

# THE TECHNICAL AND ECONOMICAL PERFORMANCE OF THE "ABC" TYPE PADDY DRYER

Sutrisno, M. Wahyudin, and E. Eko Ananto

Research Institute for Rice, Jalan Raya No. 9, Sukamandi, PO Box 11 Cikampek, Subang 41256, Indonesia

## ABSTRACT

Farmers in the villages always face the same problem of how to reduce the moisture content of paddy harvest during harvest and postharvest time, especially in wet season. At the farm level, the grain quality is poor and alternative drying using kerosene fuel is very costly. The objective of this research was to design and evaluate the technical and economical performance of drying paddy using an equipment known as "ABC" dryer. The dryer uses paddy husk as fuel. The research was conducted at Research Institute for Rice over three years (1993/94-1995/96). The result showed that the "ABC" type dryer could reduce the moisture content of 5 tons wet paddy from 22.25% to 15.03% in 9 hours or an average drying rate of 1.05% moisture content per hour, with drying cost of Rp 18 kg<sup>-1</sup>. Reducing the moisture content further to 11.83% needed 16 hours or average drying rate 0.82% hour<sup>-1</sup>, with drying cost almost doubled (Rp 32 kg<sup>-1</sup>). These costs are far below that of kerosene drying, i.e., Rp 30 kg<sup>-1</sup> and Rp 60 kg<sup>-1</sup> to reach moisture content of 15.03% and 11.83%, respectively. Budget analysis showed that the B/C ratio were 1.57 and 1.84 and the IRR are above 41.26% and 47.42% to reach moisture contents of 15.03% and 11.83%, respectively. The break even points of "ABC" dryer were 130 and 60 tons, respectively. The milling test showed that the milling rice from the "ABC" dryer had better recovery (milling rendement) and rice quality (head rice) was higher than that of from sun-drying.

[*Keywords:* dryers; rice; biofuels; technical properties; economic analysis]

## INTRODUCTION

The drying of agricultural commodities such as paddy especially in the wet season is still a big concern in Indonesia. At harvest time during the wet season, sun-drying is impractical and this results in poor quality of paddy rice. On the other hand, the dry grains from a controlled drying can be stored longer beyond harvest time during which the price is very low. Therefore, farmers are able to get better selling prices (Abdullah, 1990).

The general problem encountered in manufacturing paddy dryer was how to design an efficient dryer that could be operated easily and safely by ordinary farmers. Research has resulted various engineering designs, but these are prototypes that only pay attention to technical factors while ignoring the economical factor. The scaling up of research prototype to commercial farms is rarely occurred, because the cost of drying paddy with operated machines was still higher than that of sun-drying. Another reason is due to its low capacity (Sutrisno *et al.*, 1994).

The paper aimed to report engineering design activities to reduce the drying cost that have been done at Research Institute for Rice from 1993/94 until 1995/96 utilizing paddy husk as energy source. As paddy husk is in abundant supply, the substitution of oil fuel by husk was expected to reduce the drying cost. The specific objective of this research was to design a husk fuel dryer with the capacity of 5 tons fresh paddy.

## MATERIALS AND METHODS

This research was conducted in Mechanization Laboratory of Research Institute for Rice, Sukamandi, West Java, over three years, from 1993/94 to 1995/96. The first year was to design the structure of dryer and test its function; the second year was to verify the dryer system mechanism; and the third year was to test the technical performance of the equipment to evaluate its economic performance. Technical performance of the dryer was tested using glutinous paddy of Derty variety as raw materials by measuring parameters such as machine capacity, drying time, paddy moisture content, ambient temperature, fuel and husk consumption, repair and maintenance cost. By analyzing the data, estimates of the parameters

will be obtained, and these estimates will be used in economic analysis. Profitability and feasibility of the machines were evaluated based on the cost of drying machine and its potential revenues through budget analysis, deploying criteria such as NPV, B/C ratio, break even point, and IRR (De Garmo and Canada, 1973).

### Structural Design

The structural design was a combination of some features adopted from APPESSI and BIMASAKTI dryers, and Cilamaya furnace. All these machines used paddy husk as power source. Some descriptions of the tools are as follows:

1. APPESSI. This husk fuel dryer was made in Research Institute for Rice in 1990. The feature adopted from the APPESSI dryer is indirect air heating (Sutrisno, 1991). The husk burning in the furnace heats the iron plate of the wall furnace. Fresh air is forced by blower over the hot furnace wall. This hot drying air is forced to the plenum by the blower, and after its pressure is high enough, it penetrates the bulk of the fresh paddy in the drying chamber. The temperature of drying air in the plenum chamber is controlled by a thermometer installed at the plenum wall, normally it is maintained at 45°C (Thahir *et al.*, 1988).
2. BIMASAKTI. This fuel dryer was found at Pusakanegara farm trial, West Java. The BIMASAKTI feature adopted was the dryer structure that separated the furnace and the drying chamber (Sutrisno *et al.*, 1994). With that structure, the

dryer can be operated safely without fear of fire, especially if the blower is suddenly blocked.

3. CILAMAYA. This husk fuel furnace was found at a soybean cake factory owned by a farmer in Cilamaya, West Java. The furnace is installed with iron plate fins as in a *nako* structure. The *nako* is appropriate for aeration to keep the husk burning in the furnace effectively and continuously (Sutrisno *et al.*, 1994).

As the dryer was built by combining features from the three design APPESSI, BIMASAKTI, and Cilamaya units, it is then names the "ABC" type dryer.

### Functional Design

#### Furnace

The role of the furnace in the husk fuel dryer is very important. The drying process would only be effective if the furnace works well. On the other hand if the furnace is often blocked, the drying process would not be efficient (Sutrisno, 1986). Another method to get drying air of the proper temperature continuously is by using several furnaces. The "ABC" type dryer has five furnaces to stabilize drying air temperature. The five furnaces are installed parallel horizontally in the furnace chamber. Each furnace is made of iron pipe of 50 cm diameter, 125 cm long, and 3 mm wide. One of its end is closed by an iron plate, while the other end is left open. At the closed end, a chimney made of iron pipe of 15 cm diameter, 4 m long, and 2 mm wide is installed (Fig. 1). With this chimney, smoke can flow out quickly and fresh air can flow into furnace quickly too. The rapid

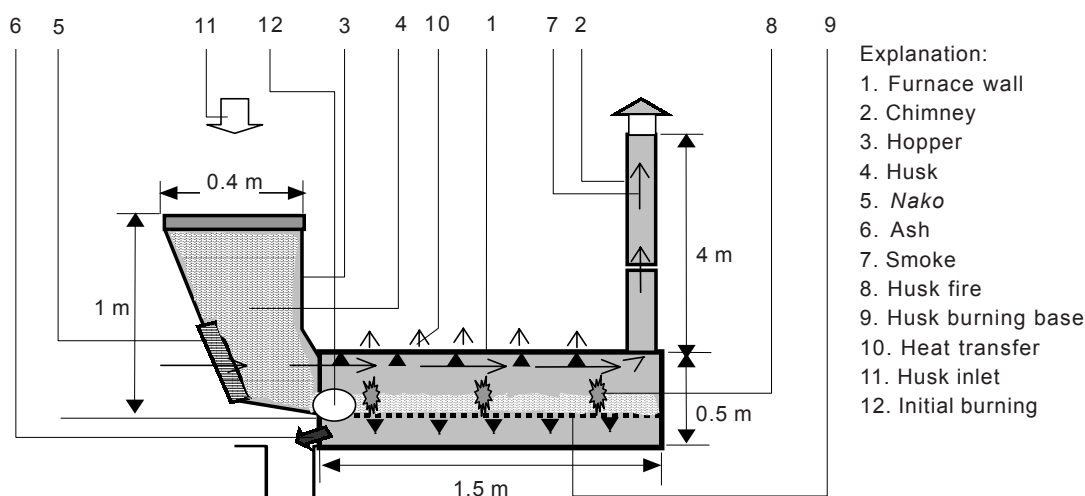


Fig. 1. Husk furnace of the "ABC" type paddy dryer.

flow of fresh air causes the husk burning effectively in the furnace.

At the open end of the pipe, a box hopper is installed to supply the husk to be burned. The hopper contains a *nako* made of plate iron for aeration. Inside the pipe there is a husk burning base positioned at two-thirds of the diameter of the pipe top part. This husk burning base is made of 3 cm x 3 cm angle iron with 40 cm long, laid parallelly facing downward position. The distance between angle irons is 1 cm, so that husk burning ash can fall down under the husk burning base easily.

### Blower

Blower is an axial press blower type, 100 cm diameter. This blower is powered by a diesel engine 24 HP, by V-belt transmission. This blower could control the flow of drying air and add dryer capacity.

### Drying box

The drying box for 5 t fresh paddy capacity is 5 m long, 4 m wide, and 0.5 m high for a total height of 0.6 m. One side of the drying box consists of three doors with each having 0.6 m long and 0.5 m wide. The doors are used to unload dried paddy for packing into

sacks. The loading of fresh paddy into drying box is done from concrete stairs behind the drying box. Below the drying box, there is the plenum with size similar with the drying box. The plenum's function is to store the drying air, and after its pressure and temperature are appropriate, it distributes the drying air into the fresh paddy in the drying chamber. The hot air distribution must be dispersed to all directions to make all fresh grain in the box can be exposed to the air dry at the same time. The air temperature in the plenum can be controlled with a pin thermometer with maximum 100°C. The "ABC" type dryer is shown in Fig. 2.

The blower is powered by 24 HP diesel engine with water cooling. The blower pushes fresh air into a storage chamber. The air flows in the furnace house through five wall furnaces and then out into the plenum. The temperature can be set according to commodity and purpose of the drying. For paddy that goes to consumption (milling), the optimal drying air temperature is 45°C (Sutrisno, 1991). The air pressure should be able to penetrate the bulk of paddy about 50 cm wide. The penetrating capability can be observed by a piece of paper laid on the paddy surface. If that paper moves, then the drying air pressure is optimal, but if that paper does not move, the blower RPM would be increased until the paper moves. If this is impossible, the bulk of paddy has to be reduced to

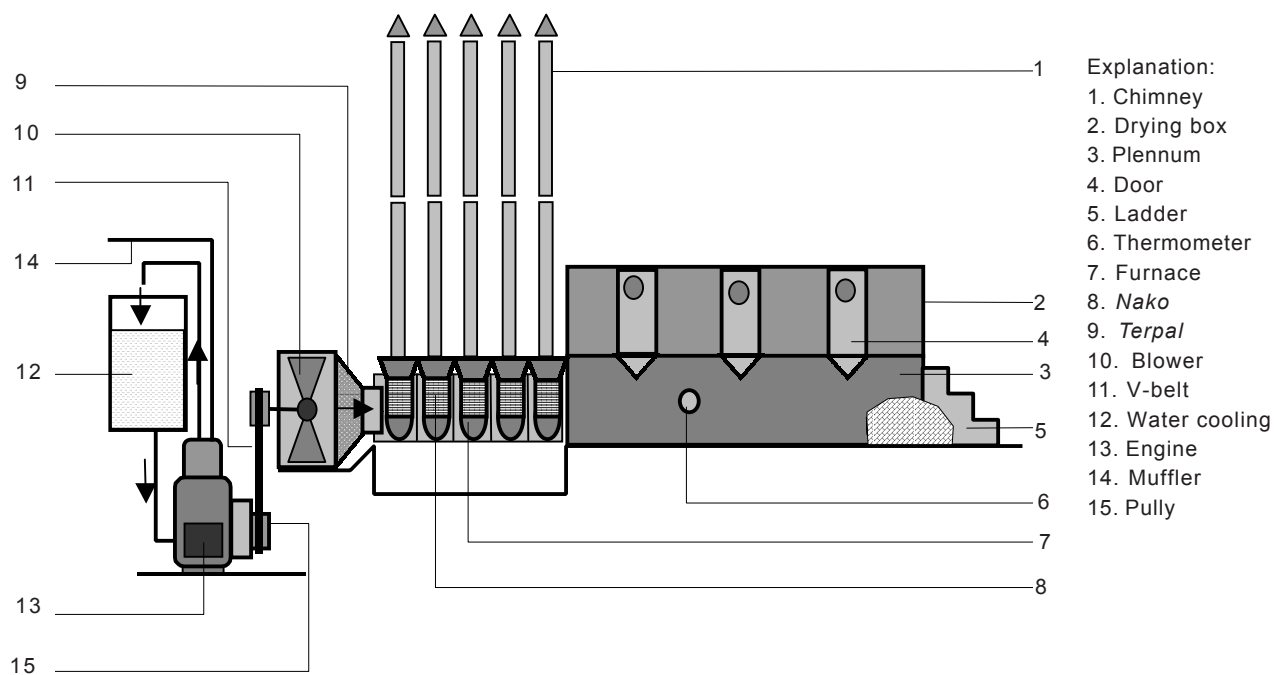


Fig. 2. The "ABC" type paddy dryer

the level that leads to the movement of the paper (Sutrisno *et al.*, 2000).

Paddy husk is put into the hopper hole and laid on the furnace base to cover about one-third of furnace room (Fig. 1). The *nako* is opened, and burning is started using kerosene to ignite the burning process. After the husk is burning on the furnace base, the *nako* is closed. The hopper box now is filled with husk. The husk burning causes a chimney effect.

The smoke flows quickly in the chimney, and then there is compensatory flow of fresh air, because the blower is not on yet. The temperature on the furnace wall reaches about 100-300°C when the blower is not working well (Sutrisno *et al.*, 1994).

## RESULTS AND DISCUSSION

### Functional Test of "ABC" Type Dryer

#### Furnace efficiency

Furnace efficiency ( $E_t$ ) means a comparison between the energy resulted from the furnace or energy prepared for drying ( $E_{sp}$ ) and energy resulted from husk burning ( $E_s$ ) in percent.

$$E_{sp} = V \times C_p \times \Delta T \times \theta \times \rho \quad (\text{Sutrisno, 1986}) \quad (1)$$

where:  $V$  = volumetric velocity of drying air ( $\text{m}^3 \text{ hour}^{-1}$ )

$C_p$  = heat factor of air ( $\text{J kg}^{-1} \text{ }^\circ\text{C}^{-1}$ )

$\Delta T$  = temperature difference ( $^\circ\text{C}$ )

$\theta$  = time (hour)

$\rho$  = air mass factor ( $\text{kg m}^{-3}$ )

Table 1 shows the drying conditions and paddy moisture contents during functional tests of the

"ABC" type dryer. Drying air flow volumetric velocity ( $v$ ) was calculated by formula:

$$V = A \times v \quad (2)$$

$A$  = drying box cross width

$$= 5 \text{ m} \times 4 \text{ m} = 20 \text{ m}^2$$

$$V = 20 \text{ m}^2 \times 7 \text{ m minute}^{-1} = 140 \text{ m}^3 \text{ minute}^{-1} \text{ or } 8,400 \text{ m}^3 \text{ hour}^{-1}.$$

$$E_{sp} = 8,400 \times 1,007 \times (43-28.6) \times 8 \times 1.1243$$

$$E_{sp} = 1,095,578,362 \text{ J} \quad (3)$$

Energy resulted from husk burning in the furnace during the drying process could be calculated with formula (4).

$$E_s = S \times E_{sk} \times \theta \quad (4)$$

where:  $E_s$  = energy resulting from husk burning during the drying process (J)

$S$  = husk weight per hour

$E_{sk}$  = energy capacity in 1 kg husk ( $\text{kcal kg}^{-1}$ )

= 3,500  $\text{kcal kg}^{-1}$  husk (Beagle, 1976)

$\theta$  = drying time (hour)

$$E_s = 37.5 \times 3,500 \times 8 \times 4,186$$

$$= 4,396,140,000 \text{ J} \quad (5)$$

Where 4,186 was conversion constant from  $\text{kcal}$  to  $\text{J}$  ( $\text{J kcal}^{-1}$ ).

So furnace efficiency,  $E_t = (E_{sp}/E_s) \times 100\%$

$$E_t = 25 \% \quad (6)$$

From these calculations, furnace efficiency of the "ABC" type dryer was estimated to be 25%. For a dryer using indirectly heated air, this value is high enough. Furnace efficiency for a dryer using an indirect air heated system was only 5.08% (Soenarjo, 1982 in Sutrisno 1986), while furnace efficiency using direct air heating systems can reach 30% (Sumangat,

**Table 1. Drying conditions and paddy moisture contents at functional testing of "ABC" type paddy dryer.**

Time (h)	Ambient air temperature ( $^\circ\text{C}$ )		Drying air temperature ( $^\circ\text{C}$ )	Moisture content (%)	Velocity of drying air flow volumetric ( $\text{m min}^{-1}$ )
	Tdb <sup>1)</sup>	Twb <sup>2)</sup>			
0	32	30	32	22.90	7
1	32	30	44	22.50	7
2	30	26.5	46	19.52	7
3	30	26	48	17.92	7
4	29	26	50	16.06	7
5	29	26	43	14.46	7
6	27	25	30	15.72	7
7	24.5	24	46	14.80	7
8	24.5	24	48	13.05	7
Average	28.6	26.4	43	17.44	7

<sup>1)</sup>Dry bulb temperature, <sup>2)</sup>Wet bulb temperature

1978 in Sutrisno 1986). The high furnace efficiency value ( $E_t$ ) for the "ABC" type dryer furnace indicates that the furnace has been well designed, which should help keep the drying cost low.

### Efficiency of energy used for drying

Efficiency of energy used for drying ( $E_{pp}$ ) was defined as a comparison between energy used for drying ( $E_p$ ) and energy prepared for drying ( $E_{sp}$ ). This could be formulated as follows:

$$E_{pp} = (E_p/E_{sp}) \times 100\% \quad (7)$$

$$E_p = B_{au} \times h_{fg} \quad (8)$$

where:  $B_{au}$  is the water weight that evaporated during the drying process (kg)

$h_{fg}$  is latent heat of water evaporated ( $J\ kg^{-1}$ )

### Calculation of evaporated water ( $B_{au}$ )

If the wet paddy weight is 3,000 kg and initial moisture content 22.90%, water weight in wet paddy is 22.90% x 3,000 kg = 687 kg. (9)

$$\begin{aligned} \text{The mass of paddy} &= 3,000\ \text{kg} - 687\ \text{kg} \\ &= 2,313\ \text{kg} \end{aligned} \quad (10)$$

Final moisture content is 13.05% (Table 1). Because moisture content is wet basis form, this could be calculated as follows:

$$0.1305 = X/(X + 2,313) \quad (11)$$

$$X = 347.15\ \text{kg}$$

where  $X$  is water weight in dried paddy.

In reality, the initial water weight is 687 kg, so the weight of water evaporated during the drying process is 687 kg - 347.15 kg = 339.85 kg. Energy used for the drying process ( $E_p$ ) = 339.85 kg x 2,690,000  $J\ kg^{-1}$  = 914,196,500 J.

$$E_{sp} = 1,095,578,362\ \text{J} \quad (3)$$

$$E_{pp} = (914,196,500/1,095,578,362) \times 100\% = 83.44\%.$$

The efficiency of energy used for drying is 83.44%, which indicates that 16.56% of the energy prepared by the furnace was not used for drying, but was lost or carried by the air flow that went out from the paddy bulk in the drying box. It is identified as  $T_e$  (T exhaust).

### Modification of "ABC" Type Dryer

The functional test indicated that the main weakness of the "ABC" type dryer was the penetrating power of the drying air, which was a maximum of 30 cm thickness of paddy bulk or a maximum capacity of drying 3 t wet paddy only. This means that the target of maximum capacity 5 t wet paddy was not achieved,

because the drying air flow was not capable of penetrating paddy bulk in the drying box of 50 cm thick. Therefore, to reach desired target, the first blower (90 cm diameter) powered by electricity was replaced by a second blower (100 cm diameter) that was powered by a 24 HP diesel engine. This also anticipates the possibility that this dryer may be used in rural regions that do not yet have electricity. The larger blower resulted in increased air mass flow. Because the blower change caused decreased drying temperature, the heat source was increased from 3 to 5 furnaces.

### Drying Test of Paddy with "ABC" Type Dryer Postmodification

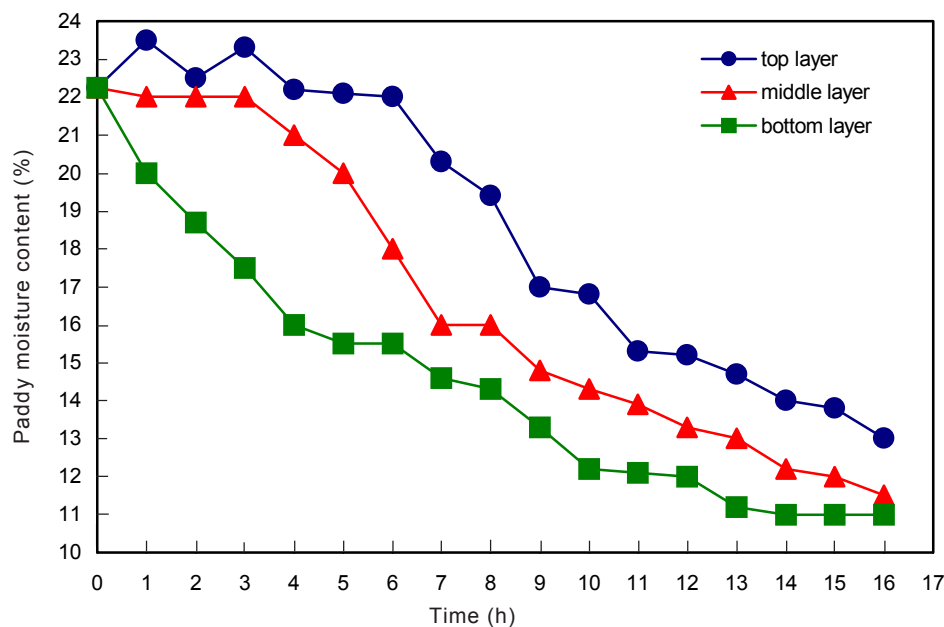
The drying test for paddy was executed in the Mechanization Laboratory of Research Institute for Rice in October 1996. The glutinous paddy of Derti variety (5 t with initial moisture content of 22.5%) was laid in the drying box; the depth of paddy in this box was 47 cm. The experiment was compared with sun-drying, and the results are shown in Table 2. Paddy moisture content at the end of the drying process was 11.83%. This value was calculated from bottom paddy layer 11%, middle layer 11.50%, and top layer 13%. This indicates that the drying machine was working well, since the difference of paddy moisture content between bottom layer and top layer at the end of the drying was not more than 2%. Furthermore, the drying process occurred at an average drying rate of 0.88%  $\text{hour}^{-1}$ , which is still in very safe limits (maximum drying rate for consumption 2%  $\text{hour}^{-1}$  and for seed 1%  $\text{hour}^{-1}$ ). Therefore, the resulting dried paddy should be saved for storage and give good quality of milled rice.

Milling test was then done on dried paddy produced by machine drying and sun-drying. The milling test and rice quality analysis from machine and sun-drying showed that milling rice recovery from paddy dried with machine drying and sun-drying was 68.43% and 59.54%, while head rice content was 85.43% and 73.19%, respectively. Figure 3 shows the decreasing moisture content pattern of Derti variety dried by "ABC" type dryer. This figure shows that during drying by an artificial flat bed such as "ABC" type dryer, paddy moisture content was in the order as follows: bottom layer < middle layer < top layer. This is caused by hot air as drying medium flowing from bottom to the top layer. It is significant that the difference in paddy moisture content between bottom and top layer was not too large (2% ideal). Furthermore, the drying air flow had to be capable of

**Table 2. The result of drying sticky paddy of Derti variety using modified "ABC" type dryer.**

Time (h)	Ambient air temperature		Drying air temperature (°C)	Exhaust air temperature (°C)	Paddy moisture content (%)			
	(°C)				Bottom layer	Middle layer	Top layer	Average
	Tdb <sup>1)</sup>	Twb <sup>1)</sup>						
0	33.0	28.0	33	33	22.25	22.25	22.25	22.25
1	34.0	28.0	42	32	20.00	22.00	23.50	21.50
2	32.5	26.5	40	32	18.70	22.00	22.50	21.07
3	33.5	27.0	40	32	17.50	22.00	23.30	20.60
4	33.0	27.0	41	31	16.00	21.00	22.20	19.73
5	33.0	27.0	41	31	15.50	20.00	22.10	19.20
6	32.0	26.5	40	30	15.50	18.00	22.00	18.33
7	31.5	26.0	40	29	14.60	16.00	20.30	16.97
8	30.5	26.5	45	31	14.30	16.00	19.40	16.57
9	32.5	28.0	39	32	13.30	14.80	17.00	15.03
10	32.5	26.0	37	33	12.20	14.30	16.80	14.50
11	33.0	27.0	44	35	12.10	13.90	15.30	13.77
12	32.0	26.0	45	34	12.00	13.30	15.20	13.50
13	27.0	24.0	40	38	11.20	13.00	14.70	12.97
14	32.0	26.0	43	38	11.00	12.20	14.00	12.40
15	32.5	26.0	45	40	11.00	12.00	13.80	12.26
16	33.0	26.5	45	40	11.00	11.50	13.00	11.83
Average	32.1	26.5	41.9					

<sup>1)</sup>Dry bulb temperature, <sup>2)</sup>Wet bulb temperature

**Fig. 3.** Decreasing moisture content pattern of paddy during drying by "ABC" type dryer.

penetrating the paddy bulk in the drying chamber, so the work of the drying air is as energy transfer in the wet paddy or as water transport from the bulk of paddy out from the dryer system.

### Profit and Cost Analysis

A problem faced in using machine to dry paddy as an alternative to sun-drying is that it is too costly and



financially viable, especially when the power source is kerosene fuel. However, by taking a different design that utilizes paddy husk as power source there seems to be some potential use of drying machines. This is shown in the budget analysis by taking some technical data and making some assumptions (Table 3). The calculation results are presented in Table 4. As it is shown in Table 4, the cost price of paddy dried with the "ABC" type dryer to achieve moisture

content of 15.03% and 11.83% was Rp18 kg<sup>-1</sup> and Rp 32 kg<sup>-1</sup> from fresh paddy, respectively. The comparable cost using kerosene fuel dryer was Rp 30 kg<sup>-1</sup> and Rp 60 kg<sup>-1</sup>, respectively. The results indicate that using the "ABC" type dryer to reduce moisture content to 15.03% or 11.83% is more profitable. This conclusion could also be shown from the B/C ratio numbers that are greater than 1, i.e., 1.57 and 1.84, and IRR values 41.26% and 47.42%, respectively that are greater than annual bank interest (18%). Another advantage of the "ABC" dryer is that its annual capacity is 130 t and 60 t for each moisture content.

**Table 3. Technical data and assumptions used in cost and profit calculation for "ABC" type paddy dryer.<sup>1)</sup>**

Explanation	Paddy moisture content	Paddy moisture content
	15.03%	11.83%
Machine investment (Rp)	15,000,000.00	15,000,000.00
Interest rate (%)	18.00	18.00
Economical life (yr)	10.00	10.00
Effective working days per year	30.00	30.00
Working hours per day	18.00	18.00
Drying working hours per shift	9.00	9.00
Capacity per shift (kg)	5,000.00	5,000.00
Operator cost (Rp h <sup>-1</sup> )	1,111.00	1,111.00
Solar fuel price (Rp l <sup>-1</sup> )	400.00	400.00
Husk fuel price (Rp kg <sup>-1</sup> )	10.00	10.00
Oil price (Rp l <sup>-1</sup> )	4,000.00	4,000.00
Solar consumption (l h <sup>-1</sup> )	1.88	1.88
Husk consumption (kg h <sup>-1</sup> )	30.00	30.00
Oil (l h <sup>-1</sup> )	0.02	0.02
Reparation cost (Rp yr <sup>-1</sup> )	1,458,000.00	1,458,000.00
Drying cost (Rp kg <sup>-1</sup> )	30.00	60.00
Capacity (t yr <sup>-1</sup> )	300.00	168.75

<sup>1)</sup>Based on 1996's price

**Table 4. Cost and profit of the "ABC" type paddy dryer at moisture content of 15.03% and 11.83%.<sup>1)</sup>**

Explanation	Paddy moisture content	Paddy moisture content
	15.03%	11.83%
Fixed cost (Rp h <sup>-1</sup> )	5,068	5,068
Variable cost (Rp h <sup>-1</sup> )	4,921	4,921
Cost price per hour (Rp)	9,990	9,990
Cost prices per shift (Rp)	89,906	159,832
Cost price per kg (Rp)	18	32
Total income (Rp yr <sup>-1</sup> )	9,000,000	10,125,000
Nonpermanent cost (Rp yr <sup>-1</sup> )	2,657,400	2,657,400
Total cost (Rp)	5,394,330	5,394,330
Profit (Rp yr <sup>-1</sup> )	3,605,670	4,730,670
NPV (Rp)	8,527,073	12,669,162
B/C ratio	1.57	1.84
Break even point (t)	130	60
IRR (%)	41.26	47.72

<sup>1)</sup>Based on 1996's price

## CONCLUSION

The "ABC" type paddy dryer with the capacity of 5 t fresh paddy could dry glutinous paddy of Derti variety from 22.25% to 15.03% moisture content over 9 hours and to 11.83% moisture content over 16 hours. It means that the drying proceeds with an average drying rate of 1.05% hour<sup>-1</sup> and 0.82% hour<sup>-1</sup> to reach moisture contents of 15.03% and 11.83%, respectively. To reduce the paddy moisture content from 22.25% to 15.03% with average drying temperature of 40.88°C and average ambient air temperature 32.5°C, it requires 270 kg paddy husk, while to reduce the moisture content until 11.83%, in average ambient air temperature 32.1°C, it needs 477 kg paddy husk.

The "ABC" type paddy dryer increases the rice recovery and milling rice quality compared to sun-drying. Rice recovery increased from 59.54% (sun-drying) to 68.43%, while milling rice quality (whole grain percentage) increased from 73.19% (sun-drying) to 85.43%.

The cost of drying the glutinous paddy of Derti variety by the "ABC" type dryer is lower than that of the kerosene fuel dryer. Reducing the moisture content from 22.25% to 15.03% and from 22.25% to 11.83% cost Rp 18 kg<sup>-1</sup> and Rp 32 kg<sup>-1</sup>, respectively. These costs are far lower than those of the kerosene fuel dryer at Rp 30 kg<sup>-1</sup> and Rp 60 kg<sup>-1</sup>. The "ABC" type dryer is profitable for drying paddy, as shown by the B/C ratio value greater than 1 (1.57 for moisture content 15.03% and 1.84 for moisture content 11.83%); and the IRR values higher than the bank interest level (18%), i.e., 41.26% for moisture content 15.03% and 47.42% for moisture content 11.83%.

## REFERENCES

- Abdullah, K. 1990. Konsep dan gagasan pengembangan berbagai teknologi pengeringan maju dan peluang komoditas hasil pertanian kering dalam pasar domestik dan luar negeri. Seminar Nasional Teknologi Pengeringan Komoditi Pertanian, Jakarta, 21-23 November 1990.
- Beagle, E.C. 1976. Rice husk conversion to energy. Roma, Italy.
- De Garmo, E.P. and J.R. Canada. 1973. Engineering economy. 8<sup>th</sup> edition. Collice-McMillan Publishers, London.
- Sutrisno. 1986. Simulasi pengeringan gabah dengan menggunakan energi surya dan sekam. Thesis Program Pascasarjana, Institut Pertanian Bogor, Bogor.
- Sutrisno. 1991. Pengembangan multipurpose dryer (APESSI) untuk pengeringan biji-bijian. Lokakarya Penanganan dan Pengeringan Biji-bijian. Direktorat Bina Usahatani dan Pengolahan Hasil, Jakarta.
- Sutrisno, M. Wahyudin, dan E. Eko Ananto. 1994. Perancangan dan pengujian pengering padi kapasitas menengah bahan bakar sekam. Seminar Nasional Strategi Penelitian dan Pengembangan Bidang Teknik Pertanian di Indonesia dalam PJP-II, Maros, 3-4 Oktober 1994.
- Sutrisno, B. Rahardjo, and E. Eko Ananto. 2000. Perbaikan penanganan pascapanen hasil pertanian melalui teknologi tepat guna. Pelatihan Manajemen dan Usahatani bagi Manajer dan Apresiasi Manajemen Usahatani bagi Penyuluh Pertanian, Palembang, 22 Oktober 2000.
- Thahir, R., Sutrisno, dan K. Abdullah. 1988. Dasar-dasar dan teknik pengeringan biji-bijian. Latihan Teknik Penelitian Pascapanen Pertanian, Balai Penelitian Tanaman Padi, Sukamandi, 7 November-3 Desember 1988.