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The reversible air dryer SRA: One step to increase the mechanization of post-harvest operations [#]

Phan Hieu Hien, Nguyen Hung Tam, Nguyen Van Xuan [##]
University of Agriculture and Forestry, Ho-Chi-Minh City, Vietnam
E-mail: phhien@hcm.vnn.vn

ABSTRACT

In Vietnam, over the past 20 years, the simple flat-bed dryer has been accepted and developed into the foremost dryer for reducing post-harvest paddy losses due to adverse rainy weather, with about 3000 units of capacities from 4 to 8 tons per batch. Good features of these dryers are: fairly high capacity, good grain quality, low drying cost, easy to install and operate. Nevertheless, as simplest dryers, they have to be changed to meet the needs for more-mechanized dryers at rice milling centers.

The series of SRA dryers (RA is abbreviation for Reversible-Air, S is drying in Vietnamese) have been designed to serve the above change. The research began in 1999 with a laboratory model for basic information about drying characteristics of various crops with reversible airflow. Next, a pilot 1.5-ton/batch SRA dryer was designed and tested with paddy and coffee. Finally, the dryer was scaled up to different models, of 2; 4; 6; 8; 10; and 12 tons per batch. Fifteen SRA units have been applied successfully in various Provinces of Vietnam; of which 6 units have each dried 500- 1000 tons in the past 2 years. Features drawn from testing and using these dryers are:

1. Saving of labor: No manual mixing is required during the drying period.
2. Saving of land space: The area for the drying bin is only half compared to that of a conventional flat-bed dryer.
3. Multipurpose: Drying of grains and other high-moisture products such as coffee beans, shrimp heads, corn-on-cob, longan fruit etc. Typical drying time for paddy from 28%MC down to 14%MC (wb) is 9 hr; for coffee from 60%MC down to 16%MC (wb) is 14 hr. With paddy, the final moisture differential is below 2 %.
4. The investment and drying cost are not higher compared to a flat-bed dryer of similar capacity.

Based on the acceptance of the processing sector in the past 3 years, it can be anticipated that the reversible-air dryer SRA will play an increasing role for agricultural production in Vietnam. This is one logical step to increase the mechanization of post-harvest operations in the context of a developing economy.

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[##] *Lecturers, University of Agriculture and Forestry, Ho-Chi-Minh City, Vietnam*

INTRODUCTION

In many developing countries, despite great efforts in promoting agricultural dryers, mechanization of drying usually lagged behind other operations such as tillage and threshing. Among various reasons, the nature of the dryer development process should be noted. Through observation and monitoring rice dryers over the past 15 years in Vietnam, and references to experience in other countries, the "theory" or "hypothesis" of this process says that, given a situation of severe post-harvest loss, the path of dryer development and promotion evolves through 4 phases:

Phase I: Some dryers start at farmers' houses, in their desperate search for a device which can save their own crop. Simple devices such as flat-bed dryers seem most appropriate as they fit farmer's limited mechanical skill. Rice farmers first dry their own crop, and next dry for their neighbors for some fees, which lead to a good profit.

The rice miller at that time has been neutral to the dryer, because the lost crop is not theirs, and the benefit from drying had not been realized.

Phase II: Now with more and more farmers building dryers, the rice millers see that they too could enter the drying business to make profit. In this phase, "stand-alone" dryers at farmers' houses co-exist with dryers at rice mills or at traders who buy wet paddy and sell dried paddy.

Phase III: As more and more rice millers install dryers, they are competing for buying wet paddy. Drying fee becomes cheaper and cheaper, because rice millers found their profit in the milling, rather than in the dryer itself. Stand-alone dryers gradually lost business. Farmers in this phase sell paddy without suffering from a low paddy price.

*Phase IV***:** As all dryers are now at rice mills, the millers look for a dryer at one higher level of technical sophistication, to replace that flat-bed dryer which takes lots of land space and is labor-consuming. The dryer at the starting of this phase is still constrained by the acceptable drying cost, which is still heavily influenced by the labor price. It is still not the present-day modern dryer of Europe and America, but later on with time, it will become more and more mechanized and automated.

The above 4 phases happened in the U.S. and Japan some decades ago, and are happening in the developing world. The implication is: At a specific phase, the technical level of the dryer should match that phase of dryer development. Too high or too low level means non-acceptance by farmers. At Phase I, a continuous-flow dryer at the rice mill is as bad a failure as a flat-bed dryer at Phase IV.

In the Mekong Delta of Vietnam, over the past 20 years, the simple flat-bed dryer has been accepted and developed into the foremost dryer for reducing post-harvest paddy losses due to adverse rainy weather, with about 3000 units of capacities from 4 to 8 tons per batch. Good features of these dryers are: fairly high capacity, good grain quality (including seed), low drying cost, easy to install and operate. Typical are the SHG-series flat-bed dryer developed at the University of Agriculture and Forestry Ho-Chi-Minh City with about 500 units transferred to all Provinces of this region. Nevertheless, in line with the above-mentioned development, the needs and demands for change from this simplest dryer towards a more-mechanized dryer at rice mills have been raised.

The reversible-air dryer SRA have been designed and studied to meet the above requirements.

OBJECTIVES

With reference to requirements of low drying cost and simple operation, currently met by the flat-bed SHG-series dryer, the study aimed at developing a new flat-bed dryer with reversible airflow. The other requirements compared to current flat-bed dryers are: a) Saving of land space; b) More mechanized, meaning less use of manual labor; and c) Multi-crop use, including high-moisture products such as coffee, sliced cassava, longan…

RELATED INFORMATION

Reversible-air drying is not a new concept. In Taiwan (Din-Sue-Fon, 1981) designed a 1-ton/batch reversible-air dryer, with a rectangular drying bin and a central box for reversing the air from the fan. In the Philippines (Kuizon, 1995) also built reversible-air dryers with similar configuration. In 1998, the American-based Advanced Dryer Systems installed the 6-ton reversible-air dryer in Vietnam; unlike the above two dryers, this drying bed is vertical while the airflow is horizontal.

Our desk evaluation of these dryers revealed some drawbacks. In the Taiwanese and Philippines designs, the air is blown at the center, thus increases the bed height level, making more difficult for manual loading. The American vertical-bed only fits granular drying materials like grains, thus could not accept other hi-moisture and sticky materials. Hence, in this study, a different air-reversal configuration has been selected (Next Section).

MATERIALS AND METHODS

Three steps of dryer design have been followed: a) Laboratory model; b) Small-scale model; and c) Scaled-up models.

Laboratory reversible-air dryer

This laboratory dryer, named SRA-TN (Figure 1), is for studying the moisture reduction curves as influenced by the bed depth, the airflow rates, and the timing of air reversal. The construction includes: *(1)* a 3-m high, 0.39m-dia. cylindrical bin; *(2)* a 1-HP centrifugal fan, with ducting for blowing air either upward or downward through the bin; the airflow is measured and controlled by an orifice plate and valves; and *(3)* a furnace burning coal at 1 kg/hr.

Small-scale reversible-air dryer

A model reversible-air of 1.5-ton/batch dryer (for paddy) has been fabricated in order to determine the suitable design configuration and the operational features (Figure 2). The SRA-1.5 design inherits experiences and good features of the flat-bed SHG-series dryer as well as results from the laboratory model.

Scaled-up reversible-air dryer

Different reversible-air dryers, of 4, 8, 10, 12 tons per batch have been installed at rice mills to determine the compatibility of the design with actual production conditions (Figure 3). The focus has been on the drying cost, as related to the investment and the operational costs.

All scales of the above dryer have three features in common: *(1)* A side-duct plenum chamber which is convenient in reversing drying air, and allows a low drying bed for convenience in loading / unloading. *(2)* A two-stage axial-flow fan, which provides airflow of 0.8- 1.0 $m^3 s^{-1} ton^{-1}$ at 500-pascal static pressure. The axial fan fits local fabrication skills, with comparatively low cost. *(3)* A "standard" drying bed of 0.6m has been based on the fan capability to push air through paddy as a high-resistance material to airflow. Still, the bin is designed to accommodate a bed up to 1 meter high, for materials with lesser resistance to airflow.

Three-ton/batch mobile dryer

Besides, a 3-ton/batch mobile dryer has also been tested; all components are on a trailer pulled by tractor (Figure 4). For compactness, the drying bin is divided into 2 decks, one on top of another, each with a 1.8m*2.0m floor containing a 0.5m-depth grain layer. The fan is 2-stage vane-axial, using 4-kW motor, and delivering 3 $m^3 s^{-1}$ airflow. A manually operated bucket loader enables the loading time within 20 minutes.

Testing

The tests have been designed to verify the drying curves as well as to obtain technical data for calculating the drying cost. Standard equipment has been used: scales, power meter, tachometer, digital thermometers, and grain moisture meters…

RESULTS AND DISCUSSION

Laboratory reversible-air dryer

Test results from the laboratory reversible air dryer SRA-TN are shown in Table 1. For an acceptable moisture differential (e.g. less than 2% with paddy), the grain layer depth is determined accordingly. For paddy, the depth is limited to below 0.7m,

Table 1: Test results from the laboratory reversible air dryer

	Paddy	Whole coffee	Whole coffee	Coffee bean	Pulped coffee	Pulped coffee	Peanut
Input grain, kg	27	88	38.6				
Initial MC, %	22.8	66	66	20	64	62	47
Final MC, %	13.9	21.4	20	13.5	31.3	12.8	11.9
Grain layer depth, cm	70	***180***	***80***	100	60	70	100
Drying temperature, ^oC	49	50	55	61	75	68	43
Superficial velocity, $m.min^{-1}$	16	14	14	14	10	12	12
Drying time, hours	5	53	22	5.5	7.5	11.5	26
Timing for reversing air, (after) hour	4	23	12	3.5	5	***5 & 8***	16
Max MC differential, %	1.2	***10.0***	4	4	***28***	***17.3***	5.5

Small-scale reversible air dryer SRA-1.5

The SRA-1.5 dryer has been tested at Can-Tho and Dak-Lak Provinces, which in Vietnam are the "capitals" of rice and coffee respectively. Test results are summarized in Table 2, with the following notes:

- The dryer operates smoothly; both the air and temperature distributions over the 2m*2m floor are uniform.
- The drying temperature is stable due to the stable combustion of coal as heat fuel.

- The air-reversal device is simple to operate, with two persons in seven minutes.
- For wet paddy (over 28% MC wb), the grain bed should be below 0.60m, with a superficial velocity of 12- 14 $m.min^{-1}$, and drying temperature below 45 ^oC. Grain should be checked for moisture content and foreign matter before loading; large foreign matter should be removed. The purpose is to distribute the input materials evenly over the floor, in order to reduce the final moisture differential, even with air reversal.
- For coffee, the drying regime depends on the processing method. For whole coffee, use a drying temperature between 60- 65 ^oC at a grain depth of 0.60m; the grain is dried from wet (≈66% MC wb) down to 20- 22 % in 22- 24 hours. For drying coffee bean of 20- 22% down to 12- 14%, the drying time is 4- 5 hours, using drying temperature 50- 55 ^oC at 0.50m grain depth.

Table 2: Test results from the SRA-1.5 reversible air dryer

	Paddy	Paddy	Whole coffee	Whole coffee	Coffee bean	Coffee bean
Date dd/mm/yy	2/4/01	4/4/01	6/12/00	10/12/00	5/12/00	15/12/00
Input grain, kg	1370	1652	1392	1547	1500	1395
Input MC, %	28.5	21.1	63	66	15.8	15.8
Final MC (average), %	15.5	14.2	14.6	19.8	11.5	11.9
Grain layer depth, cm	60	75	55	60	58	50
Drying temperature (average), ^oC	45.9	45.6	67	70	55	55
Superficial velocity, $m.min^{-1}$	12	12	11	12	14	14
Drying time, hours	9	9.5	22	19	5	3
Timing for reversing air, (after) hour	5	6	15	15	3	2
Max MC differential, %	1.7	1.1	9.8	5.9	2.8	2.3

Scaled-up reversible air dryer SRA-8, SRA-10, SRA-12

Ten units of scaled-up reversible-air dryers, with capacities ranging from 8 to 12 tons per batch have been installed at different rice mills. Results from a test batch of 10 tons at Cong-Thanh Rice Mill are shown in Figure 5.

Other five units of SRA-dryer have been installed for shrimp head (1-ton/batch capacity), longan (0.5-ton and 3-ton/batch), and corn (8- 10 ton//batch).

Six out of 10 units for paddy have each dried 500- 1000 tons in the past 2 years. Features drawn from testing and using these dryers are:

- Saving of labor: No manual mixing is required during the drying period. For the 10-ton reversible dryer, only two persons are required to handle the air-reversing device in 7- 12 minutes. Without mixing, the paddy final moisture differential is below 2 %. An 8-ton conventional flat-bed dryer usually requires 3- 4 laborers in 45- 60 minutes for mixing paddy; otherwise the product would not be uniformly dried.
- Saving of land space: The area for the drying bin is only half compared to that of a conventional flat-bed dryer. For example, an 8-ton conventional flat-bed dryer requires 50 m^2 of perforated floor, while the 8-ton SRA dryer need only 25 m^2.
- Multipurpose: Drying of grains and other high-moisture products such as coffee beans, corn-on-cob, especially “fragile” products which are susceptible to damage due to mixing such as shrimp heads, longan fruit etc.

Three-ton/batch mobile dryer

One test batch was conducted at UAF on 21 December 2001 with 2.92 ton of IR-64 paddy variety. The drying time was 6 hr 15 minutes to reduce from the initial MC of 25.3 %wb down to 13.0%, using 43 ^{o}C drying temperature and 0.97 $m^3 s^{-1} ton^{-1}$ airflow. The grain depth was 0.48m, and air reversal was done after 4 hours. As with other stationary versions, the final moisture differential was below 2%. Coal consumption was 5.8 kg hr^{-1}.

Other batches were conducted at Cong-Thanh Rice Mills (Tien-Giang Provinces). For paddy with moisture higher than 28%, the drying time was about 8 hours (Figure 6). One batch was milled and recovery rates measured. Results: 58.7% of milled rice containing 10% broken grain, 6.5% broken grain, and 11.4% bran. These were considered very good by the rice mill owner.

CONCLUSION

The study on reversible air dryer has come up with basic results in the laboratory as well as field results on the scale-up production units. Based on the acceptance of the processing sector in the past 3 years, it can be anticipated that the reversible air dryer SRA will play an increasing role for agricultural production in Vietnam. This is one logical step to increase the mechanization of post-harvest operations in the context of a developing economy.

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Figure 1: The SRA-TN laboratory dryer

Figure 2: The SRA-1.5 reversible air dryer

Figure 3: The SRA-10 reversible air dryer (10 tons per batch)

Figure 4:
Three-ton/batch mobile dryer SRA-3M

Figure 5: Paddy moisture reduction of SRA-10 reversible dryer

Note: 8m*5m floor;
0.41m grain depth;
43 °C drying temperature;
0.71 m3/s/ ton airflow ;

Up, Mid, Bot = Upper, Middle, Bottom grain layers ;

1, 2, 3 = Near, Center, Far positions from the fan , along the drying bin.

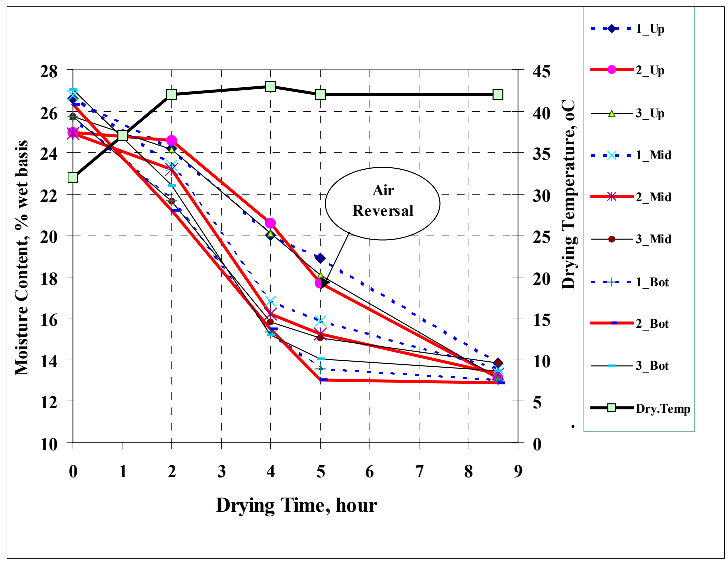

Figure 6: Paddy moisture reduction of SRA-3M mobile reversible dryer

Note:

Up = upper layer;
Bot = bottom layer;

1 to 9 = different positions on the drying bed.