Evaluation of Box Type Paddy Dryers in South Sumatra, Indonesia

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ABSTRACT

Indonesia is the third biggest paddy producing country worldwide with its annual production of around 54 million ton. South Sumatra Province has an annual paddy production of around 2.32 million ton. Paddy has high moisture content, up to 24%, when it is harvested. Moist paddy needs immediate drying after it is harvested to reduce its moisture content to 14% or less for milling or for safe storage, respectively. Sun drying of paddy has been practiced for years despite many problems associated with it. Different studies show that the post harvest loss of the paddy lies in between 10% and 37%, in which drying related losses might be from 1% up to 10%. Like in any other parts of the country, South Sumatra Province also has no commercial paddy drying systems in practice. In 2004, as a first prototype of such type, a box type paddy dryer with a rice husk burning oven was introduced in Upang village. Now there are already more than 30 box dryers installed in three neighbouring villages – Muliasari, Upang and Upangceria - where this study was carried out. The drying capacity of each dryer varies between 3.5 ton and 10 ton of harvested paddy. Although the widespread of dryers is rapid in these villages, none of the field experiments were carried out so far to evaluate their technical, economical and social performances. This study aimed to conduct the experiments on the selected dryers and to assess their technical performances at first. Three dryers were chosen for the experiments and altogether eight experiments were carried out. Parallel sun drying experiments were carried out for quality test of rice yielded from milling the paddy dried in box dryer and dried in sun drying. Based on the observed data, economic analysis of paddy drying considering two important stakeholders – investors and farmers is presented in this paper.

Key words: Post harvest loss, paddy drying, milling yield, rice quality, economics of drying, Indonesia

1. INTRODUCTION

Indonesia, like many other countries in the region, has an agricultural economy and the agricultural sector plays an important role in the economy and social development of the country. Since rice is the dominant food crop of the people, every government has identified the importance of this sector and taken several steps to improve the paddy/rice industry. Annual paddy production in the country is about 54 million ton, (PGKG, 2004). Average annual per capita rice consumption is 147.2 kg, (CBS, 2003). The country still imports about 15% of total rice consumption from other countries, mainly from South East Asian countries, (Sawit and Lokollo, 2007).

In Indonesia per hectare yields have been more than doubled from the mid-1960s to the mid-1980s. Despite continued urbanization, paddy harvested area increased steadily during the past decade, from about 10.5 million hectares in 1990 to nearly 12 million hectares in 1999 (IRRI, 2008). In spite of the rapid growth of paddy production, considerable losses are reported to occur throughout the production process, and post harvest losses account for a major share of the total loss, (FAO, 1994). These losses occur at harvesting, threshing, drying, storing, marketing and distribution. Post harvest losses of paddy associated with the different processes show that percentage loss for individual operations could vary from 1–10% and the total loss is amounted to 10–37%, (Sartaj and Ekanayake, 1991).

In many traditional harvesting systems farmers leave their harvested paddy in the field for extended time because they want to pre-dry the paddy. In this practice, often referred to as field drying, the rice plants are often stacked in piles with the panicles inside to protect them from rain, birds and rodents, a practice that can lead to massive heat build up inside the stacks. As a result molds grow quickly and infest the grains and discoloration usually develops within the first day of field drying, (FAO, 1998). Another unwanted effect is that the relatively dry grains often absorb water from the wet straw, which leads to fissuring of the dry grains and thus reduces the potential head rice recovery, (Calverley, 1994). It is very difficult to produce good quality grains with field drying practices and field drying should therefore be avoided.

At harvest time paddy grain contains high moisture, up to 24%, (IRRI, 2004). At higher grain moisture contents, there is natural respiration in the grain that causes deterioration of the rice. High moisture promotes the development of insects and molds that are harmful to the grain. It also lowers the germination rate of rice. Therefore, drying of rice is critical to prevent insect infestation and quality deterioration of rice grain and seed. As even short term storage of high moisture paddy can cause quality deterioration, it is important to dry rice grain as soon as possible after harvesting - ideally within twelve hours, (IRRI, 2004). The recommended moisture content (MC) for safe storage of paddy grain and seed, and potential problems when the moisture content exceeds these limits is shown in table 1.

Table 1. Safe moisture content of paddy for different storage periods, (IRRI, 2004)

MC, %	**Purpose**
<9	Storage for more than one year
9-13	8-12 months storage
14	Optimum milling yields
14-18	2-3 weeks of storage
>18	Rapid deterioration

A temperature of 43° C is recommended for drying the paddy for seeds and this can be achieved with shade drying, (IRRI, 2007a). Higher temperatures can lead to physicochemical disorders in the grain. Wherever possible, it is worthy to harvest most grain crops during a dry season and simple drying methods such as sun drying are adequate. However, majority of the paddy harvest does not coincide with a suitably dry period, rather it falls in rainy season in the country like Indonesia where the irrigated paddy field is limited. Natural methods of drying make exposure of the wet grain to the sun and wind. Artificial dryers employ the application of heat from combustion of fossil fuels and biomass resources, directly or indirectly, and in both natural and forced convection airflow systems, (Muehlbauer and Cheigh, 1983). Mechanical dryers, long used in developed countries, are finding increased application as farming and grain handling systems develop further day by day. There is an essential need to dry grain quickly and effectively after harvest and before storage to retain maximum quality, to attain moisture content sufficiently low to minimise infestation by insects and micro-organisms and to prevent germination, (Exell, 1980).

In order to maintain the quality of harvested paddy, mechanical dryers are needed, especially in the rainy season when sun drying is often not possible, (Hien, 2005). However, some conventional mechanical dryers with kerosene burners as heat source, those were in use in the region in past, need around 10–15 litres of kerosene for each ton of paddy, (Gummert, 2007). These greenhouse gas emissive dryers are in questions from the environmental aspects. Further, prices for kerosene are steadily increasing. Luckily, cheaper alternatives can be used, such as rice husk. Rice husk, a by product of the rice milling process, is available in abundance, is low in cost, and can be used in specially designed furnaces. Using rice husk is also more environment friendly than kerosene because, when burned, it emits only carbon that was accumulated by the rice plant from the environment into the atmosphere and thus does not increase the atmospheric carbon dioxide balance, (Gummert, 2007).

Although the box type dryers based on rice husk as fuel are being installed since 2004 in the villages of South Sumatra, performances of these devices are yet unknown. Economical analysis of these dryers is a question of very far. Replication of the units is being seen the one and the only key indicator for the authorities to prove the success of this technology. This paper has aimed to discuss the field level performances of installed dryers. The main objective of this paper is to present the results on evaluation of the technical and the economical performances of rice husk fuelled box type paddy dryers installed in South Sumatra Province of Indonesia, and on assessment of their impacts in farming communities.

2. MATERIALS AND PROCEDURES

2.1 Paddy Drying in South Sumatra

The paddy drying in the south Sumatra, like in many other provinces of Indonesia, is being carried by sun drying despite the harvest period falls on rainy seasons. For the first time in 2004, a European Commission Project named South Sumatra Forest Fire Management Project (SSFFMP) has introduced the flat bed box dryer of this type with drying capacity of four ton harvested paddy in Upang village. The dryer was provided with a rice husk fuelled oven and a fan powered by diesel engine. After the successful installation of this dryer villagers have realized the importance of such devices, and it became popular among them. Within the period of three years, some bigger dryers with drying capacity of up to 8-10 tons are also installed. Some people have tried some modification in the placement of box, fan and oven. The dryers are being used solely for drying of paddy during harvest season, yet the technology is not efficient, (Bhandari, 2007). Certain improvements are needed to get fully benefit from these dryers. Users in the region are eager to learn about the new systems developed in other regions and in neighbouring countries. As an example, one manufacturer, named Sentosa, has already started to manufacture a bigger capacity fan based on Vietnamese design. Yet the performance of this blower is to be verified.

In order to identify the total numbers of dryers installed in the region and their respective drying capacity, many field visits were carried out. Data were collected based on the interviews with the millers, leaders and farmers of the villages. It was found that about thirty numbers of paddy dryers of different capacities are already installed in the village since 2004 and their total drying capacity is now about 214.5 ton per batch. Considering average gross drying time per batch of paddy being one day (though net drying time is considered as 10 hours) and dryer operation per year being around 60 days, total annual drying capacity of installed devices is around 0.55% of around 2.32 million ton annual paddy production in the province. Figure 1 shows the total numbers of rice husk fuelled box type paddy dryers installed in the province so far and their drying capacity in one batch.

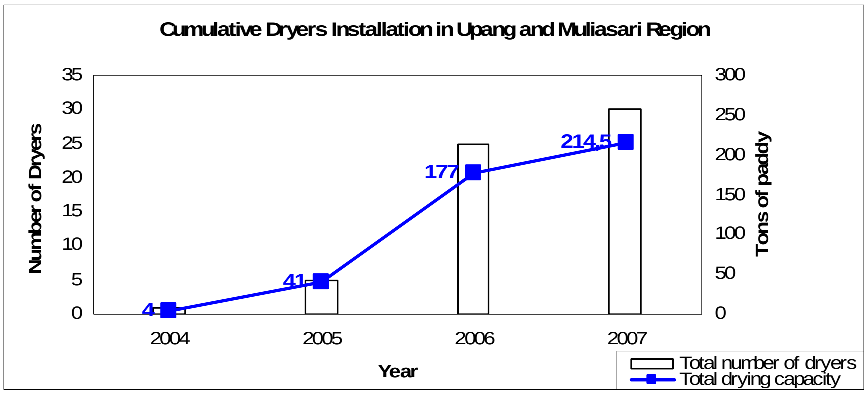

Figure 1. Total drying capacity of the installed dryers in the research area.

2.2 Flat Bed Box Dryer

A flat bed box dryer typically consists of four main components and often has some additional accessories. The main components are: the drying bin for holding the grain, the fan for blowing the air through the dryer and the grain, the heating system - an oven - for heating the drying air, and a shedding for covering all these parts against rain. Grain is contained in a rectangular box, which is called drying bin or drying box, placed on a perforated floor. Drying air is heated with the heat generated by burning the rice husk in the combustion chamber of the oven. Heated air is passed through the grain mass placed into the drying box. This air exits from the grain surface. A fan is used to create forced air circulation through the grain mass. Normally the fan is powered by a diesel engine rather than by an electrical motor in the villages. The schematic diagram for a box dryer found in the field is shown in figure 2 and its picture is given in figure 3.

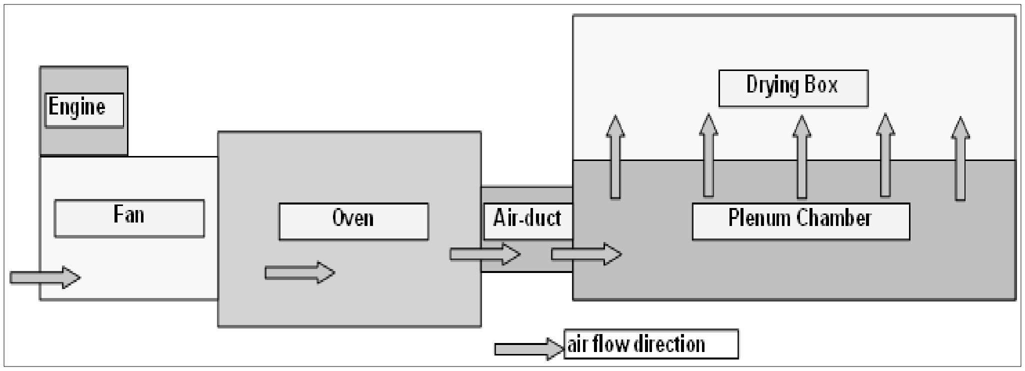

Figure 2. Schematic diagram of a box dryer.

Figure 3. Box type paddy dryer.

In the dryer as shown in fig. 2.2, the fan pushes the ambient air through the heat exchanger of the oven. Heated air coming out from the oven passes into the plenum chamber through the air duct. Normally the duct is made either of air tight cotton cloth or of metal sheet. The pressure created by the fan into the plenum chamber forces the hot air to flow up towards the drying bin through the perforated sheet. Upcoming air passes through the paddy placed into the box. The hot air takes off the moisture from the paddy before it exits from the grain surface. The fan could also be placed after the oven and before the drying box. In this case fan sucks the ambient air through the oven. Air is heated while passing through the heat exchanger surface of the oven.

2.3 Field Testing

Field testing of the box dryers was carried out to evaluate the performance of these devices at the persisting field condition. Parameters were measured in hourly basis during the experiment and measurements were taken for: ambient air temperature, relative humidity of ambient air, initial weight of paddy, initial moisture content of paddy, rice husk consumption, diesel consumption in diesel engine, rotational speed of fan, temperature of heated air inside plenum chamber, temperature and moisture content of paddy in three different layer – top, middle and bottom, bin exit air speed, bin exit air temperature and relative humidity, temperature of chimney and air pressure in plenum chamber. For the paddy dried under sun drying, ambient condition, temperature on grain surface and moisture content of the grain at different points were measured. Data recorded from the experiments were used to assess the technology of box dryers and to compare the quality of rice and the economics of drying of the paddy drying systems by using box dryers with sun drying.

Altogether eight numbers of experiments were conducted in three different box dryers at three different sites. Parallel to the experiments with box dryer, equal number of experiments were carried out with sun drying as well. Some other box dryers installed in the neighbourhood of the testing sites were visited while they were in operation. Instant measurements on some drying parameter were taken in some of these dryers to get an overview on their working conditions.

a) Field Testing Site – Muliasari

The experiments were carried out on 05-09 April 2007 in a box dryer located at the training and demonstration centre of Institute of Agricultural Technology Assessment. This was newly built dryer and only one batch of paddy was dried before these experiments were conducted. Altogether four experiments were carried out with this dryer. Same numbers of experiments were carried out with sun drying as well. The first two experiments were carried out with a fan which was manufactured by a local workshop based on Vietnamese design. The next two experiments were carried out with an existing fan which was also manufactured by a local workshop. One of the objectives of the dryer testing at this site was to find out whether the existing fan is enough for supplying the required air to the dryer or new and bigger Vietnamese fan is needed. The technical details of the dryer are given in table 2.

Table 2. Technical details of box dryer at Muliasari

Description		**Dimension**
Drying Box	Effective length	3.6 m
	Effective breadth	2.6 m
	Height of the plenum chamber	0.5 m
	Height of the drying box	0.6 m
	Wall thickness	0.1 m
	Construction material	brick, cement, wood, steel
	Perforated plate holes, in 100 cm^2	25*28 @ 1.5 mm dia.
	Drying capacity (Paddy)	3.5 ton
Diesel engine	Rated engine power	12.5 hp
	Rated RPM	2400
	Made in	China
Fan 1	Fan type	Existing, axial
	External diameter	0.6 m
	Number of blades	10
	Pully diameter	4 inches
	Length of the fan	0.6 m
	Designer/Manufacturer	Local workshop

Fan 2	Fan type	Vietnamese, axial
	External diameter	0.8 m
	Pully diameter	5 inches
	Number of blades	10
	Length of the fan	0.66 m
	Designer/Manufacturer	Sentosa workshop
Oven	Type	Heat exchanger type
	Dimension (L, B, H)	1.1 m * 0.8 m * 0.8 m
	Dimension of hopper (L, B)	0.47 m * 0.5 m
	Height of the chimney	3 m
	Number of grates	6
	Slope of grate	>45^o
	Manufacturer	Sentosa workshop
Shedding		GI sheet roof, wooden support
Sun drying mat dimension (L, B)		5.6 m * 3.7 m each

During the experiment period it was noticed that the local farmers are not convinced well of the drying technology. Some farmers even have fear for drying their paddy in the box dryer heated with fire putting questions on the quality of their paddy after drying. They think using such dryers is ‘paddy roasting’, and not ‘paddy drying’. This is why some difficulty was experienced while collecting the paddy needed to conduct these four experiments in the field.

b) Field Testing Site – Upangceria

The experiments on Upangceria were carried out on 13-15 April 2007. Two experiments were conducted with box dryer in this site. Like in any other places in the region, this dryer is also installed beside the paddy milling unit and it is owned by the same owner. The dryer was established in 2005 and since then it is in operation. The dryer owner was told to be one of the most innovative and leading farmer – miller of the village. This is why he has changed the set up of his dryer from the initial design. As a modification, this dryer now is operated with a radial fan that was manufactured locally. The fan is placed between the drying box and the oven. The fan sucks the air trough the oven and supplies it to the drying box. This dryer was visited for two times as a part of field visits before these experiments were performed and it was found in operation both times. Unlike in other places, the oven was found in good working condition. The hopper of the oven is big enough for ease of feeding the rice husk into which up to 40 kg of rice husk could be fed at once. The milling unit was also in a very good condition. Both, the milling unit and the dryer are used for commercial purpose. The owner is well satisfied with his drying and milling business. Same numbers of experiments, i.e. two, were carried out with sun drying too. Technical details of the dryer are given in table 3.

Table 3. Technical details of box dryer at Upangceria

Description		**Dimension**
Drying Box	Effective length	10.2 m
	Effective breadth	3.4 m
	Height of the plenum chamber	0.65 m
	Height of the drying box	0.55 m
	Wall thickness	0.1 m

	Construction material	brick, cement, wood, steel
	Perforated plate holes, in 100 cm^2	25*28 @ 1.5 mm dia.
	Drying capacity (Paddy)	10 ton
Diesel engine	Rated engine power	7.5 hp
	Rated RPM	2200
	Made in	China
Fan 1	Fan type	Radial, suction
	External diameter	n.a.
	Number of blades	n.a.
	Pully diameter	n.a.
	Length of the fan	n.a.
	Designer/Manufacturer	Local workshop
Oven	Type	Heat exchanger type
	Dimension (L, B, H)	2 m * 1 m * 0.8 m
	Dimension of hopper (L, B)	1.2 m * 0.8 m
	Height of the chimney	3 m
	Number of grates	9
	Slope of grate	~45^o
	Manufacturer	Local workshop
Shedding		GI sheet roof, wooden support
Sun drying mat dimension (L, B)		5.6 m * 3.7 m each

c) Field Testing Site - Upang

Unlike the two dryers discussed above, this dryer is operated by a farmers' cooperative. It was established in 2004 as the first dryer in the region and it was introduced by SSFFMP. Paddy milling unit and the dryer are installed under the same housing and there is space in between mill and dryer for the storage of rice and paddy. When the dryer was visited, the first outlook at this site was as if the dryer was not at all in operation. Condition of the milling unit was also poor. Two experiments were carried out with box dryer and also the two experiments with sun drying in this site. The technical details of the dryer are given in table 4.

Table 4. Technical details of box dryer at Upang

Description		**Dimension**
Drying Box	Effective length	4 m
	Effective breadth	3 m
	Height of the plenum chamber	0.5 m
	Height of the drying box	0.62 m
	Wall thickness	0.1 m
	Construction material	brick, cement, wood, steel
	Perforated plate holes, in 100 cm^2	25*28 @ 1.5 mm dia.
	Drying capacity (Paddy)	4 ton
Diesel engine	Rated engine power	6 hp
	Rated RPM	2400
	Made in	China
Fan 1	Fan type	Existing, axial
	External diameter	0.6 m

	Number of blades	12
	Pully diameter	4 inch
	Length of the fan	0.43 m
	Designer/Manufacturer	Local workshop
Oven	Type	Heat exchanger type
	Dimension (L, B, H)	1.35 m * 0.8 m * 0.7 m
	Dimension of hopper (L, B)	0.47 m * 0.5 m
	Height of the chimney	3 m
	Number of grates	9
	Slope of grate	>45^{o}
	Manufacturer	Local workshop
Shedding		GI sheet roof, wooden support
Sun drying mat dimension (L, B)		5.6 m * 3.7 m each

2.4 Quality Testing

In the framework of this study, the physical characteristics of rice were analysed. Focus was made to find out the quality changes in rice due to different paddy drying patterns. The samples of 100 kg of paddy dried in each experiment of box dryer and of sun drying were subjected for milling operation. Paddy was milled and amount of husk, bran and rice obtained thereby were weighted. These outcomes were used for the comparison of milling yield between box dryer and sun drying. After milling, three samples with each of 100 ml rice from each experiment were subjected for the separation of whole grains, large broken grains and small broken grains. Rice grains larger than 85% of full size grains are considered as whole grains, between 50% and 85% of full size are considered as large broken grains and those less than 50% of full sizes are considered as small broken grains, (IRRI, 2007b). Whole grains are considered as good quality rice and small broken grains are considered as bad quality rice. Separation was done by using intend grade of IRRI quality kit.

2.5 Economics of Drying

a) Economics of Dryer - Investors

With certain assumptions made for the calculation, the business plan for the three different dryers is presented. In each case, three different conditions are analyzed. In the first case, it is supposed that the dryer is in good working condition from its technical point of view. The investment is supposed to come from the banks at low interest rate. In the second case, the assumptions are pessimistic. The working condition of the dryer is supposed the same that was found during field testing. Investment is supposed to come from the middle men or brokers at high interest rate. The third case is the actual condition that is found at the sites. Working condition and technical performance of the dryer is supposed to be the same that was found during the field testing. But the investment is supposed to be of own money. In all the sites, dryers are installed by the millers. Generally millers earn and save the money earned from their milling business and then they invest it on dryers. In the analysis of this third case, opportunity cost of their own money is calculated and the profit with and without investment on dryer is compared. Details of results are given in table 7 and 8.

b) Economics of Dryer - Farmers

The costs associated with drying for one ton of paddy for the farming community is calculated in this study. In general, all the dryers at the study sites are installed by the millers and none was found to have been installed by a farmer. This is simply because of their high investment cost that the farmers can not afford. Therefore, farmers generally bring their paddy to the dryers, dry it, and perform milling at the same time. By using the dryer for drying their paddy, farmers pay some money to the owner. The amount to be paid was found different in different places. The lowest was found 50,000 IDR* per batch of paddy drying. Usual dryer size in these sites was 4, 8 and 10 tons paddy per batch. In this case the owner does not provide any service or manpower, but only the dryer and rice husk. In other places the cost was up to 135,000 IDR per ton of paddy. In this second case, the owner provides fuel (rice husk for oven and diesel for engine) as well as one person for oven operation. Besides this cost, farmers pay the manpower wage for loading their paddy into the dryer and unloading the paddy from the dryer. Paddy is to be transported to the site by farmers themselves. All these costs are analysed under this section and total cost to be paid by the farmers for drying one ton of their paddy is calculated. These calculations are extended up to the milling options of the paddy. As the results of the calculations, many options are kept open to the farmers – whether to sell wet paddy immediate after harvest or to sell dry paddy or to sell rice after milling of the paddy. The weight loss of the paddy during the drying process is also considered during the calculations.
(1 € = 12000 IDR as of April 2007)*

3. RESULTS AND DISCUSSION

3.1 Drying Technology

Different drying parameters found out after the analysis of measurements are listed in table 5.

Table 5. Results – technical parameters of dryers

	Muliasari				Upangceria		Upang	
Parameters	**Expt.1**	**Expt.2**	**Expt.3**	**Expt.4**	**Expt.1**	**Expt.2**	**Expt.1**	**Expt.2**
Amount of Paddy, ton	2.99	3.057	2.973	3.052	8.898	8.514	3.395	3.26
Drying Time, hrs	14	17	10	15	17	16	19	23
Avg. initial moisture content, %	21.6	23.4	22.2	22.4	22.8	20.1	21.3	21.2
Avg. final moisture content, %	14	14.5	13.9	13.6	11.6	11.5	11.8	11.6
Avg. plenum chamber temp, ^{o}C	41.7	39.4	43.7	40.9	51.8	49.2	40.3	39.4
Rice husk consumption, kg/hr	12.2	9.8	15.4	14.7	49.2	50.2	21.5	20.1
Rice husk consumption, kg/t paddy	53.1	51	46.7	67.36	88.53	88.4	113.8	135.7
Fan speed, rpm	1022	1011	3101	2845	1238	1172	1359	1458
Bin exit air speed, m/s	0.14	0.12	0.14	0.12	0.08	0.08	0.1	0.1
Air pressure, Pa	126	131	148	149	81	56	103	119
Airflow, m^3/s	1.3	1.1	1.3	1.1	2.6	2.6	1.19	1.25
Airflow $m^3 s^{-1} ton^{-1}$ paddy	0.43	0.36	0.44	0.36	0.29	0.31	0.35	0.38
Diesel consumption, l/t paddy	2.44	2.91	3.09	3.53	2.33	1.73	1.76	1.68
Drying rate, %/hr	0.54	0.52	0.83	0.59	0.65	0.54	0.5	0.42
Efficiency, %	26.8	32.3	31.4	24	24.1	18.9	16.6	14.2

In the box dryers of around four tonnes capacity, existing fans are enough to supply the air at required air speed. The airflow measured was in the range of 0.35-0.44 $m^3 s^{-1} ton^{-1}$. This value could be further increased with the same fan by increasing the engine speed. But the radial fan used in one bigger capacity dryer was found not enough to supply the air at required air speed. Air flow measured was in the range of 0.29-0.31 $m^3 s^{-1} ton^{-1}$. It was the maximum value for this fan. In Upang, improper combination of oven and fan as well as inefficient oven has caused the drying time for one batch up to 23 hours, which is simply tedious to work as well as expensive to operate the dryer because it reduces the utilization of the dryer and thereby reduces revenue. In many cases v-belt used to couple fan and diesel engine was found loose and slipping. It was intentionally made loose by the operators to save diesel consumption. But this will reduce airflow to the box and then increase drying time. The bearings on the fan in some of the observed dryers are dry and then it causes frequent fractures.

The most common problem found in many sites is with oven. Amount of rice husk consumption per ton of paddy drying is highly dependent on the operating condition of oven. Most of the chimneys on oven are not functioning well. The common problem is the cover (cap) of the chimney is too close to the chimney pipe (~10-20 cm) and it almost stops the smoke coming out. In some oven there are some small holes on the surface of combustion chamber occurred by lack of repair maintenance works. In one dryer having suction fan, it helps in proper combustion by supplying more air (oxygen) into the combustion chamber of the oven. It was found that the temperature of the air leaving the furnace towards the plenum chamber was higher in this case than in the normal case. While in the other dryers with axial fan, these holes have adverse effect on combustion. Air blown from the fan enters into the combustion chamber through these holes and it pushes the flame of the combustion chamber outside from the opening of the grates and also from the hopper. This not only makes whole working area smoky but also reduces the efficiency of the dryer causing high heat loss. The heat recovery from the chimney by using an external cover around the chimney is found worthwhile. The temperature increase because of external chimney was measured up to 15^o C higher than the ambient temperature. The efficiency of the dryers is calculated using energy balance equations. The value is very low for the cases where the rice husk, a major energy source for heating the ambient air, consumption was very high because of inefficient working condition of the oven. Operation of the dryers in day time, only applicable for the reduced drying time achievable with efficient dryers, can save energy consumption because the ambient air temperature is higher during the day time than in night time.

Many milling units in the field were found relatively in poor operating conditions. Dryers owned by private persons are found in better working condition than that owned by cooperative. There might be always lack of responsibility among cooperative members.

3.2 Quality Testing

There was no significant difference between the milling yield from the paddy dried in box dryer and from the paddy dried under sun drying. Proportion of the husk and the bran was also the similar. Unlike milling yield, the quality rice yielded from the paddy dried in box dryer was always more than that from the paddy dried under sun drying. Details of the result is given in table 6.

Table 6. Results on rice quality test

	Muliasari				Upangceria		Upang	
Box Dryer	**Expt.1**	**Expt.2**	**Expt.3**	**Expt.4**	**Expt.1**	**Expt.2**	**Expt.1**	**Expt.2**
Amount of rice, %	66.5	66	59	63.5	71	68.5	63	63
Amount of bran, %	17.5	17.5	22	17.5	8.5	10.5	22	20.5
Amount of husk, %	16	15.5	19	17.5	20	20.5	16	14
Amount of whole grains, %	62.3	64	36	48	72	85	50	61
Amount of large broken grains, %	6.3	6	8	6	5	3	10	6
Amount of small broken grains, %	31.3	30	56	46	23	12	40	33
Sun Drying	**Expt.1**	**Expt.2**	**Expt.3**	**Expt.4**	**Expt.1**	**Expt.2**	**Expt.1**	**Expt.2**
Amount of rice, %	67	65	59.5	63	71	69	62	63
Amount of bran, %	17	18	14	22	9	10	22	22
Amount of husk, %	16	16	26	17	20	20	15	14
Amount of whole grains, %	52	45	22	30	52	52	39	19
Amount of large broken grains, %	7	7	10	8	8	10	12	19
Amount of small broken grains, %	41	48	68	62	40	38	49	62

Besides the drying methods, the milling yield and rice quality is dependent on quality of the paddy, working condition of the milling unit and the experience and the skills of the mill operator. This is why the percentage of the quality rice yield was different in the different sites and it was even different in the different experiments at the same site.

3.3 Economics of Dryers

a) Investors (Owners)

The results for the three different dryers obtained from the calculations considering three different scenarios on the investment from the interests of the investors are shown in table 7.

Table 7. Results on economic calculation from the interests of the investors

	Sites	Muliasari			Upangceria			Upang		
	Unit	**C 1**	**C 2**	**C 3**	**C 1**	**C 2**	**C 3**	**C 1**	**C 2**	**C 3**
Assumptions										
Dryer service life - oven, fan	years	5	5	5	5	5	5	5	5	5
Dryer service life - engine, box, shedding	years	10	10	10	10	10	10	10	10	10
Loan payback period	years	5	5	0	5	5	0	5	5	0
Interest rate	%	12	24	7	12	24	7	12	24	7
Capacity of the dryer per batch, wet paddy	ton	3.5	3.5	3.5	10.0	10.0	10.0	4.0	4.0	4.0
Average drying time per batch	hours	10	14	14	10.0	16.5	16.5	10	21	21
Dryer Utilization per year	days	60	60	60	60	60	60	60	60	60
Dryer Utilization per year	batch	60	30.0	30.0	60	30.0	30.0	60	30.0	30.0
Initial average moisture content, wet basis	%	22.0	22.0	22.0	22.0	22.0	22.0	22.0	22.0	22.0
Final average moisture content, wet basis	%	14.0	14.0	14.0	14.0	14.0	14.0	14.0	14.0	14.0
Contingencies, portion of investment	%	10	10	10	10	10	10	10	10	10
Annual inflation rate	%	6	6	6	6	6	6	6	6	6

Tax on income	%	15	0	0	15	0	0	15	0	0
Revenue from drying, per ton of paddy	IDR	11.25	11.25	11.25	11.25	11.25	11.25	5.83	5.83	5.83
Exchange rate, 1 Euro to ~ Rupiah	IDR	12000	12000	12000	12000	12000	12000	12000	12000	12000
Calculated Results										
Investment cost per ton of harvested paddy	€	2.06	3.89	3.89	0.65	1.22	1.22	1.59	2.98	2.98
Variable cost per ton of paddy in 1st year	€	2.60	2.86	2.86	1.27	1.34	1.34	1.92	2.11	2.11
Revenue from one ton of paddy	€	11.25	11.25	11.25	11.25	11.25	11.25	5.83	5.83	5.83
Net present benefit	€	10218	2519	5055	42375	21806	24080	3987	-700.6	1522
Cumulative dividend at the end of 10th year	€	14950	3925	7167	62241	32249	35173	5816	-807.1	2020
Opportunity cumulative dividend	€			8154			7309			7070
Benefit cost ratio	ratio	2.24	0.61	1.23	10.23	5.92	6.54	0.98	-0.19	0.42
Payback period	years	5.35	-16.35	8.21	0.93	1.87	1.40	22.11	-6.46	31.81

C 1-Theoretical (Bank Investment), C 2-Actual Field Condition (Broker Loan), C 2-Actual Field Condition (own investment)

From the results shown in table 6, it seems that establishing a box dryer with small capacity (3-4 ton of paddy) in not economically attractive for the owners under the existing poor operating conditions and low annual utilization of the dryers. But the dryers with bigger capacity seem good in making sound profit. If the dryer has smaller paddy drying capacity, it means generation of less revenue from drying, and then the chances of making profit by its operation are very low in compared to the bigger capacity dryers. This is because the investment cost for large capacity dryer is not proportionally higher to its capacity increase. The variable cost per batch of paddy drying is almost the same for any dryers under their efficient working conditions because the operation time for the dryers is almost the same. The negative sign in payback period is due to negative value of net present benefit in the first year.

b) Farmers

Cost of drying per ton of harvested paddy for the farmers is different at different sites depending on the different rates charged by the dryer owners per ton of paddy drying. The local market price for paddy and rice was found the similar for these three sites. The results of the economic calculations from interests of the farmers are listed in table 8. These values are for the one ton of harvested paddy.

Table 8. Results on different economical options to the farmers for handling their paddy

Farmers' level	Unit	Muliasari		Upangceria		Upang	
		Box dryer	**Sun drying**	**Box dryer**	**Sun drying**	**Box dryer**	**Sun drying**
Total cost of drying	€	15.00	5.90	15.00	5.90	9.58	5.90
Money at hand by selling wet paddy	€	150.00	150.00	150.00	150.00	150.00	150.00
Money at hand by selling dry paddy	€	158.84	167.93	158.84	167.93	164.25	167.93
Money at hand by selling rice after milling	€	159.36	160.69	185.85	183.09	163.38	156.18

Farmers have five different alternatives for handling of their harvested paddy - Selling of wet paddy immediate after harvest, selling of paddy dried under sun drying, selling of rice yielded from the milling of paddy dried under sun drying, selling of paddy dried in box dryer and, selling of rice yielded from the milling of paddy dried in box dryer.

3.4 Others

Despite these complicated figures of the economic calculations, millers are establishing more and more dryers in the last few years in these villages. This is because there are some other motivating factors that give millers indirect benefits. As the most of the dryers are less than one year old, it is difficult at the moment to quantify these benefits in monetary terms.

If the miller installs a dryer, he does not need to buy the land for it. This is because the millers can install the dryer besides the existing mill. In many cases dryers are installed under the existing shedding of the milling unit and paddy/rice storage hall. In some cases millers are coupling a small generator, normally in the range of 3 kW, with the diesel engine used for fan operation in the box dryer. This generator provides light for the mill and living home. In some other villages people are using diesel generator solely for lighting purpose. It was found that the more amount of paddy is available for milling if they have dryer at the milling site. Instead of taking dried paddy back home, in most cases, farmers perform milling of their paddy at the same time when they dry it. By doing this, farmers can save the cost of double transportation. The additional amount of paddy that millers get for milling is not quantified yet, because most of these dryers are newly installed and are used only for single harvest season. Millers normally charge 10% of milled rice as a milling charge. This charge is supposed to be much higher than the cost associated for milling. Also millers take bran for free from the farmers. This bran also could be sold at the rate of around 100-120 IDR per kg in the local market. No dryer is found to have been established not together with the milling unit. Some other millers are found having established the dryers without any known benefits from it, but just because the neighbouring miller has established it. Many millers are also the rice traders. Farmers normally sell their rice to the millers after they do milling.

4. CONCLUSIONS

1. Technical performance of most of the installed dryers is not good. Major problems are seen in oven. Engine – Fan – Bin sizes do not match in some cases because of lack of technical knowledge among the owners. There are no standards recommended by authorities working for agricultural technology in the country for the proper selection of dryer components. Drying time per batch of paddy is long in all three sites, and dryer utilization per year is relatively low. Chimney on the oven of the dryer at sites Muliasari and Upang is not optimal. Size of hopper on the oven in these both sites is relatively smaller and the bigger size can help to avoid the frequent feeding of rice husk into it. Existing fan is enough to supply required airflow to the dryer at site Muliasari. Fan in use in Upangceria can not supply required airflow to the dryer. The success of the technology is measured by counting the numbers of dryers installed during the past few years. Few attempts have been made to improve the technology. Multiplication in the number is not because of their better working condition, but because users have no better alternatives. The number of such types of dryers installed in the province with respect to amount of paddy to be dried is negligible, only about 0.55% of annual production. None of the dryer components are tested for individual performance, at which fan is of more critical.

2. There is no difference in amount of rice yield after milling the paddy dried in box dryer and the paddy dried under sun drying. The quality rice yielded from the paddy dried in box dryer is always more than that yielded from the paddy dried under sun drying.

3. Results obtained from the economic calculations show that the box dryers of small drying capacity (3-4 ton) are not attractive for the investors under prevailing operating conditions. Box dryers of big capacity (~10 ton) are capable to generate sound profits even in the existing operating conditions. Some of the dryers at sites that generate revenue 50,000 IDR per batch can not be sustained. Profit from a dryer is highly dependent on its annual utilization (number of batch/year and drying capacity/batch).

4. Sun drying, whenever possible, is the cheapest option for the farmers if they want to sell their dry paddy. If the farmers sell rice, use of box dryer for drying their paddy makes more profit than using sun drying, provided a market for different quality rice exists. If the operating condition of milling unit is good, selling the rice makes more profit than selling the dry paddy.

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