Application of two-stage drying for effective and economical wet grain handling in selected rice and corn farmer cooperatives in the philippines[1]

Justin A. Tumambing[2], Manolito C. Bulaong[2], Robelyn E. Daquila[2] and Lorena N Miranda[2]

Abstract

This paper provides a case study in the successful application of two-stage drying technique in one rice farmer cooperative and one corn farmer cooperative in the Philippines The two-stage drying system is composed of a high-temperature pre-dryer for the first stage drying and an in-store dryer for the second stage drying.

The principle of the systems approach was adopted in the development of the two-stage drying technology for the selected farmer cooperatives Technical, economic and social data were gathered for at least one wet season and one dry season in each farmer cooperative. The results have shown the technical feasibility, economic viability and social acceptability of the two-stage drying system to selected rice and corn farmer cooperatives. The drying system provides incomparable benefits in terms of improved grain handling capability, low operating and drying costs, premium quality grain, more affordable investment, easy to operate and flexible drying capacities. The in-store dryer used for second stage drying can then serve as storage structure for dried grain after the last drying operation.

Introduction

Two-stage drying has been gaining a headway in the grain industry in the Philippines in providing a practical solution to the wet grain handling problems. This drying system is now widely practiced in areas with wet and very wet weather conditions not only in the Philippines but in other ASEAN countries (Tumambing et al., 1996; Srzednicki and Driscoll, 1996; de Padua, 1996, Naewbanij, 1996). In this system of drying, the high moisture grains (> 24%) is dried rapidly down to a more manageable level of about 18% followed by slow drying to 14%. At 18% moisture content level, the grain can be safely stored up to 21 days without significant quality loss. The first stage of drying can be accomplished using any dryer that can provide uniform drying in a matter of minutes or a few hours The second stage drying should be done gently to minimize or prevent grain fissuring and breakage This can be done by a batch dryer, a continuous-flow dryer, well-operated sun drying pavement or preferably an in-store dryer.

After more than ten years of collaborative research and development work, the Bureau of Postharvest Research and Extension (BPRE formerly BPRE) and the Australian Centre for International Agricultural Research (ACIAR) through the University of New South Wales (UNSW) have developed a two-stage drying technology suitable to medium and large scale grain processors (e. g. farmer cooperative, private miller). This two-stage drying technology is composed of the BPRE flash dryer or any efficient high temperature dryer for the first stage drying and the in-store dryer for the second stage drying This two-stage drying technology which is otherwise known as combination high temperature low temperature drying offers higher drying efficiency, often superior grain quality, lower drying cost and more operational flexibility than the conventional fixed bed or continuous flow drying technologies for paddy.

Tumambing et al. (1996) reported the feasibility of 66-ton capacity in-store dryer in combination with the 0.6 ton/hr BPRE flash dryer in the Dayap Development Cooperative (DDC) in Calauan, Laguna, Philippines. The integration of the two-stage drying system into the postharvest operations of the Dayap cooperative greatly improved its rice grain handling capability. The coop used to rely heavily on sun drying, but now it can depend totally to the new system to meet its drying needs In terms of economic benefits, there was a reduction in drying cost from P9.81/cavan to P3.75/cavan, an increase in return on investment from 16.71% to 28.53%, a benefit-cost ratio of 7.31, a payback period of 3.5 years and an internal rate of return of 28%. For the same drying capacity, this system is at least seven times cheaper than a commercial scale LSU dryer. Due to premium grain quality, the milled rice can be sold at least P100 higher than the regular milled rice sold in the market.

---

[1] Paper presented at the 7th International Conference on Stored Product Protection, October, 1998, Beijing, China

[2] Director I, Division Chief And Research Assistants, respectively, Postharvest Engineering Department, Bureau of Postharvest Research and Extension (BPRE), CLSU, Nueva Ecija, Philippines

In support of the Philippine government's goal of developing the agricultural sector through the empowerment of the small farmers, BPRE continued its collaboration with ACIAR and embarked on a developmental research project on the application of the two-stage drying system at the farmer cooperative level. The selected rice and corn farmer cooperatives will serve as demonstration sites or models. The introduction of a highly efficient, cost effective and socially acceptable drying technology is a significant contribution in the total effort of reducing postharvest losses and increasing the use of improved postharvest technologies by the farmers This effort is geared not only towards increasing the income and developing the farmer cooperatives to become effective business entrepreneurs but also towards attaining self sufficiency in rice and corn, the two staple commodities in the country

This developmental research aims to demonstrate the feasibility of the two-stage drying system in selected business-oriented rice and corn farmer cooperatives in the Philippines.

Methodology

Selection of one rice farmer cooperative and one corn farmer cooperative as demonstration sites

The two rice and corn farmer cooperatives were selected based on the following criteria:

a good track record in terms of credit standing (financially stable);
b. has existing postharvest facilities especially warehouse and multi-pass rice mill;
c. site should be readily accessible to national highway;
d. has suitable space for installation of the two-stage drying system

Determination of system requirements

Relevant field data were gathered before the design of an appropriate two-stage drying technology for a farmer cooperative. These data inputs were as follows:

a. harvest data-these included procurement schedules, volumes and moisture distribution at harvest, techniques used, delays, harvest quality, dryer needs, labor and energy costs, interest rate and other basic data needed in understanding the postharvest infrastructure and acceptability of a dryer into that infrastructure.
b. postharvest facilities existing in the selected farmer cooperative.
c. weather – this included temperature, relative humidity, solar incidence and rainfall patterns in the selected area.
d. Infrastructure to include distribution and transport patterns.
e economics; such as location of markets, current prices, criterion for purchase both at point of sale and at farm and after milling, for typical varieties, quality assessment throughout the postharvest chain, pricing structures at all postharvest points, seasonal variation

Design and development of a two-stage drying system

Based on the drying requirements especially on the drying capacity and operation, an appropriate design of an in-store dryer and a first stage dryer was made through computer simulation modeling. The specific design of a two-stage drying system was then fabricated at the BPRE fabrication shop in Muñoz, Nueva Ecija After fabrication, the whole drying system was installed at the selected farmer co-op centers

Commercial scale operation

After installing the developed dryers, the dryer performance was observed during the dry and wet seasons The technical feasibility, economic viability and social acceptability were assessed During the dryer operation a technician from each farmer coop was trained how to operate the dryer

Results and Discussion

Description of Rice and Corn Farmer Cooperatives

Christian Farmers Cooperative (Rice Coop)

The Christian Farmers Kilusang Bayan for Credit and Allied Services, Inc (CFKB) was initiated and organized by some members of Iglesiang Itinayo ni Jesucristo-Mga Cristiano sa Pilipinas (Church Founded by Jesus Christ-Christians in the Philippines) in Homestead II, Talavera, Nueva Ecija to improve the quality of life of Filipino farmers and other Christian brothers. By collaborating with concerned agencies, the co-op has carried out its objective to initiate varied programs and services aimed to support members to increase their income and uplift their living conditions and to enhance community improvement.

CFKB was registered with the Bureau of Cooperative Development on October 27, 1987. Initial membership in 1987 was 44 and as of 1994, there are about 440 farmer-members. It operates in 14 cities/municipalities in Nueva Ecija namely Talavera, Cabanatuan City, Llanera, Rizal Mu? oz, Palayan City, Laur, Gabaldon Jaen, Zaragoza, Quezon, Sta. Rosa, Sto Domingo and Aliaga.

Aside from capital build-up among members, there are other organizations funding and supporting CFKB namely Landbank of the Philippines, Department of Agrarian Reform, Department of Trade and Industry, Department of Agriculture, Solid Bank Cabanatuan Branch and Philippine Business for Social Progress.

CFKB is involved in trading and marketing of members produce, providing credit for farm inputs and other livelihood projects for members, consultancy and training, networking and managing of all special projects.

CFKB has its main office at Homestead II, Talavera, Nueva Ecija (Fig. 1). It has a total lot area of 10,000 square meters. The area belongs to type-I climate with two pronounced seasons, dry season from January to June and wet during the rest of the year.

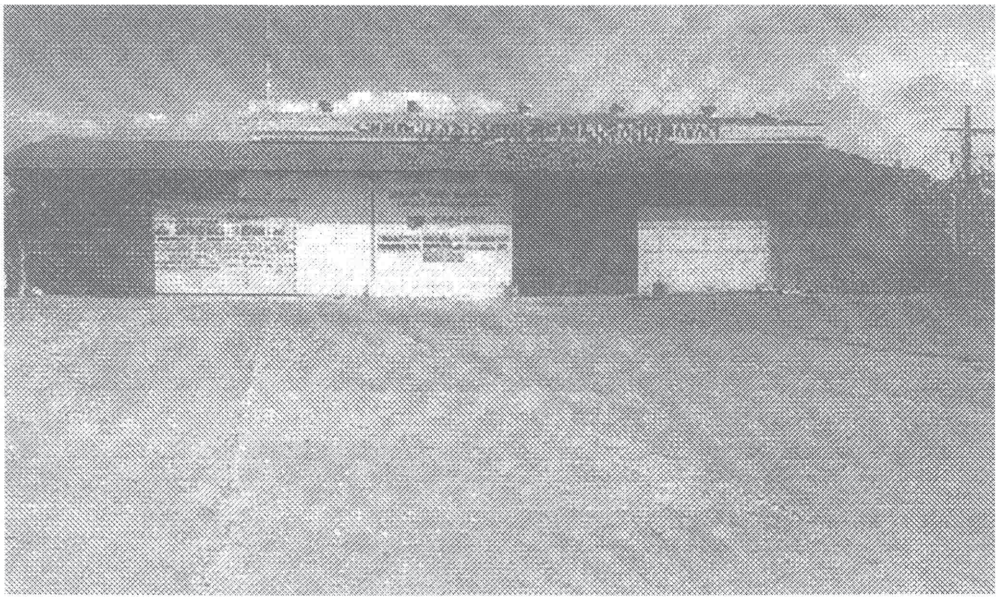

Fig. 1. The Christian Farmer's Cooperative's main office and processing complex located in Homestead II, Talavera, Nueva Ecija.

The cooperative is composed of a General Assembly: the Board of Directors, 5 Committees namely, Education and Training Committee, Credit Committee, Credit and Inventory Committee, Election Committee, and Advisory Council (Consultancy); and the General Manager and Administrative Officer.

Postharvest facilities of the cooperative were obtained through a loan from Landbank and grants from other government institutions like BPRE. These facilities include a 2.5 tons/hr Satake Multi-Pass rice mill, four units of recirculating batch type dryers (5.5 tons capacity each) and a 0.6 ton/hr BPRE flash dryer. The co-op also has solar pavement (2,556 m^2), two warehouses (35,000 bags capacity each) and two units of hauling trucks with 36.5 tons hauling capacity.

Tupi Integrated Agricultural Cooperative (TIAC-Corn Coop)

TIAC is basically a multi-purpose corn cooperative with office at the town proper and their warehouse at Bgy. Crossing Rubber of the town of Tupi, 35 km. North of Gen. Santos City, South Cotabato (Fig. 5 and Fig. 6). The coop is also engaged in handling rice on a very limited extent.

Farmer members of the cooperative are from the towns of Tupi, with 430 members, and Tampacan, with 70 members. The members from Tupi own a total area of 1,350 hectares of agricultural land while the members from Tampacan own a total area of 280 hectares. Agricultural land in Tampacan which is relatively more fertile gives a higher average yield of 3.5 tons/ha than in Tupi with an average yield of 3.0 tons/ha. The average farm size of each member is about 4 hectares.

At the beginning of every planting season, the coop prvides production loan to each member in the amount of not greater than P 6000/ha. The loan is payable at 22% interest per annum in cash or in kind.

The coop is managed by a Board of Directors which are elected by its members for a 3-year term and can hold office for a maximum of 2 terms. The operation of the coop is run by a general manager, a bookkeeper, and other utility workers, all of which are employed by the coop.

System of Operation and Drying Requirements

Christian Farmers Cooperative

The postharvest operations at the farm level starts from harvesting followed by threshing, then drying, storage and milling. Harvesting is accomplished through contract labor by special arrangement and are usually paid 10% of the total harvest (10 sacks for every 100 sacks of grain that will be recovered). The harvested paddy is commonly threshed using the mechanical thresher usually paid in kind at 6%

share of the total output or harvest Forty nine percent of the total harvest goes to the cooperative as payment for the production loans incurred at the start of cropping season An average of 5% are retained for seed purposes for the next cropping season and about 19% are left to meet the consumption requirement of the family The remaining 11% are either sold to the cooperative or traders.

CFKB has a total area of 827.5 has. devoted to rice production. Harvesting schedule started from April to May for the dry season while October to November for wet season CFKB started it's operation in 1987 only as mere credit cooperative It was only during the mid 1992 that the co-op engaged in the direct trading and marketing of members produce

The cooperative procures paddy from its members during harvest season The designated group leader communicates thru his two-way radio with the coop's administrative officer and identifies the farm or any assembly point to which the harvest is ready for pick-up. The stocks were directly picked up by the coop's hauling trucks.

Procurement depends on the harvest season of paddy from its members. The coop procures paddy from its members and during lean months (January, February, July, August) when there's no harvest, the coop procures paddy from nearby provinces like Isabela and other neighboring towns There are about nine months in a year when there is postharvest operation

The co-op classified paddy being procured either as skin dried (>18%), high skin dried (15% – 18%) and dried (14%). In terms of mode of purchase, the average procurement of co-op during dry season for skin dried, high skin dried and dried paddy were 832.2 tons, 142.3 tons and 1,366.37 tons, respectively For the wet season they procured 899 87 tons, 300.84 tons and 1277.11 tons for skin dried, high skin dried and dried paddy respectively (Table 1) It can be seen that there is a large volume of wet (referred to as 'skin dried' by the co-op) paddy that are needed to be dried especially during the wet season Before, the coop encouraged the farmers to dry their own produce for an incentive because they don't have enough dryers to accommodate large volume of wet paddy being delivered into the co-op Also the co-op is forced to utilize highway drying and rent other available drying pavements to save their paddy from deterioration. But now that the highway drying is prohibited by law, the need for a sound mechanical dryer is greatly evident.

Table 1. Procurement of skin dried, high skin dried and dried paddy for 1993 – 94 at Christian Farmers Cooperative

	Wet Season (tons)			Dry Season (tons)		
	Skin Dried (19 – 26%)	High Skin Dried (15 – 18%)	Dried (<14%)	Skin Dried (19 – 22%)	High Skin Dried (15 – 18%)	Dried (<14%)
1993	766.5	318.72	1050.59	686.06	93.71	1,389.06
1994	1033.24	282.96	1503.63	978 37	190.88	1,343.68
Average	899.87	300.84	1277.11	832.2	142.3	1366.37

The procured paddy is dried using the mechanical dryer and is complemented by using the solar drying pavement Dried paddy is either sold to the traders when there is order or stored for milling. Milling of stocks is done based on orders from retailers/wholesalers and traders. The cooperative disposed their produce mostly as milled rice than dried paddy. The coop had realized that selling milled rice instead of dried paddy earned higher income due to additional revenue derived from the disposal of rice bran and binlid (very small brokens)

Tupi Integrated Agricultural Cooperative

The postharvest operations in corn in the South Cotabato area include harvesting by hand picking of the cob, followed by wet shelling, drying and milling. In the case of TIAC, their operation ends in drying after which the grains are sold to the traders, feed millers or food processors

The facilities of the coop are a warehouse (4000 bags capacity), a forward and elf truck, 2 tractors, 100 bags capacity solar drying pavement, a 2 tons/hr mobile sheller and a moisture meter.

The climatic type in this area is Type IV where rainfall is evenly distributed throughout the year. The harvesting months are during the periods June to August and December to February. During these harvesting period, rainfall in the afternoon is a common occurrence such that the use of sun drying pavement is unreliable to completely dry the high moisture corn. Hence, the wet corn is very susceptible aflatoxin contamination

The coop procures corn directly from its members. Most of the procurement comes from the payment in kind of its members. Because of the limited drying capability, the coop procures mainly dried corn at about 14.5% A penalty of 25% in weight at moisture content greater than 14.5% wb is being practiced to discourage the farmer members from selling wet corn. Although procurement of wet grains (> 14.5% m.c. w.b.) will give higher profit, the coop cannot do so due to lack of postharvest facilities particularly mechanical dryers to accommodate large amount of wet grains. Hence, the installation of a two-stage dryer will enable the coop to procure wet grains, process it and sell at a higher price.

During procurement, the quality of corn delivered to the coop is oftentimes inferior in quality (discoloration and high incidence of aflatoxin contamination) due to the delay in drying and rewetting of grains in using the sun drying pavement.

Design, Fabrication and Installation of a Two-stage Drying System

Christian Farmers Cooperative

Analysis of the monthly receival rate of the co-op showed that the months with the highest procurement of wet paddy were October and November, peak harvesting months of the co-op members during the wet season. During these months the need for a dryer is highly evident. Thus, the design should be based on the average daily receival rate during these peak months. Since the coop has recently acquired four units of recirculating dryers, these dryers can be effectively used as pre-dryers at a combined rate of at least 5 tons/hr. Based from the data, the designed capacity of the in-store dryer for second stage drying is set at 100 tons.

1. Description of the dryer: The dryer was erected inside the coop's warehouse beside the recirculating dryers and rice mill (Fig.2).

Fig.2. The 100 tons in-store dryer together with the 4 units of 5.5 tons capacity recirculating batch dryers and 2.5 tons/hr Satake multi-pass rice mill.

a. Drying bin: The drying bin is an all-metal construction with an overall dimension of 3.66 m in width, 3.66 m in height and 18.30 m in length (Fig.3). This rectangular bin is partitioned into 5 equal compartments to allow flexibility in operation. Each compartment has a floor area of 3.66 m × 3.66 m and can contain about 20 tons of skin dry paddy (18%) at 2.6 m grain depth. This set-up is the modified version of the first two set-ups installed at Tupi, South Cotabato and Dayap, Calauan, Laguna. Aside from corrugated bin walls, each compartment has unloading ports on two sides of the bin so that gravitational unloading of paddy can be done either on both sides of the dryer. It also has centralized air duct located inside the plenum. The amount of air that enter each compartment can be regulated by a crank connected to the gate by a bevel gear. A perforated floor placed 0.91 m from the ground serves as support to the weight of the paddy and entry point for uniform flow of air into the grain. Located at the center of the perforated floor is a removable section which provides a passage way for maintenance work in the plenum chamber and air duct. Catwalk (ladder) is provided for easy access inside the compartment.

b. Blower: A 10-hp backward curved centrifugal blower was installed which can deliver 269.21 m^3/min (900 cfm) of air at 3" water static pressure through a centralized air duct. When all bins are loaded in full capacity, the blower supplies air to each compartment at 4 m/min superficial air velocity. The drying front will reach the top of 2.6 m grain depth in about 5 days or 120 hours of continuous operation. A vaporizing pot burner placed near the blower is used when supplemental heating is required (Fig. 4). For an overload protection, a 60-ampere wye delta magnetic starter was connected between the power supply line and the electric motor.

c. Loading and unloading system: Manual loading was temporarily adapted by the cooperative. A movable stair/landing with dimension of 0.9 m. in width and 1.2 m in length and elevated at 2.4 m. in height was fabricated for loading of paddy.

Unloading was done manually on both sides of the bin.

2. Operation of the two-stage dryer: The in-store dryer will act as a second stage dryer during wet season and frequently as a single stage dryer during dry season. Prior to in-store drying, paddy will be pre-dried down to 18% either by using the coop's 4 units of recirculating dryers or BPRE flash dryer. The dryer will be operated when the relative humidity of inlet air falls within the range of 65 – 75% to achieve an equilibrium moisture content of 13 – 14%. Supplemental heating will be applied when ambient air relative humidity exceeds 75% especially during wet season. Since the dryer is divided into 5 equal compartments, it can hold up to 5 batches of grain with different grades and varieties. The operator can also have the option to operate selected number of compartments.

Tupi Integrated Agricultural Cooperative

The coop is presently doing the drying of wet corn on a limited basis with use of the unreliable sun drying pavement. The design of two-stage drying system found suitable to meet the drying requirements of the coop is composed of a BPRE flash dryer and a 30-ton capacity in-store dryer (Fig. 7). Setting-up a bigger capacity drying system right away is inappropriate due to the limited space available. It would also take awhile for the coop to graduate from the use of the sun drying pavement. Hence, the set-up is designed to be capable of drying half of the total wet corn production of its farmer members. However, the system is flexible enough and once the coop has gained experience in the use of the two-stage dryer, the coop can put-up another flash dryer and the capacity of the in-store dryer can be expanded by adding more modular drying bins and another unit of centrifugal blower.

The above two-stage drying set-up also intends to validate the feasibility of using the in-store dryer for skin-dried corn at which condition aflatoxin contamination can still occur.

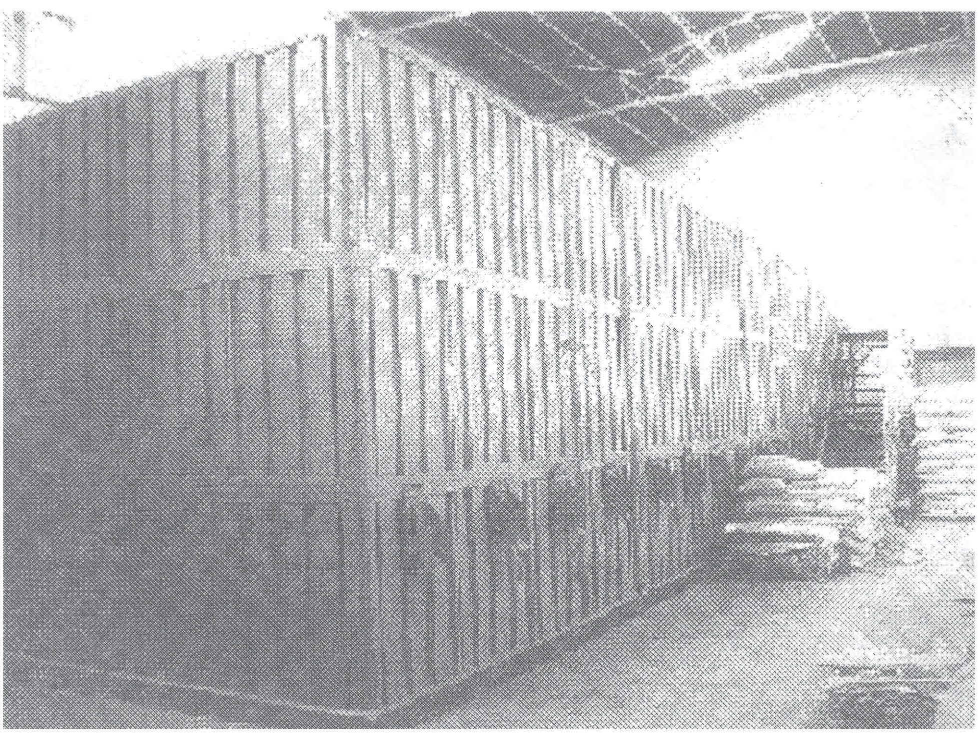

Fig. 3. The drying bin made from corrugated metal sheets with dimensions of 3.6m width, 3.66m height and 18.30m length. The bin is divided into five equal compartments each compartment having 4 unloading ports on both sides.

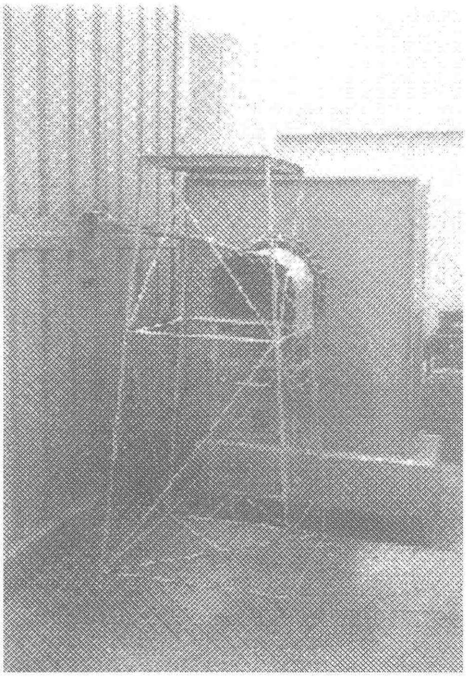

Fig. 4. The back ward-curved centrifugal blower with a back-up kerosene vaporizing pot burner.

1. Description of the in-store dryer

a. Drying bin: The drying bin has an overall dimension of 1.83 m in width, 10.98 m in length and 3.05 m in height (Fig. 6,7 and 8). This rectangular bin is divided into 3 compartments. Each compartment has a capacity of about 10 tons skin dry (18% w. b.) corn at 2.00 m grain depth. This dryer has more features than the Dayap co-op in-store dryer (Tumambing et al.,1996). Aside from the corrugated bin walls, each compartment has four sliding type unloading ports for gravitational unloading of dried corn in bags and sampling ports for monitoring the moisture content while the dryer is in operation. A fully perforated floor placed 0.91 m above the ground serves as support to the weight of the corn for each compartment and entry point for uniform flow of air into the grain. The amount of air that enters each compartment can be regulated by a crank connected to the gate by a bevel gear. The drying bin is also provided with catwalk (ladder) for easy access inside the compartments.

b. Blower: A 2-hp backward curved centrifugal blower is installed in the in-store dryer. It can deliver 100.47 m^3/min of air at 500 Pa. (2 in. H_2O) static pressure through a centralized air duct (Fig. 8). The blower supplies an airflow of 5m/min when all compartments are loaded at 2 m grain depth. It will take about 5 days to dry the 28 to 30 tons corn samples from 18% to 14%. A vaporizing pot burner is placed besides the blower and is used when supplemental heating up to 5℃ is required.

c. Manual loading system: Manual loading system was adapted in Tupi co-op primarily because the coop enough laborers for loading corn samples to the in-store dryer. A metal platform with dimensions of 1.83 m in width, 9.15 m in length and elevated at 2.66 m in height is placed parallel to the bin length. The two ladders of 2.66 m in height are installed on the two ends of the platform (Fig. 8). Each bin is also provided with a catwalk (ladder) for leveling the grains after reaching the desired load and for monitoring the moisture content of the top layer.

2. The BPRE flash dryer: The BPRE flash dryer was developed to flash dry high moisture grain from 24 to 18% using high temperature and airflow. Initial findings showed that corn could be dried using a temperature of 100 to 150℃ and airflow of 3000 cfm. The dryer has a capacity of 3 – 5 sacks per hour if drying is done up to 18% moisture from an initial moisture of 28 to 35%. The unit installed at TIAC is a stationary type and uses a corn cob-fired furnace (Fig. 7).

The two hauling trucks of the co-op are used in transporting the harvested corn from the farm to the cooperative. The flash dryer and the drying pavement are used in the pre-drying of the daily procurement of the cooperative.

3. Operation of the two-stage dryer: The moisture content of freshly harvested corn in South Cotabato falls within the range of 30 to 35%. Pre-drying is always needed before loading the corn to the in-store dryer. The BPRE flash dryer and the TIAC drying pavement are used in the first stage drying and the in-store dryer for the second stage drying to a moisture content of 18 and 14%, respectively.

The drying bin is divided into three compartments. Each compartment has separate control lever for air entry and unloading ports. The operator have the option to operate selected number of compartments because of these features.

The in-store dryer should be operated when the relative humidity falls within the range of 65 to 75%. to come up with an equilibrium moisture content of 13 – 14%. Results of the weather analysis in the area showed that the relative humidity of the ambient air varies from 71% to 96%. Supplemental heating during the period of very high relative should be done to achieve the 13 – 14% moisture content distribution within the grain bed.

Drying Operation

Christian Farmers Cooperative

A total of about 114 tons of skin dry paddy were dried in two batches. The first batch was 66.3 tons and 47.3 for the second batch. The moisture content of freshly harvested paddy ranged from 22% to 28% thus first stage drying is needed. The coop recirculating dryer and drying pavement were used in the first stage drying. The pre dried paddy of an average moisture content of 17.5% were loaded manually to the in-store dryer. Paddy with different grades and varieties were loaded into separate bins. After loading, the paddy in the top layer were leveled and the air velocity was set at 4 m/min.

Fig. 5. The main office of Tupi Integrated Agricultural Cooperative in Bo. Crossing Rubber, Tupi, South Cotabato.

Fig. 6. The front view of the 30 ton in-store dryer showing the corrugated metal bin walls and unloading ports.

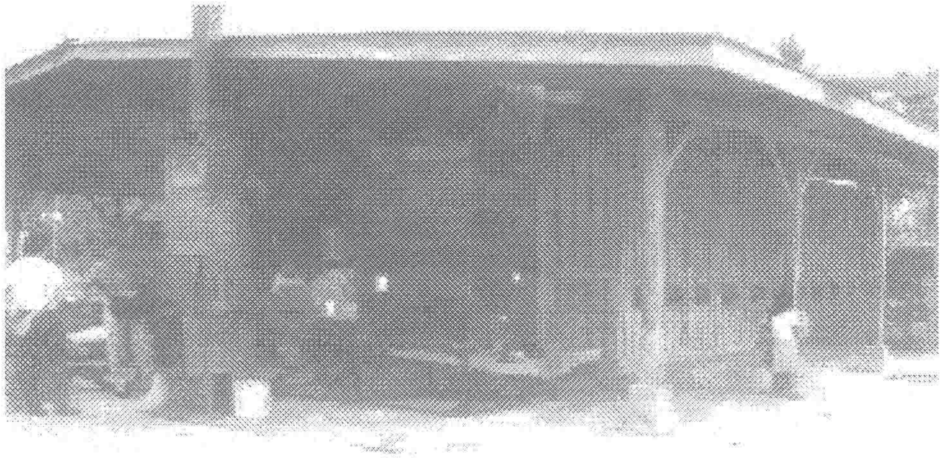

Fig.7. The 30 tons in-store dryer together and the BPRE 0.6 ton/hr flash dryer with corn cob fired furnace.

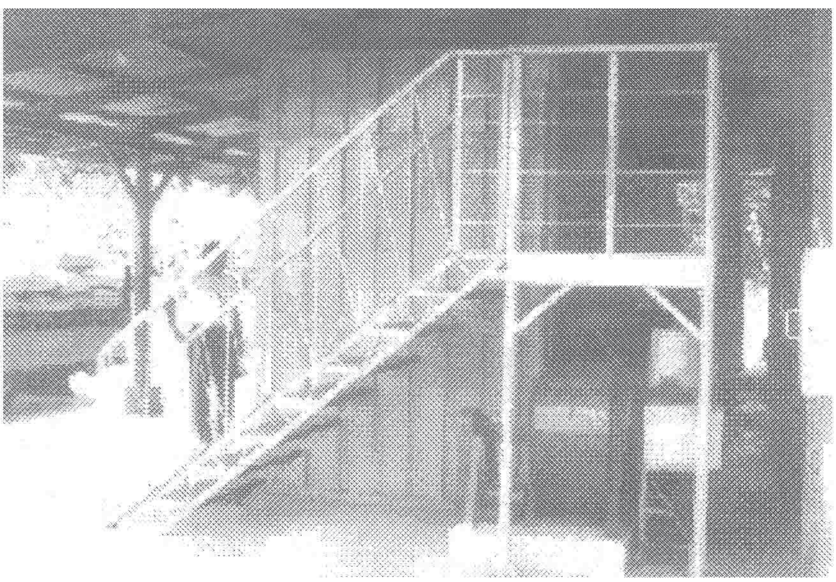

Fig.8. The side view of the in-store dryer showing the step ramp, 2 hp backward-curved centrifugal blower and kerosene vaporizing pot burner.

Tables 2 and 3 show the summary of the results of the drying operation conducted from October to November 1996. Continuous mode of drying was adopted. The operating time varied from 36 hours to 137 hours due to differences in initial moisture content, bed depth and air flow rate. The average final moisture content was 14%. Low ambient relative humidity inside the warehouse resulted to a burner operating time of 28% of the total drying period. The average energy cost of P 1.15/cav (US $0.87/ton) was broken down into an electricity cost of P 1.00/cav (US $0.75/ton))and P 0.15/cav (US $0.11/ton) for the fuel cost(kerosene).

In terms of uniformity of drying, the lowest moisture gradient of 0.6% between the top and bottom layers was obtained. The head rice recovery of paddy after the in-store drying ranged from 84% to 92%. There was also no significant change in color. A comparison was made among the milled rice samples obtained from the same batch of paddy that wet into the sun drying pavement, the recirculating dryer and the two-stage dryer for complete drying. Ocular inspection of the milled rice samples showed marked differences in the head rice recovery of the samples with up to 90% head rice recovery for the two-stage dryer, up to 80% head rice recovery for the recirculating dryer and up to 60% for the sun drying pavement. There was no significant difference in terms of milling recovery and whiteness.

Tupi Integrated Agricultural Cooperative

Two batches of in-store drying operation were made in the 1995 wet season test run of the in-store dryer Only one compartment was loaded per batch due to decrease in coop procurement caused by insect infestation in the towns of Tupi and Tampakan It was observed that most of the harvested corn during the wet season have high initial aflatoxin level and not recommended for in-store This is due to continuous raining in South Cotabato that delays the pre-drying of corn.

Table 2. Summary of the results of the first batch drying operation at Christian Farmers Cooperative.

	Bin 1	Bin 2	Bin 2	Bin 3	Bin 4	Bin 5
VARIETY	IR-64	RC-18	RC-18	IR-64	IR-64	RC-18
INITIAL M.C., % w b.	17.0	18.0	18.2	17.0	17.0	16.5
FINAL M.C %w.b						
Average	14.10	13.80	14.20	14.50	14.10	13.70
Minimum	13.60	13.10	13.10	14.10	13.60	12.30
Maximum	14.80	14.00	15.00	14.70	14.50	14.90
AMBIENT AIR TEMP. °C						
Average	29.05	28.94	29.46	29.61	28.78	29.16
Minimum	26.00	26.50	26.00	27.50	26.50	26.00
Maximum	33.00	31.50	33.50	31.50	31.50	33.00
PLENUM AIR TEMP. °C						
Average	30.68	30.91	31.10	31 65	30.47	30.76
Minimum	27.50	27.50	27.50	29.00	27.50	27.50
Maximum	34.50	34.00	34.50	34.00	34.00	34.50
AMBIENT REL. HUMIDITY %						
Average	75.20	77.69	74.96	76.41	74.87	73.97
Minimum	60.40	67.60	57.70	70.30	67.60	57.70
Maximum	92.70	85.50	92 70	82.20	85.20	92.70
PLENUM REL HUMIDITY %						
Average	68.47	69.48	68.01	68.05	68.08	67.47
Minimum	55.50	58.70	61.00	61.00	58.70	53.10
Maximum	85.00	80.40	76.60	76 60	80.20	85.00
BED DEPTH m.	2.1	1.3	2.0	0.6	0.7	1.8
AIR VELOCITY m/min	4.12	4.35	3.62	4.18	4.82	3.75
AIRFLOW RATE (m^3/min/m^3 paddy)	1.96	3.35	1.81	6.97	6.89	2.08
PLENUM STATIC PRESSURE (in H_2O)	1.5	0 7	1.25	0.4	0.5	1.25
MASS OF WET GRAIN kg	18480	9870	16100	4510	3470	13895
MASS OF DRIED GRAIN kg	17495	9455	15675	4260	3230	13570
WT. OF WATER REMOVED kg	945	415	425	250	240	325
FAN OPERATING TIME hrs.	137	74	113	36	44	102
BURNER OPERATING TIME hrs	37	26	12	0	12	26
DRYING TIME days	Oct 4 – 10	Oct. 4 – 7	Oct. 8 – 15	Oct 5 – 6	Oct 6 – 8	Oct 7 – 11
DRYING RATE kg H_2O/hr.	7.19	5.61	3.76	6.94	5.45	3.22
ENERGY COST (P/cav) (US$ /ton)	1.07 (0.81)	1.16 (0 88)	0 84 (0.63)	1.18 (0.89)	1 77 (1.34)	0.87 (0.66)
Fuel cost (P/cav) (US$ /ton)	0.16 (0.12)	0.20 (0.15)	0.10 (0.08)	0.20 (0.15)	0	0.06((0.04)
Electricity cost (P/cav) (US$ /ton)	0.91 (0.69)	0.96 (0.73)	0.74 (0.55)	0.98 (0.74)	1.77 (1.34)	0.81 (0.62)

Notes:

1 Continuous drying operation

2 Air velocity measurement done using the Casella

3 Ambient relative humidity derived from the dry and wet bulb temperatures

Table 3. Summary of the results of the second batch in-store drying at Christian Farmers Cooperative

	Bin 1	Bin 2	Bin 3	Bin 4
VARIETY	RC-18	IR-64	Mixed Variety	IR-64
INITIAL M C., % w b.	17.5	17.8	18 1	17.2
FINAL M C. %w.b.				
Average	14.3	13.9	13.8	14.1
Minimum	13.9	12.6	12.1	13.2
Maximum	14.6	14.8	14.5	14.7
AMBIENT AIR TEMP. °C				
Average	28.75	28.80	29.37	29.37
Minimum	27.00	27 00	27.00	27.00
Maximum	30.50	31.50	34.00	34.00
PLENUM AIR TEMP °C				
Average	31.34	30.55	30.80	30.85
Minimum	29.00	28.00	28.00	28.50
Maximum	33.00	34.50	35.00	35.00
AMBIENT REL. HUMIDITY %				
Average	77.52	77.48	71.15	74.34
Minimum	70.00	62.10	56.60	58.10
Maximum	85.2	85.6	85.6	85.6
PLENUM REL. HUMIDITY %				
Average	66.87	70.18	65.58	68.33
Minimum	59	54.3	52	53.4
Maximum	77.7	80.8	80.8	80.8
BED DEPTH m.	0.8	1.8	2 2	1.4
AIR VELOCITY m/min	4.95	4.21	4.11	5.13
AIRFLOW RATE(m^3/min/m^3 paddy)	6.19	2.34	1.87	3.66
PLENUM STATIC PRESSURE (in H_2O)	0.6	1.2	1.5	1.0
MASS OF WET GRAIN kg	5915	13556	17272	10595
MASS OF DRIED GRAIN kg	5614	12797	16312	10291
WT. OF WATER REMOVED kg	301	759	960	304
FAN OPERATING TIME hrs.	45	102/	135	69
BURNER OPERATING TIME hrs	24	18	17	9
DRYING RATE kg H_2O/hr.	6.69	7.44	7.11	4.4
DRYING TIME days	Oct. 26–27	Oct. 27–31	Oct. 28–Nov. 6	Oct. 29–Nov. 4
ENERGY COST (P/cav) (US$/ton)	1.45 (1.09)	1.04 (0.78)	1.05 (0.79)	1.07 (0.81)
Fuel cost (P/cav) (US$/ton)	0.35 (0.26)	0.12 (0.09)	0.09 (0.07)	0.09 (0.07)
Electricity cost (P/cav) (US$/ton)	1.10 (0.83)	0.92 (0.69)	0.96 (0.72)	0.98 (0.74)

Notes:

1 Intermittent drying operation

2 Air velocity measurement done using the Casella air velocity meter

3 Ambient relative humidity derived from the dry and wet bulb temperatures

The delivery of the BPRE flash dryer was delayed from November 1995 to February 1996 and was not used in the wet season operation Because of continuous raining and delay in the delivery of flash dryer, the in-store dryer was used as flat bed dryer. The Target method of aflatoxin detection was used in monitoring the aflatoxin level during the first stage drying operation Only corn samples with aflatoxin level less than 20 ppb were loaded in the in-store dryer for second stage drying. An average of 7 tons per batch was loaded in the in-store dryer. The airflow rate was set at an average of 5 m/min. The initial moisture content of the first and second batch were 17.68% and 15.72%, respectively. As shown in Table 4, the operating time of the fan varied from 62 hours to 84 hours due to differences in initial moisture content

The in-store dryer was successfully operated during the two consecutive harvest seasons (July-September 1996 and December 1996 – February 1997) of corn at Tupi, South Cotabato. Field moisture content of the freshly harvested corn ranged from 30 – 35% thus, pre-drying was done prior to in-store drying Both the in-store dryer and drying pavement were utilized as first stage dryers. When using the in-store dryer as pre-dryer, the grain depth was limited to about 0.5 m and drying air temperature of 50℃ was used. Some form of manual mixing was done to ensure uniformity of drying. After the first stage drying, the partially dried corn were loaded manually into the dryer. Each bin was loaded with depths varying from 1.1 to 1.9 m. Only corn samples with aflatoxin level less than 20 ppb were loaded. The aflatoxin level was monitored by using the Rapid Method of Aflatoxin Detection Grain surface was levelled manually to avoid uneven airflow within the grain depths and operation of the dryer was started.

Table 5 summarized the results of in-store drying operations conducted. Two batches of in-store drying were conducted during the July-September harvest period and one batch for the next harvest period. About 43 tons of skindried corn (16.8% – 17.5%) were dried by continuous and intermittent modes of drying. The plenum static pressure recorded ranged from 1 – 1.25 inch water with an equivalent air velocity of 4.02 – 5.6 m/min. During periods when the ambient air relative humidity exceeds 75%, supplemental heating was applied. Average temperature difference between ambient and drying air was 2.7℃ This is comprised of 1℃ average temperature rise due to heat of compression in the blower and 1.7℃ average temperature rise due to heat from kerosene burner Note that the grain depth, initial moisture content and airflow rate differ for each bin. Due to these differences in operating conditions that the fan operating time varied from 44.83 hours to 120 hours. As expected, bins with the highest initial moisture content and bed depth required the longer drying time. Consequently. The energy cost which consists of the fuel and electric cost varied also from P1.39 – P2.53/cavan (US $1.05 – US$1.90/ton).

Using the CB Method of Aflatoxin Level Determination, it turned out that there was no significant difference in the aflatoxin level before and after drying. The aflatoxin level is less than 10 ppb and therefore still safe for human consumption.

Analysis of the ambient air during the duration of drying periods in July-September and December-February showed that the climate in Tupi was generally cool and humid. The ranges of temperature and relative humidity throughout the day were 24 – 33℃ and 68 – 100%, respectively The average ambient air temperature and relative humidity were 24 ℃ and 83%, respectively. During early morning (6am – 8am) ambient air relative humidity were as high as 85% – 100%. Only in late morning (About 9 30 am – 11 00 am) that the relative humidity fell down to an average of 78% Also, it usually rains during mid-afternoon such that the ambient air became cooler and more humid the rest of the day Thus, if the coop will rely on sundrying, majority of the corn being procured by the coop will deteriorate (i e growth of molds, discoloration, etc.) either due to delay in drying or longer drying period resulting to very slow drying rate. Hence with the integration of two stage drying system, the coop greatly improved its grain handling capability and reduced its operating cost.

Benefits Derived From the Two-Stage Drying System

The primary benefit that the two farmer cooperatives derived from the use of the two-stage drying system was the great improvement in their capability in handling wet grains. Grain postharvest losses due to delay in drying, rewetting, discoloration and grain fissuring will now be problems of the past The coops can now receive most if not all of the total production of their members. Despite the variability in the quality and variety of grain being harvested by individual farmers, the flexibility in the operation of the two-stage drying system can still contain the situation. This means that the coops have more grains to store and to market.

The use of the two-stage drying system entailed an operating cost in the range of P2.00/cavan (US$1.51/ton) to P5.00/cavan (US$3.77/ton), depending on the harvest season and rainfall pattern in the area. The above cost is highly competitive with sun drying which costs about P5.00/cavan (US $3.77/ton). In addition, while the conventional heated air dryers are cost effective only during the wet season, the two-stage drying system is cost effective for both the dry and wet seasons. This means that the annual utilization of the dryer will at least be doubled. Hence, this will have corresponding decrease in the drying cost.

The production of premium quality dried product is another big advantage of the two-stage drying system. Considering the price differential between the regular milled rice and premium quality rice, at least P100/cavan (US $7.55/ton) of additional income can be realized. In the case corn, the price of high quality grain with tolerable level of aflatoxin demands a higher price than the regular processed corn. The Christian Farmers Cooperative is now regularly supplying about 8,000 bags per month of high quality milled rice to three private companies in Metro Manila The Tupi Integrated Agricultural Cooperative is currently negotiating a contract with a big private corn processor in Mindanao in the regular supply of high quality dried corn

In terms of investment cost, the two-stage drying system is much cheaper by at least four times than the available heated air dryers of the same capacity available in the market The TiAC set-up which can handle about 8 tons per day of completely dried corn will cost about P 300,000 (US $11,321) in the market The CFKB set-up with a cheaper and more efficient first stage dryer and which can accommodate about 20 tons per day of completely dried grain can be sold at about P 1,000,000 (US $ 37,736).

Table 4. Summary of the results of the 1995 wet season test run of the in-store dryer for corn at TIAC in Tupi, South Cotabato.

	Bin A	Bin B
VARIETY	Yellow corn	Yellow corn
INITIAL M.C., % w.b	17.68	15.72
FINAL M.C. %w b.		
Average	13.81	13.60
Minimum	12.36	12.54
Maximum	14.98	14.74
AMBIENT AIR TEMP °C		
Average	28.15	27.64
Minimum	25 50	24.00
Maximum	32 00	33.00
PLENUM AIR TEMP °C		
Average	30.78	30.87
Minimum	26.50	27.50
Maximum	37.00	39.00
AMBIENT REL HUMIDITY %		
Average	85.00	86.94
Minimum	70 80	74.00
Maximum	96.20	96.10
PLENUM REL. HUMIDITY %		
Average	71.04	72.08
Minimum	52.10	50.30
Maximum	93.40	86.60
BED DEPTH m.	1.32	1.40
AIR VELOCITY m/min	5.20	4.53
PLENUM STATIC PRESSURE (in. w g.)	0.92	1.00
MASS OF WET GRAIN kg	7017	7323
MASS OF DRIED GRAIN kg	6375	6957
WT. OF WATER REMOVED kg	642	366
FAN OPERATING TIME hrs	84	62
BURNER OPERATING TIME hrs	71	58
DRYING PERIOD days	Dec 13 – 20	Feb. 9 – 12
DRYING RATE kg H_2O/hr.	7.64	5.9
ENERGY COST (P/cav) (US $ /ton)	2.30 (1.74)	1.87 (1.41)
Fuel cost (P/cav) (US $ /ton)	1.20 (0.91)	1.12 (0.84)
Electricity cost (P/cav) (US $ /ton)	1.10 (0.83)	0.75 (0.57)

Notes:

1 Intermittent drying operation

2 Air velocity measured using vane anemometer

3 Relative humidity derived from dry bulb and wet bulb temperatures

Table 5. Summary of the results of in-store drying operation at TIAC, Tupi, South Cotabato (1996 – 97)

	July – Sept Harvest Season				Dec – Feb Harvest Season*	
	1st Batch*	2nd Batch**				
	Bin 1	Bin 1	Bin 2	Bin 3	Bin 1	Bin 2
VARIETY	Yellow corn	Yellow corn	Yellow corn	Yellow corn	Yellow corn	Yellow corn
INITIAL M.C , % w.b.	17.50	17.60	17.00	16.80	16.80	17.30
FINAL M.C. %w b.						
Average	13.20	13.70	13.20	13.60	13.80	13.70
Minimum	11.90	12.45	11.80	12.80	12.80	12.50
Maximum	14.90	14.90	14.30	14.40	14.70	14.90
AMBIENT AIR TEMP. °C						
Average	27.80	29.68	29.30	29.30	28.02	28.21
Minimum	24.00	24.50	24.50	24.50	25.00	25.00
Maximum	33.00	33.50	33.00	33.00	33.00	33.00
PLENUM AIR TEMP. °C						
Average	30.07	32.38	32.01	32.01	30.70	30.75
Minimum	26.00	26.00	26.00	26.00	26.00	26.00
Maximum	34.50	37.00	34.50	34.50	34.50	34.50
AMBIENT REL. HUMIDITY %						
Average	82.72	81.01	81.14	81.14	82.83	82.90
Minimum	68.40	68.70	68.70	68.70	68.10	68.10
Maximum	92.40	100.00	96.00	96.00	92.50	96.20
PLENUM REL. HUMIDITY %						
Average	72.37	69.54	69.52	69.52	71.00	71.63
Minimum	58.5	57.9	57.9	57.9	58.50	58.50
Maximum	87.00	94.30	87.80	87.80	87.20	90.70
BED DEPTH m.	1.7	1.9	1.15	1.2	1.10	1.20
AIR VELOCITY m/min	4.02	4.2	4.3	5	4.73	5.60
PLENUM STATIC PRESSURE	1	1	1	1	1.0	1.25
MASS OF WET GRAIN kg	8552	10574	6084	6230	5365	6084
MASS OF DRIED GRAIN kg	8029	9816	5700	5678	5156	5853
WT. OF WATER REMOVED kg	523	758	384	552	209	231
FAN OPERATING TIME hrs.	120	102.5	44.83	44.83	66	72
BURNER OPERATING TIME hrs	84	68.25	27.76	27.76	47	47
DRYING PERIOD days	Aug 11 – 16	Aug. 23 – Sep. 1	Aug. 23 – 26	Aug 23 – 26	Dec 6 – 9	Dec 6 – 9
DRYING RATE kg H_2O/hr.	4.43	7.4	8.57	12.3	3.17	3.21
ENERGY COST (P/cav) (US$ /ton)	2.53 (1.91)	1.98 (1.49)	1.43 (1.08)	1.39 (1.05)	2.49 (1.88)	2.45 (1.85)
Fuel cost (P/cav) (US$ /ton)	1.45 (1.09)	0.80 (0.60)	0.60 (0.45)	0.58 (0.44)	1.52 (1.15)	1.52 (1.15)
Electricity cost (P/cav) (US$ /ton)	1.08 (0.82)	1.18 (0.89)	0.83 (0.63)	0.81 (0.61)	0.97 (0.73)	0.93 (0.70)
Aflatoxin level ppb						
Initial	6.74	2.39	6.88	5.12	ND	1.528
Final	9.48	1.63	8.63	2.8	ND	1.09

* Continuous drying operation
** Intermittent drying operation
ND-Not Detected

Acceptability to the End-user

The two-stage drying system has breezed its way through into becoming an integral part the post harvest operations of the selected farmer cooperatives due to the following reasons or features:

1. It greatly improved the coop's grain handling capability.
2. It is competitive with sun drying in terms of operating cost.
3. It provides additional income due to premium quality grains.
4. It is more affordable than available dryers in the market.
5. It is relatively easy to operate once the drying principles and procedures are learned
6. It has a wide range of design capacities.

Conclusions and Recommendations

The two-stage drying system has proved to be feasible in the selected rice and corn farmer cooperatives. This system has offered incomparable benefits in terms of improved grain handling capability, low operating and drying costs, premium quality grain, more affordable investment, easy to operate and flexible drying capacities

The success of the two-stage drying system in selected farmer cooperative has prompted the government to adopt this drying technology on a much wider scale. Under the Gintong-Ani (Golden Harvest) Program of the Department of Agriculture, 12 units of the two-stage drying system with the in-store dryer for the second stage drying are being allocated to deserving rice and corn farmer cooperatives nationwide as demonstration and promotional units in each region of the country.

The end-user of this two-stage drying system should process the dried paddy and sell the grain in milled rice form to take advantage of the additional income due to premium quality grains

References

de Padua, D. B 1996. Perspectives on drying problems in the Southeast Asian Region and the results of R & D projects to solve them. In Champ, B.R., Highley, E. and Johnson, G.I eds. Grain Drying In Asia – Proceedings of an International Conference, FAO Regional Office for Asia and the Pacific, Bangkok, Thailand, 17 – 20 October, 1995.

Naewbanij, M. 1996. Problems and priorities of grain drying in Thailand. In Champ, B. R., Highley, E. and Johnson, G.I eds. Grain Drying In Asia – Proceedings of an International Conference, FAO Regional Office for Asia and the Pacific, Bangkok, Thailand, 17 – 20 October, 1995

Srzednicki, G and Driscoll, R H 1996 Two-stage concept for grain drying in Southeast Asia Invited paper presented in the International Conference on Food Industry Technology and Energy Applications November 13 – 15, 1996, King Mongkut's Institute of Technology Thonburi, Bangkok, Thailand.

Tumambing, J A., Bulaong, M C, Miranda, L. N. and Daquila, R E 1996. Application of in-store drying in the grain industry in Southeast Asia. Tecnical Bulletin No. 17. National Postharvest Institute for Research and Extension, 20 p.