42	83
25-20	45	73
20-15	55	47
<15	60	30

The drying was run in two stages. In the first stage, the drying was run by utilising only solar energy to decrease the wood moisture content from green to 40%. This was done by considering that the green Rasamala wood was sensitive to deform when being exposed to high/medium temperature level. Thus, Basri (2005b, personal communication) suggested to apply the schedules when the boards reached moisture content level of around 40%. The second stage of drying process used the combined energy from solar and stove during the day and heater during the night to decrease the moisture content from around 40% to final level of around 15%.

C. Data Collection and Analysis

The primary data collected were drying period, electricity used, volume of diesel-oil used and quality of the dried boards. These data were tabulated and analysed descriptively to obtain the general frame of technical information.

To assess whether this drying procedure is feasible for the industries to adopt, a financial feasibility analysis was also carried out. The data required for this study included the installation cost for 1 unit of solar dryer equipped with kerosene/diesel-oil-powered stove and heater, price of kerosene/diesel-oil per litre, electricity cost for industrial purpose (particularly for housholder/small to medium scale enterprises), market price of green and dry Rasamala, general administration cost for small/medium industries/woodshops and general drying operator salary. The data were collected through intensive literature review, consultation with solar dryer experts in Forest Products Research and Development Center (FPRDC) and direct survey. These data were then tabulated to produce investment cost, production cost, annual benefit and basic price of dry timber. Financial feasibility of the drying technique applied was analysed using parameters such as Net Present Value (NPV), IRR (Internal Rate of Return), BEP (Break Even Point) and PBP (Payback Period). The NPV parameter gives information on the current value of a property for the investor. The IRR informs about the rate of return if a property is bought at a certain price. The BEP parameter provides information about a point of production volume or sales volume where the production cost spent is equal to the revenue gained. The

Payback Period informs about the period required to return the investment cost. Microsoft Excel 2003 software was used to obtain these parameters values.

IV. RESULTS AND DISCUSSION

A. Technical Information

Table 2 showed the result obtained when drying Rasamala using the drying procedures mentioned above. As read in the table, the drying period at the first stage (using solar energy only) took about 16 days to reach average moisture content of around 40% from average initial moisture content of around 63.23%. When most boards reached a moisture content level of around 40%, the combination of energy from solar and alternative heat was applied. The second stage of drying process took about 5 days to reach the targeted final moisture content. Thus, total drying period required using the implemented technique was 21 days, or about 86-90% shorter than the period when using air drying method alone (i.e. approximately 5-7 months) (Martawijaya *et al*, 2005).

As illustrated in Table 1, for rasamala timber with moisture content of 40%, the temperature required for further drying process was 42^0C-60^0C. During the day, the heat mainly came from solar energy. Additional heat from stove was applied if the supply of heat from solar energy could not attain the desired temperature level. When the supply of heat is adequate to reach a particular temperature level, the stove will automatically stops operating. Based on the values displayed in Table 1, it can be seen that additional heat will be mostly required when the timber has reached moisture content level of around 20% or below. The hot air produced from the stove and/or solar energy was circulated inside the drying chamber using the inhaust fans. These inhaust fans were located at the top of the drying chamber and behind the pipes that distributed the heat from the stove. The drying process during the night was run using energy produced by the heater. At this phase, the hot air circulation was carried out using the inhaust fans located on the top of the the drying chamber. With the combination of heat from solar energy, stove and heater, the second drying stage only took 5 days. The diesel-oil volume and electricity capacity required were only 9.52 litres and 592.2 Kwh, respectively (Table 2).

The quality of dry boards produced with the above drying technique was good. Further observation showed that only 1-2 timbers from the total drying samples used ($\pm$ 6 m^3) had end check and/or light bowing following the drying process. However, these defects did not limit its further utilization.

Table 2. Results of drying Rasamala with combined heat released from solar energy and stove during day's use and heater during night's use

(*Tabel 2. Hasil percobaan pengeringan kayu Rasamala dalam bangunan pengeringan dengan sumber panas berasal dari kombinasi tenaga surya dan tungku untuk pemakaian siang hari dan pemanas ruangan untuk pemakaian malam hari*)

No	Parameter (*Parameter*)	Values (*Nilai*)
1	Average moisture content/*Kadar air rata-rata* (%) : a. Initial / *Awal* b. Final / *Akhir*	 63.23 16.26
2	Drying period (days)/ *Waktu pengeringan* (*hari*) : a. From green to 40% /*Dari kondisi basah ke 40%*) b. From 40% to final/ *Dari KA 40% - akhir*	 16 5
3	Average drying rate (%/day)/ *Laju pengeringan rata-rata* (%/hari) : a. From green to 40%/ *Dari kondisi basah ke 40%* b. From 40% to final / *Dari KA 40% - akhir*	 1.28 5.29
4	Total energy required for drying drom MC 40% to final / *Kebutuhan energi total untuk pengeringan dari KA 40% - akhir*: a. Diesel-oil (Littre) / *Solar* (Liter) b. Electricity (KwH)/ *Listrik* (Kwh)	 9.52 592.2
5	Temperature and humidity during drying process from 40% to final/*Kondisi suhu dan kelembaban selama proses pengeringan dari KA 40% -akhir :* a. Temperature / *Suhu* (^{0}C) b. Humidity / *Kelembaban* (%)	 40-60 40-52
6	Quality of dried boards/ *Kualitas kayu kering*	Good, only 1-2 boards had light end check and light bowing

B. Financial Analysis

1. Investment Cost

Total investment cost for establishing 1 unit of solar dryer equipped with heater and fuel-powered stove was around Rp 54 million in 2003-2005, as shown in Table 2. Assumming that there is an increase of about 50% of the current prices, thus the estimated construction cost for the same unit in 2008 would be around Rp 81 million. The cost included the establishment of 6-m^3 drying chamber, 1 unit of fuel-powered stove, 4 units of heater, 4 units of inhaust fans, 2 units of exhaust fan and other supporting elements (pipes, etc).

Table 2. Investment cost
Tabel 2. Biaya investasi

No	**Description (*Uraian*)**	**Cost (*Biaya*) Rp (x 1,000)**	
		2003-2005	2008*
1	One unit of solar dryer equipped with solar collector (*1 unit bangunan pengering lengkap dengan kolektor tenaga surya*)	15,000	22,500
2	One unit of fuel-powered stove with its peripherals (*1 unit tungku bahan bakar migas lengkap dengan perangkatnya*)	17,000	25,500
3	Four units of 6-KW heaters (*4 unit pemanas ruangan masing-masing berkapasitas 6000 watt*)	1,800	2,700
4	Two units of inhaust fans to distribute heat from collector or heater (*2 unit kipas untuk distribusi panas dari kolektor/heater*)	4,000	6,000
5	Two units of exhaust fans to drive away wet air (*2 unit kipas untuk membuang udara basah*)	2,400	3,600
6	Two units of inhaust fans to distribute heat from stove (*2 unit kipas untuk distribusi panas dari tungku*)	5,000	7,500
7	Other supporting elements (*Peralatan penunjang lainnya*)	2,000	3,000
Sub total		***47,200***	***70,800***
8	Miscellaneous cost, 15% from sub total (*Biaya tidak terduga,15% dari sub total*)	7,080	10,620
TOTAL COST (*BIAYA TOTAL*)		**54,280**	**81,420**

Remarks (*Keterangan*) : * = Current projected cost with an increase of 50% from initial value (*Biaya perkiraan sekarang dengan kenaikan 50% dari biaya awal)*

2. Production Cost, Estimated Revenue and Net Benefit

The production cost per year for drying Rasamala in the solar dryer with the drying procedures used in this experiment consisted of fixed cost and variable cost. Included as fixed cost were annual maintenance, depreciation cost, operator salary, administration cost, and land rent. The variable cost consisted of fuel (solar) cost, electricity cost, substitution cost for fans and heater, procurement cost for green timber, and other cost.

The production cost was calculated based on these assumptions:

a. The investment cost was Rp 81,420,000.
b. Market price of green rasamala wood was Rp 2,700,000/m^3 .
c. Operational period was 12 months, with recovery rate at 90% and capacity of solar dryer at 6 m^3.
d. Fuel (solar) cost was Rp 4,500/litre.
e. Electricity cost was Rp 495/KwH.
f. Land rent was Rp 1,000,000 per year.
g. Maintenance of machines/equipment used was carried out every year and the cost was 10% from the basic price.
h. Heaters and fans were replaced for every 2 years and every 6 years, respectively.
i. Service life of the solar dryer equipped with heater and stove was 15 years.

Based on these assumptions, the production cost was various each year, in a range of Rp 239,689,748– 251,789,748 (Table 3). Details of calculation were given in Appendix 1. Minimizing operating cost could be done by using the combination of energy from solar and stoves using biomass or diesel-oil as its fuel. The use of heater is not only costly but also requiring high electricity power. A drying chamber with capacity of 6-m^3 requires heater with minimum electricity power of 12 kilowatt.

By assumming that total dry rasamala produced every year was 64.8 m^3, the production price of dry Rasamala was calculated around Rp 3,741,817 per m^3. According to Basri and Supriadi (2006), the price of dry timber is usually 40%-70% higher than the green timber. Therefore, by assumming that the sales price of dry Rasamala was Rp 4,000,000 per m^3 and the recovery rate was 90%, then the estimated revenue, net and gross benefit were projected as shown in Table 3. In the first year, where the industries only establish the solar dryer and do not operate, no profit is gained. In year 6 and 12, where fans were replaced, the net benefit gained in both year was only Rp 4,598,714 per year. Maximum net benefit that could be gained was Rp 16,583,714.

Table 3. Production cost, estimated revenue and benefit avhieved for producing 64.8 m^3 of dry Rasamala (Rp/year)

Table 3. Biaya produksi, prediksi penerimaan dan keuntungan bersih untuk pengeringan 64,8 m^3 kayu Rasamala kering (Rp/Tahun)

Year	**Production cost (*Biaya produksi*)**	**Estimated revenue (*Penerimaan*)**	**Gross benefit (*Keuntungan kotor*)**	**Net benefit (*Keuntungan bersih*)**
	Rp/Year (*Rp/Tahun*)	**Rp/Year (*Rp/Tahun*)**	**Rp/Year (*Rp/Tahun*)**	**Rp/Year (*Rp/Tahun*)**
0	81,420,000	0	(81,420,000)	(81,420,000)
1	239,689,748	259,200,000	19,510,252	16,583,714
2	242,389,748	259,200,000	16,810,252	14,288,714
3	239,689,748	259,200,000	19,510,252	16,583,714
4	242,389,748	259,200,000	16,810,252	14,288,714
5	239,689,748	259,200,000	19,510,252	16,583,714
6	253,789,748	259,200,000	5,410,252	4,598,714
7	239,689,748	259,200,000	19,510,252	16,583,714
8	242,389,748	259,200,000	16,810,252	14,288,714
9	239,689,748	259,200,000	19,510,252	16,583,714
10	242,389,748	259,200,000	16,810,252	14,288,714
11	239,689,748	259,200,000	19,510,252	16,583,714
12	253,789,748	259,200,000	5,410,252	4,598,714
13	239,689,748	259,200,000	19,510,252	16,583,714
14	242,389,748	259,200,000	16,810,252	14,288,714
15	239,689,748	259,200,000	19,510,252	16,583,714

Remarks (*Keterangan*) : Figure with brackets signed no benefit gained during the year (*Angka yang diberi tanda kurung menandakan tidak ada keuntungan yang diperoleh di tahun tersebut*)

3. Financial Feasibility

The financial feasibility of operating the solar dryer for drying rasamala was assessed using NPV, IRR, BEP and PBP. By assumming the interest rate was 15% and the sales price of dry rasamala was Rp 4,000,000 per m^3, the NPV value obtained was Rp 2,991,465 and the IRR value obtained was 15.9% (Table 4). Since the NPV showed positive value and the IRR value was higher than the interest rate used for the analysis (15%), drying rasamala in a solar dryer with the drying technique used in this experiment was feasible for the industries to adopt.

However, based on sensitivity analysis result, if the interest rate applied in the market is 18% or 20%, then the project is no longer economically viable (Table 5).

Further analysis, under assumption that the interest rate is 15%, shows that the industries will reach break even point at production level of 43.95 m^3 dry rasamala at the achieved sales Rp 175,787,284 (Table 6). The investment cost will be returned (payback period) in 5.7 years (Table 7).

Table 4. The NPV and IRR values when drying rasamala with combined solar energy, stove's heat and heater's heat (by assumming that the interest rate was 15%)
Tabel 4. Nilai NPV dan IRR untuk proyek pengeringan rasamala dengan kombinasi energi surya dan panas tungku serta pemanas ruangan (dengan asumsi suku bunga yang berlaku adalah 15%)

No	**Parameters (*Parameter*)**	**Value (*Nilai*)**
1	NPV (Rp)	+2,991,465
2	IRR (%)	15.9

Table 5. The values of NPV and IRR of the project when the interest rate was raised to 18% and 20%.
Tabel 5. Nilai NPV dan IRR proyek dengan kenaikan tingkat suku bunga menjadi 18% dan 20%.

No	**Parameters (*Parameter*)**	**Values change due to increase in interest rate (*Perubahan nilai akibat kenaikan suku bunga*)**	
		18%	20%
1	NPV (Rp)	(6,079,763)	(10,854,098)
2	IRR (%)	-	-

Tabel 6. Prediction of break even production
Tabel 6. Prediksi titik impas produksi

No	Parameters (*Parameter*)	Value (*Nilai*)
1	BEP (m^3, unit)	43.95
2	BEP (Rp, sales)	175,787,284

Table 7. Payback period (PBP) of investment cost
Tabel 7. Perhitungan masa pengembalian biaya investasi

Year	Annual cash flow (*Aliran kas tahunan*)	Cumulative cash balance (*Neraca kumulatif*)
	Rp/Year (*Rp/Tahun*)	Rp/Year (*Rp/Tahun*)
0	(81,420,000)	(81,420,000)
1	16,583,714	(64,836,286)
2	14,288,714	(50,542,572)
3	16,583,714	(33,963,857)
4	14,288,714	(19,675,143)
5	16,583,714	(3,091,429)
5.7*	(3,091,429)	0
6	4,598,714	1,507,285
7	16,583,714	18,090,999
8	14,288,714	32,379,714
9	16,583,714	48,963,428
10	14,288,714	63,252,142
11	16,583,714	79,835,856
12	4,598,714	84,434,570
13	16,583,714	101,018,285
14	14,288,714	115,306,999
15	16,583,714	131,890,713

Remarks (*Keterangan*) : * payback period of investment cost

V. CONCLUSION AND RECOMMENDATION

Several points could be concluded from this experiment, as follows:

a. The drying period of Rasamala wood using only solar energy took about 16 days to decrease the moisture content from average level of 63.23% to around 40%, while the drying period using combination of solar energy and heat from stove or heater took about 5 days to decrease the moisture content from 40%

to about 15%. Total drying time required was therefore 21 days or about 86-90% shorter than when using air drying method alone.

b. The quality of dried Rasamala wood were good, i.e only 1-2 timbers from total samples used had light drying defects (e.g. end check and light bowing).

c. During the second stage of drying process (using combination of solar energy and alternative heat from stove or heater), the volume of diesel-oil and electricity capacity used were 9.52 litres and 592.2 Kwh respectively.

d. By assumming the interest rate is 15% and the sales price of dry rasamala was Rp 4,000,000 per m^3, the financial feasibility study shows that drying rasamala with the technique used in this experiment is feasible for the industries to adopt (the NPV value was positive and IRR value was higher than the interest rate).

e. At interest rate 15%, the payback period of investment will be achieved in 5.7 years and the break even point will be reached at production level of around 43.95 m^3 of dry rasamala.

f. When the interest rate is 18% or 20%, the project is no longer feasible for the industries to adopt.

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