Research and development issues in grain postharvest problems in Asia

GASGA

GROUP FOR ASSISTANCE ON SYSTEMS RELATING TO GRAIN AFTER HARVEST

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GASGA-the Group for Assistance with Systems relating to Grain After-harvest-is a voluntary association of organizations primarily linked with donor operations.

These organizations all have major involvement in most, if not all, of the following:

- the provision of professional advice;
- the conduct of field projects;
- the training of developing country personnel; and
- and the conduct of research and its application in relation to the problems of the postharvest sector of the production of grain and other major food commodities in developing countries.

The association is essentially technical; it is international in character, but informal and limited in membership, so that its deliberations, aimed at the specific objectives indicated below, can take place readily.

GASGA consists of the following organizations:

- Australian Centre for International Agricultural Research, Canberra, Australia (ACIAR)
- Centre de Cooperation International en Recherche Agronomique pour le Developpement, Montpellier, France (CEEMAT/CIRAD)
- Deutsche Gesellschaft fur Technische Zusammenarbeit (GTZ) GmbH, Eschborn, Federal Republic of Germany (GTZ)
- Food and Agriculture Organization of the United Nations, Rome, Italy (FAO)
- Food and Feed Grain Institute, Kansas State University, Manhattan, Kansas, USA (KSU)
- International Development Research Centre, Ottawa, Canada (IDRC)
- Koninklijlc Instituut voor de Tropen, Amsterdam, The Netherlands (Kim
- Overseas Development Natural Resources Institute, Chatham, England (ODNRI)

GASGA aims to stimulate improvement in the technical help given to developing countries in the postharvest handling, processing, storage and transport of grain, and to harmonise activities so that the most effective use is made of members' resources. GASGA seeks to identify and suggest ways of meeting needs for research, development, training and information in this subject field, in the light of existing or planned operations by GASGA members and other organizations.

The Group is also prepared to answer requests for technical advice put to it by developing countries.

GASGA also seeks to facilitate the appropriate dissemination of information about technical developments and activities in the postharvest sector to donors, developing countries, and other interested organizations. The last group includes, for instance, the International Agricultural Research Centres whose commodity-oriented preharvest programs need links with postharvest activities and requirements.

The GASGA Executive meets annually to review progress in its activities and discuss proposals for future work

Since the 19th Executive Meeting, held at Feldafing, West Germany, a technical seminar has been held in association with the annual meetings and the papers presented at the seminar published in the GASGA Executive Seminar Series.

This volume, the second in the series, publishes the papers presented at a seminar during the 20th GASGA Executive Meeting, held at ACIAR Headquarters in Canberra from 31 August-1 September 1988.

Overview of grain drying and storage problems in India

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Abstract

India produces about 150 million tonnes of food grain per year and production is rising due to higher cropping intensities and the introduction of high-yielding varieties. However, annual post production losses have remained static at about 10%, which means that about 15 million tonnes of food grains are lost during harvesting, threshing, and storage. Storage losses amount to 6%.

Drying is an important operation that can preserve grain and lower losses during storage. In India, dryers are used mainly in grain processing industries, such as in rice and pulse mills. Some dryers are being used in modern drying-cum-storage complexes. However, 70% of the grain stored is sun dried. The reasons for non-use of dryers at farmer level are: unawareness of the importance of Brain drying; non-availability of dryers within their reach; high initial capital investment required; and lack of incentive for properly dried grain. Establishing drying-cum-storage complexes has been suggested as a possible solution. The use of dryers at rural-level food industries has also been targeted and units suitable for this level of operations are identified and described.

The proper scientific storage of well dried grain is also very important to reduce losses during storage. The grain is stored at farmers, traders and organizational levels by cooperatives and government departments engaged in public distribution of grain. Suitable storage structures at each stage are identified and described. The most promising among them are a coal tar bin developed at CIAE and low-density polyethylene-embedded bin for on-farm grain storage. A new type of multipurpose dryer developed at CIAE has been reported where, by changing the trays, the same drying chamber can be used for drying both grain and food products.

Introduction

India produces about 150 million tonnes of food grains per year. The major components of production are 47 million tonnes of wheat, 64 million tonnes of rice, and 13 million tonnes of pulses (Anon. 1987). Due to technological advances in agriculture and the introduction of high-yielding varieties, this may increase. From this production, an average 10% is lost during postharvest operations between the field and the consume. This means that about 15 million tonnes of food grain, valued at about $A240 million (Indian Rupees 2400 million) goes to waste. The major share of the loss occurs during storage of surplus stock. Among the various causes of losses, the most important one is improper drying before storage.

The preservation of agricultural produce by drying is a long-established technique. Sun drying in the open, on mud-plastered or concrete floors, is the conventional method of drying grain and also cash crops like chillies, and plantation and horticultural crops. The drying time required in the open sun for these crops ranges from 5 to 45 days depending upon the crop to be dried. Unfavourable weather conditions are likely to occur during the drying period and degradation in quality of the final produce therefore becomes unavoidable.

It is well-known that deterioration in quality caused by improper drying cannot be eliminated until improved drying systems based on mechanical dryers have been adopted. However, for many reasons, these systems have not been adopted. The main reason that is encountered is a lack of organizational or government incentive to the farmer to deliver a quality product that might command a premium price. This results in not only a negative attitude, but also leads to the overall quality of the product gathered at market points being alarmingly poor.

A second important reason for not using dryers is their high initial costs. Most of the commercially available dryers are designed to suit the needs of the processing industry and their output capacity is therefore far above the needs of individuals, or even of farmer groups.

An awareness of availability of dryers and of their use and advantages in drying food grain for better storage and marketing is lacking among crop growers. The main reason for this is inadequate extension programs. So far, extension agencies have concentrated on increasing production. The time has now come to see that grain saved is equivalent to grain produced. High technology has led to production targets being achieved, but much less attention has been given to minimising losses which have remained constant since the beginning of the 'Green Revolution'. Annual postproduction losses by crop in India, expressed as a percentage of total production, are estimated to be as follows: wheat, 8%; paddy, 11%; pulses, 9.5%; and all food grains, 9.3%.

This paper describes the use of various types of dryers in the Indian food industry and the efforts of research and development organizations to devise dryers suitable for individuals or small groups in the rural population. However, even with properly dried grain, scientific storage remains important and recent advances in developing various storage structures are also described.

Commercial use of dryers

Dryers are used extensively in grain processing industries such as rice milling, pulse milling, and oil extraction. Here the need for dryers has been realised not only for proper storage of stock but also for timeliness of subsequent operations where wetting of grain and redrying are involved.

In the case of the rice milling industry, parboiling of rice is a common practice. The population of the coastal belt of the country consumes parboiled rice and about 70% of production is processed in this manner. The paddy is soaked in water for variable lengths of time depending on the process used and is then steaming.

High moisture content (m.c.) paddy is dried to 12-14% m.c. for milling. There are about

100 000 rice mills with a total installed capacity of about 40 000 tonnes of paddy per hour. About 30000 dryers of 1-2 t/h drying capacity are in use in the industry. The most commonly used dryer is the LSU type in which air is heated for drying by burning rice hulls. The steam requirement for drying is 21.3% of the total steam produced in the boiler, which consumes about 4% of the total power required by the mill. In this type of dryer, the grain is tempered for 30 minutes after every hour of drying so to equilibrate the moisture and avoid stress cracking in further milling operations.

Dryers are also used in the pulse milling industry. Here both LSU-type and flat-bed perforated-floor dryers are wed, ranging in capacity from 1-4 t/h. There are about 4000 pulse mills in India having an average processing capacity of 10-20 t/day. Dryers are required in industry for the following reasons:

- to dry the stock purchased from market before storing it; and
- to dry the grain which has become wet during processing.

In the LSU-type dryer, steam is used as the heating source, while in the flat-bed dryers, light diesel oil is wed, fuel consumption being 7-12 l/h One such commercial dryer is shown in Figure 1. It consists of a drying tray or platform, an oil-fired burner, and an air blower. The cost of a 3 t/h dryer is about SA13 500 and the drying cost has been reported as $1A/t (Thermax India Ltd. personal communication 1988).

Use of dryers at farmer level or in community drying systems

About 70% of total grain production in India is retained at farmer level: only 30% is sold on the open market. This means that a sizeable quantity of about 105 million tonnes is kept by farmers. The losses here, though perhaps not felt by individuals, on a collective basis have a substantial impact on the country. It is therefore essential that drying technology be disseminated to this group which is a major custodian of the nation's grain.

To promote the use of dryers in rural areas, the concept of a community drying-cum-storage system was put forward by T.P. Ojha in 1984. He suggested that changes in ecological balances and the introduction of high- yielding varieties of field crops necessitated the use of mechanical dryers and other devices to protect the food grains from spoilage due to untimely rains.

If rain-soaked food grains are not dried properly, farmers have to sell their excess stocks at low prices to meet urgent financial needs. A community drying-cum-storage centre would therefore serve them well by way of protecting the grain from spoilage and also by advancing temporary loans on their grain deposits. As soon as grain prices stabilise, stocks can be sold and payments can be made to the farmers after deducting dues such as rental and service charges, loans paid, and interest on advances. Such a system would no doubt benefit farmers. They would not be required to make forced sales of their produce and, as a result, storage losses would be minimised.

For such complexes, selection of a dryer of the correct design is very important. The largecapacity dryers used in grain-processing industries are not economical or feasible for most farmer groups. In India, the average village has a population of about 1000 and the small amount of surplus grain available for drying at this level suits dryers of 2-4 t/day capacity operating for 60 days per year. In India, many research organizations have developed, or are currently developing dryers for village groups, but so far with little success.

The main considerations for selection of a grain dryer suited to this level are:

- 1. the dryer should be of a size that matches the amount of grain available in a village or a cluster of villages;
- 2. the dryer's cost should be within the reach of users;
- 3. it must be simple in construction and operation and easily understandable to users;
- 4. the dryer should be simple in design so that it is easy for local artisans to repair, and
- 5. the dryer should be suitable for drying a range of crops.

Grain dryers suitable for rural level use

Some important grain dryers developed at different R&D institutions and agricultural universities are described in the following sections.

Small-Capacity, Continuous Grain Dryer

Fig. 1. Commercial batch dryer.

The dryer developed at G.B. Pant University of Agricultural and Technology, Pantnagar, is a continuous type consisting of a frame, grain column, plenum chamber, feed hopper, discharge hopper, heating unit, and blower (Fig. 2). The grain column consists of two vertical columns sandwiched between two vertical screens. Each screen wall consists of an expanded metal netting and wire mesh screen on the inner and outer sides. The plenum chamber has been provided between the two grain columns in order to distribute the air uniformly and at right angles to the direction of grain movement. A centrifugal blower forces the air at 37 m3/min airflow against 2.5 cm of Hg. The air is heated from 40C to 70C by 20 kW electric heaters. The dryer has capacities of 0.8 t/h for wheat, 0.8 Ah for paddy, 0.96 t/h for maize, and 0.8 t/h for red gram. The cost of the dryer, excluding the heater and fan, is about $A330 (Indian Rupees 3300), based on 1982 estimates, and the cost of drying is around $A0.50/t

(Singh et al. 1982).

Fig 2. Continuous grain dryer (dimensions are in mm)

Cup and Cone Dryer for Paddy Drying

A somewhat different design of dryer has been tested at the Paddy Processing Research Centre (PPRC) at Thiruwarur in India. It consists (Fig. 3) of five cups each having a diameter of 1070 mm and a slope of 52. Each cup and cone is made of mild steel rod and wire mesh. A hot-air duct of 300 mm diameter passes through the centre of the dryer from the top; the bottom end of the duct is closed.

Individual cups and cones are mounted one above the other by means of bolts and nuts. Paddy passes through the inner surfaces of the cups and exteriors of the cones. To divert the flow of paddy from the outer surfaces of the cones to the inner surfaces of the cups, cylindrical retainers of mild steel sheet are provided. A two-way valve is provided just beneath the bottom of the dryer. A slide is provided at the junction of the two-way valve and the bottom of the cup. This is kept completely open during recirculation and bagging. The hot air generated in a husk-fired furnace passes through a vertical duct and enters the paddy column by means of a central duct having perforations at points covered by cones and the top portion. A circulation rate of 3.5

to 4.5 tonnes per hour is maintained while drying.

Trials conducted during high humidity weather indicated that 950 kg of parboiled paddy of 30% m.c. can be dried to 14% in 2 hours at a drying temperature of 120c and an airflow rate of 127.5 m^3/min. The drying cost is calculated at $A2.10(Rs 21.33)/t (Pillaiyar et al. 1982).

Fig. 3. Cup and cone paddy.

IGSI Batch Dryer

A batch dryer of 1 tonne capacity has been developed at the Indian Grain Storage Institute (IGSI), Hapur (Fig. 4). The unit consists of an electric fan, semi-fluidised bed furnace firing agricultural waste, and three vertical columns (250 mm each) in a paralleloid drying chamber. The drying chamber has provision for manual tilting. The dryer can accommodate 1.5 t of paddy per batch which takes 4 hours to dry. A tempering time of 20-30 minutes is incorporated between drying operations. The cost of the dryer is about $A1350 (Rs 13500) and the operating cost about $A3.20 (Rs 32)/t of paddy (G. Shankar, personal communication 1988).

Community Grain Dryer

The dryer developed at the Central Rice Research Institute (CRRI), Cuttack, is useful for village communities or small-scale rice millers (Fig. 5). It consists of a drying chamber, a husk-fired furnace (inclined grate 0.5 m at 45 inclination, horizontal revolving grate 0.15 m, and fluted roller-type husk feeding mechanism), solar collector (flat plate, black painted galvanised iron corrugated sheet with 23 slope towards south, 43.5 m surface area provided with 40 mm thick insulation of paddy straw and tar-felt sheet combination), blower {backward curved fan operated by a 5 hp motor with airflow capacity of 160 m/min at 25 mm water gauge static pressure), and a bucket elevator (2 t/h capacity operated by a 0.5 hp electric motor). Generally, it takes 6.5 hours to dry 1 t of paddy from 24% to 1496 m.c. The cost of the dryer is estimated at $A5000 and the cost of drying $A10.6/t (Kachru et al. 1986).

Fig. 4. IGSI 1 tonne batch dryer.

Solar cum Husk-Fired Paddy Dryer

This dryer has been developed at the Indian Institute of Technology (IIT.), Kharagpur (Fig. 6). The system consists of an unglazed flatplate collector which houses an inclined-type husk-fired grated furnace, a 3 hp electric blower and a batch-type dryer. Dampers are provided to put either the collector or the furnace into operation, depending on weather conditions. The absorber surface is a corrugated galvanised iron sheet coated with ordinary blackboard paint. A false roof of bamboo functions as an insulator. Two sides are closed to form channels for airflow. The blower assembly forces the heated air to pass it onto a batch dryer. The capacity of the dryer is I t/day. The cost of the dryer has been estimated at $A2000 and drying cost at $A8.8 /t (Kachru et al. 1986).

Recirculating Batch Dryer

A batch-type recirculating grain dryer has also been developed at IIT, Kharagpur. The unit consists of a dryer and a husk-fired furnace (Pig. 7). The dryer has two concentric perforated cylinders (the inner cylinder has a diameter of 900 mm and a height of 1500 mm and the outer cylinder has a diameter of 1350 mm and a height of 2250 mm), a 6000 mm-high bucket elevator with a capacity of 2.5 t/h, and a fan of 85 m/min capacity at a static pressure of 5 cm of water.

The husk-fired furnace consists of a hopper, a combustion chamber with inclined grate, and a curtain wall. It can burn 20 kg of paddy husk per hour. The fan draws air through the combustion zone of the furnace and blows the hot air to the inside chamber which acts as a plenum chamber. Air from this chamber travels through the paddy column and the outside cylinder. Paddy is fed in at the top of the inside cylinder and comes in contact with hot air while flowing downwards between the two cylinders. The feed rate of paddy is controlled by closing or opening the gate provided to the discharge hopper of the dryer. Paddy is circulated till the moisture content falls to 14%. The capacity of the dryer is 1.25 t/batch. The cost of the dryer is $A4000 and the drying cost $A4.5/t (Kachru a al. 1986).

Dryers for cottage-level industries

There is plenty of scope for setting up cottage-level food industries in the villages in developing countries. Recent trends indicate that the rural population is migrating to urban areas at an alarming rate in search of jobs. Due to the immediate sale of food grains or crops produced, the primary as well as secondary processing operations are in the hands of middle-men. This has created a social problem in rural areas.

Fig. 5. Community grain dryer.

Recently, the Government of India created a separate department to promote food processing industries at the rural level. Only some two centuries ago Indian villages were self sufficient, not only in food grains but also in value-added commodities based on those crops. Since the produce was processed at rural level, gainful employment was also available in rural areas. This discussion may appear irrelevant to the topic, but there is tremendous scope in developing agro-processing industries at the rural level. This would greatly reduce the present problem of unemployment in the country.

Pulse processing, rice processing, producing badi-like products from pulses (a cooked and dried product from pulses which is used in India for making curries), producing snacks like chakali, kurdaya, papad, etc. from pulses and cereals are all operations which can be done in villages at the domestic as well as collective level. Thus, there can be a viable processing industry in villages due to the labour-intensive nature of this work. Most of these operations are of the wet-processing type, where raw material is soaked either at the start or at an intermediate stage. However, where this is currently done, drying in the open is used because of ease of operation and also because it is the most economical method. Even fruit and vegetable drying is profitable at the grower level provided a proper drying system is available. The main considerations for adoption of dryers for these industries are:

- 1. they should be inexpensive;
- 2. installation, fabrication, operation, and maintenance should be easy;
- 3. they should use locally available construction materials and sources of energy;
- 4. they should need less space and if possible only temporary shelter, and

- 5. they should maintain complete hygienic conditions if used for drying food products.

Many R&D organisations in India have developed dryers suited for the above purposes but, for various reasons, they are not being used

Two types of dryers solar and mechanical) have been developed to meet the requirements of agro-industries:

Fig. 6. Solar cum husk-fired paddy dryer.

Solar Dryers

As India is a tropical country, solar energy is abundant. Broadly speaking, there are three main types of solar dryers:

Direct type: the material to be dried is placed in an enclosure with a transparent cover and side panel. Heat is generated by radiation absorption on the product itself as well as on the internal surface of the drying chamber. These dryers are used for crops which are not sensitive to sunlight.

Indirect type: solar radiation is not directly incident on the material to be dried. Air is heated in a solar collector and then inducted to the drying chamber.

Mixed type: the combined action of radiation incident on the material to be dried and air preheated in the solar air heaters provides the heat required to complete the drying operation. These dryers are used for materials which are not sensitive to light, and are quicker drying and have higher capacity ranges than the direct type of dryer.

Some promising solar dryers developed in India that can be used for food processing industries at cottage level are described in the next part of this paper.

Fig. 7. Recirculating batch dryer (dimensions in mm.)

CIAE Solar Cabinet Dryer

The CIAE solar cabinet dryer is a tray-type natural-convection dryer which can dry 30-50 kg per batch. The dryer can be constructed from materials such as wood, glass, plywood, wire mesh, and mild steel sheeting. It is simple in design and does not require any mechanical prime mover (Fig. 8). The dryer has been found suitable for drying chillies and potato chips. The cost of the dryer is $A150 and the cost of drying

$A94/t (Kachru et al. 19863.

CPCRI Solar Dryer

This is a cabinet-type dryer developed at the Central Plantation Crops Research Institute (CPCRI), Kasaragod. The frame of the dryer is made of wood. The drying surface (1.06 m) is made of 22 gauge corrugated galvanised iron sheet to give an absorber area of 1.19 m. The surface is inclined at an angle of 12.5 and is fitted on a 30 mm-thick wooden board with a 2 kg coir-fibre insulation between. The drying chamber is made up of 3 mm window glass on the sides, and 3 mm acrylic plastic on top to reduce the risk of breakage during handling.

The drying chamber is uniformly 40 cm high from the inlet to the exhaust end. The inlet and exhaust are covered with wire mesh. Commercial-grade aluminium foil mounted on hardboard is used for reflectors on three sides. The inlet opening is covered with a blackpainted galvanised iron sheet hood inclined at 45. Castor wheels are provided for changing the direction and for moving the dryer short distances. The galvanized iron rod on the top is used to determine the direction for sun tracking (Fig. 9). The cost of the dryer is $A220 and it can dry the material in half the time it would take using open drying, with double the spreading capacity. The dryer has been found suitable for drying copra, arecanut, and black pepper (Patil 1984).

Fig. 8. Solar cabinet dryer (CIAE) (dimensions in mm)

Fig. 9. CPRCI dryer (dimensions in mm)

Mechanical Dryers

Though solar dryers are economical, their use is limited. They are entirely weatherdependent, and the volume of the structure limits the quantity that can be handled. Solar dryers are less flexible when there is a range of crops to be dried. For these reasons, there is a need for a dryer that is low in cost, simple to operate, and uses locally available sources of fuel. The tray-type dryers are the most suitable for such types d operations. The commercially available tray dryers used in large food industries are not suitable for cottage industries because of their high capital and operating costs.

Some low-cost mechanical tray dryers developed by R&D organizations in India which have the potential to strengthen the agro-food industries are described in the following sections.

Mechanical Copra Dryer

This dryer (Fig. 10) has been developed at the Central Plantation Crops Research Institute (CPCRI), Kasaragod. The dryer can be made from materials such as wood, galvanised iron sheeting, AC sheet, asbestos rope, and mild steel sheet. The dryer consists of drying chamber, air distribution unit, plenum chamber, heating unit, and blower. The drying chamber has an air distribution unit in the centre with copra trays on both sides. The heating unit has 8 kW air heaters and the blower is equipped with a 1.5 hp motor. The hot air is distributed over the trays by the air distribution unit and the exit of the air is provided such that the hot air then passes through the material to be dried. This ensures uniform mixing of air and material being dried. The capacity of the dryer is 1000 nuts/batch and drying time is 30 h. The cost of the dryer is $A1200 and the operating cost $A65.3/t (Patil and Singh 1983).

Fig. 10 Mechanical copra dryer developed by CPCRI

Fig. 11 Natural convection food dryer for soybean (dimensions in mm).

Natural Convection Tray Dryer for Soybean

A tray dryer using agricultural waste as fuel and working on the principle of natural convection of hot air currents has been developed at CIAE (Patil and Shukla 1988). The dryer is made in two parts (Fig. 12). The bottom portion (i.e. plenum chamber) is made of mild steel angle frame and is covered with asbestos sheet on the sides and wire mesh on top. A drum-type, combustion heat-exchange unit with fins for effective heat transfer is located at the centre of this chamber. A chimney with a regulator valve has been provided at the other end to allow the smoke to escape.

A drying chamber made of softwood and plywood which can hold 20 trays is kept on the plenum chamber. The bottom of the drying chamber which rests on the plenum chamber is open and the top portion is provided with an air vent with an adjustable opening. Fuel is burned in the burning chamber at the rate of 3 kg/h. The dryer can take 100 kg of wet material. The average temperature in the dryer at this rate of combustion is 49C at no load, and 46C while drying. The trays are interchanged and the material is mixed/stirred at one-hour intervals. The drying time for soy split to reduce moisture content from 60% to 10% was 15 hours. To dry flakes from 30% to 10% required 6 hours. The cost of the dryer is about $A570 and the cost of drying $A25/t.

A new approach to developing a dryer for cottage level food industry

Given a proper sized, low-cost dryer, food processing can proceed uninterrupted in rural areas. At the village level, an industry to process surplus crops into acceptable and marketable food items needs a dryer for two kinds of operations.

Firstly, to dry the grain to maintain its storability until it is processed, and secondly to dry the finished product. Grain drying requires a dryer that can facilitate better mixing and contact between grain and air.

For food-product drying, drying in thin layers on trays is preferable. To have two different dryers for these operations is not feasible due to the limited space available and, in any case, would be uneconomical.

The plenum chamber and heating unit are generally common to all the dryers whether they are used for food or grain drying. Only drying chamber design varies according to the type of material to be handled. The drying performance of the dryer is then decided on the optimum quantity of material processed and required air characteristics. By making use of this fact a simple but unique dryer has been developed at CIAE Bhopal.

The dryer has a 2 hp fan, a 10 kW electric heating unit, and a drying chamber as shown in Figure 12. A trapezoidal plenum chamber is located in front of the drying chamber to ensure uniform mixing of hot air. The drying chamber is a simple short tunnel with panelling on both sides, insulated with rockwool. Mild steel angles are provided on the panels as runners for wire mesh trays or baffled trays.

When baffled trays are put on the runners, it forms a 200 kg holding capacity LSU-type dryer for drying food grain in small cottagelevel pulse processing or soy processing plant. When the dryer is needed to dry food products made after processing of raw material such as wet, scratched pulses, soy snacks, blanched soybean splits to make soyflour and soybean flakes, trays with plywood sides and wire mesh bases are used. This makes a tray dryer suitable for drying 100 kg of wet or soaked material per batch. The wooden trays are kept open on one side and closed on the other allowing variation in the drying chamber as required by the particular material being processed. If all the open portions are on the heater side, then the material is exposed to more air. If other combinations of open ends are used, the quantity of air entering and coming in contact with the material and its residence time can also be varied.

The dryer has been successfully tested for drying soybean grain and also blanched soydal or soysplits. It can dry 200 kg of soybean grain from 2496 m.c. wet basis to 10% in 4 hours.

Intermittent removal of dried grain raises the capacity of the dryer to 500 kg per day. When used as a tray dryer, it can dry 100 kg of blanched soysplits in 6-8 hours with intermittent mixing of materials. The cost of the dryer is about $A800 (Rs 8000), including a 2 hp blower.

Storage of food grains

In India, about 70% of farm produce is stored by farmers for their own consumption. Farmers store grain in bulk, using different types of storage structures made from locally available materials. The pre-treatment necessary for better storage life is cleaning and drying of the grain, but storage structure design and its construction also play a vital role in reducing or increasing the losses during storage. Storage losses constitute a major share of food grain loss in postproduction operations (Fig. 13).

When scientifically constructed storage structures are available, it is essential that the grain being loaded is of good quality. Therefore, the grain is cleaned to remove impurities, fungus infestation, and rotten seeds, and then dried to a safe storage moisture level. The present trend is to harvest the crop at a high moisture content. Therefore, grain moisture is generally twice the safe limit at the time of harvesting.

Oilseeds and vegetable seeds are harvested at 3-7 times higher moisture than their safe storage moisture content. The safe storage moisture limits for major food grains are given in Table 1.

Fig. 12. CIAE multi-purpose dryer (dimensions in mm).

Storage Structures at Farmer Level

The major construction materials for storage structures in rural areas are mud, bamboo, stones, and plant materials. They are neither rodent-proof, nor secure from fungal and insect attack. On average, out of a total 6% loss of food grain in such storage structures, about half is due to rodents, and half to insects and fungi. Some of the major considerations in building a storage structure to minimise losses are:

- the structure should be elevated and away from moist places in the house;
- as far as possible, the structure should be airtight, even at loading and unloading ports;
- rodent-proof materials should be used for construction of rural storages;
- the area surrounding the structure should be clean to minimise insect

breeding; and
- the structure should be plastered with an impervious clay layer to avoid termite attack, or attack by other insects.

Various research and development organizations in India have identified some proven, age-old structures from certain areas of the country and based on these, some improvised storage structures have also been developed and recommended for use at farmer level.

Fig. 13. Diagrammatic representation of percentage losses of wheat, paddy, pulses, and all food grains at various stages in the postharvest chain.

Coal Tar Drum Bin

This simple device (Fig. 14) has brought a major change in the storage system at farmer level. Farmers showed little resistance to this technology, mainly due to its low cost and easy availability. It was developed at the Central Institute of Agricultural Engineering (CIAE) and compares very well with other metal structures.

Basically, it is a used or empty bitumen drum. After the road construction authority has used the coal tar, the drums are discarded as junk or are sometimes used for protecting roadside plantations. The drum is heated by open fire to remove any excess tar. A layer of tar remains inside, and serves as an insulator as well as a protective coating for the galvanised iron sheet. The local artisan can bring this drum to an attractive shape and can also fabricate a lid and a discharge chute. A drum to hold 150 kg of cereal costs about $A11.00 (us 110/-), whereas a metal bin of the same capacity costs about $A35-40. depending on the thickness of the galvanised iron sheet used. At CIAE the local artisans have been trained to fabricate these bins to suit village requirements and have thereby generated gainful employment for themselves.

Fig. 14. Coal-tar drum bin (150 kg capacity) (dimensions in mm).

Domestic Hapur Bin

The Indian Grain Storage Institute, which is engaged in the development and dissemination of advances in storage technology to users, has developed metal bins for domestic storage of food grains (Fig. 15). They are made of galvanised iron and/or aluminium sheets. The bins are available from 200 to 1000 kg capacity and cost $A35.00 to $A120.00 (Rs 350-1200) per bin.

Fig. 15. Hapur bin (200 kg capacity) (dimensions in mm).

Chittore Stone Bin

As described earlier, locally available materials should, wherever possible, be used in the construction of grain bins. In Rajasthan, stone slabs are naturally available and abundant. At the College of Agricultural Engineering, Udaipur, a stone bin called the Chittore bin has been developed using 40 mm stone slabs. It is a rectangular bin of 250 kg capacity and is constructed by the farmers themselves using mud as a cementing material.

Double-Walled, Polyethylene-Lined Bamboo Bin

Conventionally, the bamboo bin fitted with a lid and with a plastering of mud inside and outside is a very common storage structure used by farmers in India. It provides employment to a particular community in rural areas who are trained in making these bins. The average life of a bin is about three years. They are not impervious and are prone to attack by insect pests. The modification of these bins by lining them with polyethylene has been found to be very effective. One such bin, developed at the College of Agricultural Engineering, Akola, can store about 500 kg of grain and it costs about $A22.00 (Rs 220/-). The only additional cost incurred is for the polyethylene and metal parts introduced in the modifications. The bin is mounted on a metal tripod with rat barriers as shown in Figure 16. At the discharge end, the use of a metal cone has made unloading very easy without spillage of grain. It ensures airtightness of the opening due to the constant pressure head of grain (Chouksey 1984).

Table 1. Upper limit of grain moisture content for safe storage.

Commodity	**Moisture content (% wet basis)**
Paddy, rice (raw)	14
Rice (Parboiled)	15
Wheat Kabuligrun, Bengal gram	12
Sorghum, maize, barley, ragi, bajra, pulse, turmeric, wheat atta maida besan	12.5
Coriander, chillies	10
Groundnut pods	6-7
Mustard seed	5-6

Source: Agricultural Engineering Directory, 1983.

On-farm food grain storage

Farmers need storages of 1-4 t capacity to store grain. If the storage time is short (2-3 weeks) a flexible PVC sheet covering (30-50 micron size) known as a crop umbrella is used. Sometimes tarpaulins or large canvass sheets are also used to protect the grain, especially at night to avoid the surface layer of the grain becoming moist with dew. However, for 2-3 months storage periods, the bin developed at the Indian Agricultural Research Institute (IARI) is the most suitable. It is a LDPE (low density polyethylene) sandwiched bin, popularly known as Pusa bin.

It is worthwhile explaining here the detailed construction procedure of the Pusa bin which can be widely adopted not only in India but in several developing nations. Except for the LDPE which is purchased by the farmer, the bin is made with mud. The performance of this bin is similar to any other metal or concrete structure. In fact, because of the good insulation properties of the mud bricks used for construction, the problem of moisture migration during storage is minimal in the Pusa bin. About 9.5 million tonnes of food grain are stored in such bins in India (IPCL 1985).

Fig. 16 PKV Akola bin

Method of Constructing Pusa Bins

The bin is constructed on a hard surface to prevent rodent attack (Fig. 17). If the surface is not hard, a platform of burnt bricks is built. The black LDPE film (700 gauge) is spread over the platform, extending 60 mm from all four sides. Another platform of unburnt bricks is constructed ova the LDPE layer. The inside wall is built to the required height, depending on the capacity of the structure. The surface of the wall is plastered with mud.

A wooden frame with an additional pole at a distance of 450 mm from the end of the structure is prepared and is placed at the top of the inner wall to support the roof. An additional pole is placed 250 mm from the outer side of the structure to provide further support. A small hole, 90 mm in diameter, is cut at the bottom in the middle of the front wall for delivery of the grain. A mud slab, 50 mm thick, is placed over the raised inner wall to serve as a roof, leaving a manhole of dimensions 500 x 500 mm at one comer. The structure is then plastered with mud on top and on all four sides, and is left to dry well. An LDPE film cover of 700 gauge black sheet made in the form of a mosquito net is then placed over the dried structure.

At this stage, a pouch made out of galvanised iron or plastic pipe 90 mm in diameter with a cap, is fitted into the delivery hole. The LDPE cover is pulled down to meet the extending portion of the earlier layer on the platform. The edges of both the films are heat sealed. A small hole is cut in the LDPE cover to accommodate the exit pouch and the pouch is pulled out through this hole. A little soft wax is applied around the pouch touching the LDPE film to make the portion completely airtight. The LDPE film covering the manhole is cut diagonally.

Fig. 17. Construction details for Pusa bins.

The outer wall of the structure is erected using burnt bricks up to 450 mm and unburnt bricks for the rest of the portion. Alternatively, a band of metal is provided at 450 mm to make it rodent proof. The whole structure is again plastered with mud on top as well as on all four sides and allowed to dry before use.

After filling the structure with grain, the diagonal cut on the film covering the manhole is sealed with adhesive tape and the manhole is plugged with mud. For efficient performance, the Pusa bin is used only after it is completely dried and filled completely so that minimum free space is left The bins can be made of various capacities. The quantities of raw materials required for construction of a Pusa bin are given in Table 2.

Bulk storage of food grains in India

The grain is stoma in bull: mainly by traders, big farmers, cooperatives and government agencies such as the Food Corporation of India (FCI). The available storage capacity of these sectors is of the order of 18.55 million tonnes which is about 12% of total production and 41% of surplus (i.e. 30% of total production) production which comes to market for sale. The main agencies storing surplus grain, and the amounts involved, are as follows:

- **the FCI-7.7 million tonnes (Mt)**
- **Central Warehousing Corporation 2 Mt**
- **State Warehousing Corporation-24 Mt**
- **grain marketing cooperatives-4.5 Mt**
- **some state governments 1.9 Mt.**

There are many kinds of storage systems followed depending on the length of storage and the product to be stored.

Cover and Plinth Storage

This is an improvised arrangement for storing food grains in the open, generally on a

plinth which is damp- and rat-proof. The grain bags are stacked in a standard size on wooden dunnage. The stacks are covered with 250 micron LDPE sheets from the top and all four sides. Food grains such as wheel, maize, gram, paddy, and sorghum are generally stored in CAP (cover and plinth) storage for 6-12 month periods. It is the most economical storage structure and is being widely used by the FCI for bagged grains.

Community Storage Structures

Bulk storage structures of higher capacity, ranging from 25-100 t are termed community storage structures (Birewar 1985). They are made from reinforced bricks, corrugated galvanised sheets and aluminium sheets in capacities ranging from 25 to 57 t.

Rural Godowns

The rural godowns are primarily meant for providing warehousing facilities to the farmers. The godowns are of 100 to 1000 t capacity. They are owned by FCI, central and state warehousing corporations, market committees, or cooperatives looking to the need for having storage structures or facilities for agricultural produce. The Government of India (GOI) appointed an expert committee (1979-1980) which

concluded that there was a need for storage facilities for 2 million tonnes of food grain. The GOI, keeping in view these recommendations, has given a 50% subsidy for the construction of rural godowns. Therefore, godowns are being constructed on a large scale in Indian villages.

Table 2. Raw material requirements for construction of Pus bins.

S1	Capacity	Internal dimension (mm)			Quantities of material required		
No.	(t)	L	B	H	LDPE film (m)	No. unburnt bricks	No. burnt bricks
1.	0.5	610	610	1360	8.1	800	80
2.	1.0	840	840	1400	1 1.7	900	95
3.	2.0	1400	1000	1600	15.3	1150	100
4.	4.0	1720	1520	1600	20.9	165	210

Source: IPLC report on plasticulture 1985.

Large-Scale Modern Storage Structures

Silos are being used on a large scale for bulk storage of oil seeds (soybeans) and cereals by the Oil Federation of India and FCI. Bulk storage has advantages over bag storage, as follows:

- **low running costs;**
- **low labour requirements;**
- **rapid handling;**
- **low through spillage and rodents;**
- **efficient and effective fumigation operation;**
- **less land area requirement;**
- **complete control of aeration;**
- **possible to store the grain for longer periods;**
- **possible to mechanise all operations; and**
- **possible to store moist grain for short periods.**

The silos are either metal or concrete. Metal silos are cheaper than the concrete ones by 1520% depending on their size. The difference is more in small capacity units, e.g. 200 t (Fig. 18).

Generally, the silo system is equipped with other preparatory units like cleaning and drying equipment. Comparison of godown and silo systems of 10 000 tonnes storage

capacity, as detailed in Table 3, indicates that under Indian conditions the silos are initially 50% more expensive than a godown system, but that this additional cost should be recovered within 2 -4 years and thereafter a saving of $A100000 - 190000 (Rs 1-1.9 million) per annum can be realised. The loss due to moisture is only 0.2% compared with 1% in the godown system. The loss caused by rodents, insects, fungi, and handling is as high as 8% in the godown system, compared with only 0.2% in the silo system (Sawant 1984). A grain saved is a grain produced and the adoption of such structures has been taken up by the government through cooperatives and various storage organisations in the country.

Fig. 18. Relationship between capacity and cost of storage.

Standards for Storage Structures

To achieve uniform performance from any structure, it is essential that the construction material and the method of construction should conform to a predetermined standard. The same applies in the case of storage structures, and for this purpose the Indian Bureau of Standards, New Delhi, has devised standards after careful examination of the storage needs. The standards followed for storage structures are listed in Table 4. In order to minimise losses during storage, users are exhorted to adhere to these standards during construction.

Table 3. Comparative costs for silo and godown storage.

Item	**Silo system**	**Codown system**	
	(Rs.*)	**(Rs.)**	
Capital costs			
Land	20 000	60 000	
	(1850 m)	(5550 m)	
Construction	6 500 000	3 940 000	
Total	6 500 000	4 000 000	
Recurring costs/year: grains/year		For grain-1 year	For oilseeds 4 6
		of storage	months storage
Loss due to moisture	40 000 (0.2%)	200 000 (1%)	100 000 (0.5%)
Loss due to rodents, insects, fungi, and handling	40 000 (0.2%)	1 600 000 (8%)	800 000 (496)
Operational costs			
Electric power	27 500	80 000	40 000

			(Fumigation)
Fuel for dryer	37 500	25 000	25 000 (Manual handling)
Total	145 000	1905 000	965 000

Source Sawant (1984)
***Conversion rate adopted: $Aust.1 = 10 Indian Rupees.**

Conclusions

India produces about 150 million tonnes of food grains per year. Production has been steadily increasing due to advancement in production technology, but losses have remained static at 10%. This means that the loss of food grains is also increasing with the increase in food production. The main reason for this is improper storage, and an average of 6% out of a total 10% loss takes place during storage of food grains.

For scientific storage, drying of food grains to a safe moisture level is a top priority. In India there are about 35 000 dryers in the rice and pulse milling industry, but all of them are used to process the grain. The use of dryers to dry surplus grain kept for storage is not common. The main reasons for this are a lack of awareness among the

rural populations, high capital cost, and no incentive given for farmers to produce properly dried grain. An immediate answer to this problem would therefore be to develop and select a proper size of dryer which is simple in construction and operation, and lower in cost.

Setting up a community drying-cum-storage complex as suggested by Ojha (1984) has great potential as it will help to reduce losses and to provide a better return for the grower. The types of dryers suitable for this level are identified and described. They need to be popularised among potential users.

Another area where the dryer indirectly plays a very vital role is at cottage level industry. A new concept in dryer design, i.e. tray-cum-LSU dryer developed at CIAE, has been described in this paper. The dryer can prove a backbone for rural industry, as the same unit can be used for drying the grains as well as processed food products by changing the trays.

Storage of grain in India is done at many levels. The major production is stored at farmer level and the root cause of massive storage loss lies here. The suitable low-cost structures developed have been identified.

On-farm storage is also important as it stores the surplus for a short duration and

appropriate structures are explained with design features and construction procedures. Large-scale structures like silos and organizationally maintained structures are also explained. The use of dryers and scientific storage practices, if followed, can reduce the loss by about 6% and this will save Rs 13 500 million ($A1350 million) every year, and make available an additional 9 million tonnes of grain to feed the people.

Acknowledgment

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Table 4. Indian standards for storage structures and storage management.

S1 No.	IS Number	Title
1.	IS 607-1972	Bagged food grain storage structures
2.	IS 8453-1977	Bins, earthern, polyethylene embedded for bulk storage of

		food grains
3.	IS 7715-1975	Bins for safe storage of food grain, method to test suitability of.
4.	IS 600-1955	Code of practice for 'Bukhari' type food grain storage structure
5.	IS 5826-1970	Flat storage structure for food grains (cap. 200 t)
6.	IS 6201-1971	Flat storage structure (100-200 t)
7.	IS 601-1955	Code of practice for construction of Kothar type rural grain storage structure
8.	IS 602-1969	Silos for grain storage (Part I) construction requirements
9.	IS 5503-1973	Part II-Grain handling equipment and accessories

10.	IS 7174-1973	Steel bins for domestic storage (Part I)
11.	IS 5606-1970	Steel bins for grain storage
12.	IS 6151-1971	Part II-General care in handling and storage of agricultural produce
13.	IS 603-1960	Underground rural food grain storage structure

Source Agricultural Engineering Directory 1983

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Overview of grain drying in China

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Abstract

There are many links in the grain postharvest chain, including threshing, cleaning, drying, storage, transportation, and processing. Grain drying is one of the key links in terms of minimising postharvest losses, since it directly affects safe storage, transportation, and processing quality, as well as distribution.

Great losses to stored grain occur every year around the world. For instance, moulding during storage and transportation, deterioration in quality and an increase in brokens and cracked kernels can be attributed to delayed or improper drying.

China is one of the world's largest grainproducing and consuming countries. To minimise grain postharvest losses, particularly in the case of wet grain, has always been a key issue in the management of grain. The following introduction addresses three aspects of the problem.

The geographic distribution of wet grain in China

China is a vast country, spanning thousands of kilometres from north to south. Geographic and climatic conditions vary from place to place, and so do the varieties of grain. This has resulted in a wide range of grain moisture contents as well as postharvest technologies in China.

Wet grains are mainly maize and paddy, two major crops in China, with very small quantities of soybean, rapeseed, and wheat. They are geographically distributed in the following provinces, cities, and autonomous regions: Heilongjiang, Jilin, Liaoning, Inner Mongolia, Beijing, Hebei, Anhui, Xinjiang (Sinkiang), Jiangsu, Hubei, Jaingxi, and Zhejiang.

Maize is produced mainly in the north of China, with high yields but longer maturing periods. The weather is not favourable, with a short no-frost period, low temperatures

during the maize maturing period, and low hours of sunshine, which results in huge amounts of wet grain after harvest.

When maize comes into the state grain depots, its moisture is normally as high as 2226%. In the years when frost comes earlier, it can be as high than 30%, and sometimes over 40% in some places. Every year, the grain depots in the north receive wet maize in very large quantifies.. To reduce the moisture content to a safe storage level is a prime activity in the depots during the whole winter period.

Paddy is produced mainly in the south of China. Late-season paddy harvested there is wet because of higher rainfall and relative humidities at harvest time.

Most paddy is harvested manually and sun dried in the field for one or two days after harvest (depending on the weather), so the moisture content of wet paddy is not as high as that of maize in the north. Normally, it is between 16 and 18%. In a bad year it could be around 20% and even 24%, when drying becomes imperative before long-term storage and transportation.

In terms of quantity, the amount of wet grain procured by the government is around 20 million tonnes, about one quarter of the total state procurement. This is made up of about 15 million tonnes of maize, with the rest mainly paddy. The wet grain is more

concentrated in the north-east, where 70% of the total procurement is wet maize. In recent years, grain output has increased markedly and so too has the amount of wet grain.

Methods of grain drying

Generally speaking, grain drying can be classified into sun drying and mechanical drying.

China is a large agricultural country at a low level of agricultural mechanisation. particular, mechanical grain drying capacity cannot keep pace with the increase in grain production. At present, only about 30% of wet grain in state depots is mechanically dried; the rest has to be sun dried. All grain retained at farm level for consumption by farmers is sun dried.

Sun Drying

As is well known, sun drying has greater requirements of labour and space, especially in the case of large-scale and centralized treatment Although labour is relatively cheap in China, the cost of commercial-scale sun drying is still very high.

In addition, sun drying depends very much on the weather, and takes more time. If there are long spells of bad weather, there is a high risk of grain losses. Also, the handling losses during sun drying are not insubstantial.

However, sun drying does have some advantages. There appears to be no appreciable reduction in grain quality associated with the process, and grain can be kept fresh, of good colour, and free of contaminants.

There are many ways of sun drying in China. The most popular method is to spread wet grain on the ground, turning it from time to time to remove extra moisture.

In the north-east, farmers usually put maize cobs into hubs. Moisture is removed by natural aeration during storage. Farmers also take measures before maize is harvested. When it is in its waxy ripening stage, farmers tear the husks off the cobs for sun drying while on the stalk. This method not only removes moisture but also promotes maturity, thus increasing yield. Under the climatic conditions of the north-east, it takes about 10 days to reduce maize moisture by 4%.

Clearly, the main disadvantages of sun drying are that it is more labour intensive and takes longer. Some local governments give farmers incentives to encourage sun drying at farm level so as to solve the problem of insufficient capacity in state depots. This

has not been successful to date.

Mechanical Drying

For mechanical drying, design and manufacture of grain dryers started in the late 1950s. However, early development was not rapid enough. In the late 1970s and early 1980s, successive bumper harvests created a large grain drying problem. Mechanical means of grain drying have been developed more rapidly since then.

Most grain dryers are designed and manufactured by local Research and Design Institutes and end users. There are three main types of grain dryers: tower dryers; rotary drum dryers; and fluidised-bed dryers.

Tower dryers are very popular for maize drying in the north. They can be classified as direct or indirect dryers. In the direct dryers, the heated gas is in direct contact with the grain so giving better drying efficiency.. Anthracite coal is required as fuel to minimise contamination.

Indirect dryers normally use heat exchangers. Since there is no contamination possible, there are no special fuel requirements. However, the energy losses are high during heat exchange.

The capacities of tower dryers using coal as fuel are around 10-20 tonnes per hour with moisture removal of about 10% for each pass.

Rotary drum dryers and fluidised-bed dryers are popular in the south for paddy drying, with capacities ranging from 5 to 15 tonnes per hour and moisture removal of about 3%. They use mainly paddy husks and coal as fuels. Producergas is also used as a heat resource for grain dryers in the south. It can provide stable heat and maintain grain quality, but its use increases the cost of drying.

The grain dryers using solar energy, infrared radiation, and microwaves were tested in the early 1980s, at an experimental level. The technical and economic data collected were not promising for potential commercial utilization.

Apart from dryers, when we say mechanical drying, we should include mechanical ventilation, which is simple in construction, and economic and reliable in operation. Fans, ducts, controllers and suitable ambient air are the total requirements for a grain ventilation system, with the aeration time controller as a key component. In some cases, supplementary heating equipment is probably needed for reducing the relative humidity of the ambient air and raising its temperature. Ventilation technology for wet grain drying is now practiced in the both the north and the south of the country, with good results.

In summary, mechanical drying has many advantages it is independent of the weather, has low operating costs; and is suitable for fast, large-scale and centralised facilities. However, good design and operations are very important, because grain is easily damaged by over-drying.

Current Problems and Developments

At the moment, the major problem faced after harvest in China is a shortage of mechanical drying capacity. The government each year has to make substantial inputs of labour, materials, and money for sun drying in order to protect grain-particularly maize in the north-from moulding or other kinds of damage during storage and transportation,

Under the present management system, the state grain depots have to procure a huge amount of wet maize within a short period after harvest. Although the temperature is low and wet grain can be stored for a certain time without drying, the huge amount of wet maize in depots waiting to be handled by a very small drying capacity is still a great pressure on safe storage. It keeps all store keepers busy with grain drying (mainly sun drying) throughout the winter.

In years when frosts are early, the problem is further exacerbated, with even greater

amounts of maze at moisture contents more than 10% over the standard. Depots have to ask local government for help as the drying season is short. Roads, squares, other public spaces, and even airport landing strips have been used to dry all wet maize to a level safe for storage before the temperature rises in the spring.

High moisture paddy in the south represents the second biggest wet grain problem in China. Its moisture content is lower than that of maize, but the ambient temperature in the south is much higher than that in the north. Wet paddy therefore needs to be dried as soon as possible. In addition, exposure to high temperatures awing uneven drying can reduce paddy quality, leading to broken and cracked kernels during milling. It is essential to increase mechanical drying capacity and develop drying technology to solve these problems.

Nevertheless, the development is uneven in the north and south. Large capacity dryers able to remove substantial amounts of moisture in each pass are urgently needed in the north, while in the south, advanced drying technology that preserves paddy quality is the top priority. Here, drying systems based on aeration would probably be more suitable and effective. This would seem to be the best way to develop grain drying policy at present.

China is eager to learn from other countries about postharvest technology in general

and grain drying in particular, including:

- **new types of high efficiency grain dryers;**
- **elimination of contamination when coal, a common energy source in China, is used as fuel;**
- **reducing heat consumption;**
- **automatic controller systems and computer simulation design methods;**
- **manufacturing technology, etc.**

Efforts should also be made to develop new, high-yielding and early maturing varieties of maize in order, for example, to reduce grain moisture content in the field before harvest.

China is a developing country and, because of financial constraints, the government is unable to tackle all problems immediately. However, there are a few important first steps that could usefully be taken to overcome the grain drying problem:

- **it would help greatly if farmers were to deliver dry or at least partly dried grain to state procurement centres;**
- **price incentives or subsidies could be introduced to induce farmers to undertake at least some drying on farm;**

There are two factors that support this idea. Firstly, grain production in China is decentralized and small scale at present. For this reason, on-farm drying may be easier than centralised drying in state depots. Secondly, farmers have many traditional and effective methods suited to small-scale grain production. No doubt they could do the job well, as long as government policy is practical.

Some imperatives in crop drying research

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Abstract

Crop drying research has produced components of a drying system. There is now a need to consider the integration of the knowledge gained about the drying

characteristics of products, the drying load, the product quality preferences of consumers, and the dryer with its supportive infrastructure. Procedures for generating the requirements of the marketing system, for evaluating available component hardware, and for determining optimum combinations for different commodities, users, environments, and marketing channels have to be developed. If they are to be adopted on a sustained basis, system dryers must increase the profitability of the operations of the end user.

Introduction

There has been no sustained adoption or increase in the utilisation of more 'efficient' drying technology for crop preservation in the region, despite continuing investments in research in the past 10 years towards providing drying capability. This does not mean that advances have not been made. Progress has been made in the understanding of the technical, economic, and people or system issues involved. There is a continuous proliferation of learned papers on the subject. But if continued support for drying research is to be considered, we need to make an analytical review of the situation and come up with a more strategic plan. The development of drying technology seems to be towards a blanket prescription for the industry, or an assumption that, given a good drying technology, the agricultural industry in the

region will adopt it. The question is, what is a good drying technology, and who are the targets in the industry? The engineers complain about the non- engineered designs, and the economists claim the problem is a failure of the market to respond. They are probably right, but what are we supposed to engineer, and how does one go about developing a responsive market?

I would like to try the hypothesis on this exalted group of donors that system dryers are needed, but that no one drying technology is appropriate for all users and for all conditions. They key words here are system dryers. This is akin to the terminology: drying strategy. The term 'system dryers' is used in this paper to connote dryers that are designed to be compatible with the system where they are used. They could be simple batch units with forced or natural convection modes of moving the drying air, continuous flow dryers that complement sun drying, or the Australian instore drying technology, or a combination of these technologies.

Sun drying of paddy on the highways is not a technology, it is a practice which is one of the indications of a problem. The terms mechanical dryers and artificial dryers are used in the literature. This may be semantics, but this is a clue to the isolated or component thinking, and besides, there is nothing mechanical or artificial about dryers. To discuss drying strategies and to be able to design a system dryer, we need to identify commodities, users, environmental conditions, the production and

marketing systems of which the system dryer is a subsystem, the costs and benefits, and the distribution of costs to beneficiaries. In this context, the problem issues have to be identified and defined, the probable causes of the problems, and then decide the nature of, and direction for research. This paper contains only perceptions derived from working with the grain industry to trigger the relevant discussions and to enable those concerned to make their own decisions.

What is the need for crop dryers in the Southeast Asian region?

Drying is one of the most practical methods for primary preservation. A corollary to the hypothesis is that system dryers offer an advantage over the traditional drying practices under certain conditions. The agricultural commodities that are traditionally dried are paddy, maize, groundnuts, soybeans, coffee berries, some fruits (e.g. mangoes and longan), spices (e.g. chill), garlic, onions), fish, meat, chipped root crops (e.g. cassava and sweet potato), and coconut meat (cope). Direct sun drying or free/natural convection drying over a fire is the traditional practice. The need for system dryers varies with each commodity, the area where they are grown, and how they are marketed. System dryers for paddy are acutely needed in, say, Indonesia and the Philippines, but not for the majority of production in Thailand. System dryers for maize are needed very badly in the Philippines and Thailand, but maybe not in

Indonesia.

To focus discussion, we shall now restrict reference to commodities to the two staple food crops in the region: rice and maize. A major portion of these two commodities is harvested during the rainy season where sun drying is not dependable. The consequence of this lack of drying capacity is physical and qualitative loss of commodity. While loss figures are available which are often used for justifying intervention, the quantified benefits of intervention attributable to investment in system dryers are also necessary for decision making. For example, an analysis of paddy drying in the Philippines by Habito (1986) states that in a mechanised rice postharvest system and a purely traditional one, the former can have the advantage of providing a more stable net income (to farmers) due to its independence of the weather, particularly the task of grain drying. However, he further indicates that the mean incomes obtained under each system were not significantly different and therefore concludes that there is no strong incentive for farmers to mechanise these operations. Habito, in the same paper, ventures the opinion that, based on his findings, dryers should not be designed for farm level use, but rather for traders and processors who can take advantage of economies of scale as the target users. He argues correctly that the harvest has to be dried anyway for storage and milling.

The drying strategy that suggests traders and processors as target users of dryers

should recognise the fact that the marketing system is dealing with very high moisture grain that is unstable, that most of the irreversible deterioration occurs within the first 24 hours at the farm level, and that conditions for aggregating, purchasing, transporting from small farm lots over unpaved rural roads to drying plants can take more than 24 hours. The strategy can be operationalised. This has been done with corporate enterprises, but for small family-owned mills, which form the majority of processors in the region, the incentive for investment has to be proven. Point one in this discourse is that what is needed is not just a mechanical-artificial dryer, but a system for drying. Point two is that mechanised drying on the farm by farmers may not be feasible, but a low-cost, passive drying system may be what is needed in the small farms of Asia. Point three is the introduction and utilization of dryers must provide an opportunity for financial and economic gains to the investor/user.

What are the purported advantages of system dryers?

Drying is just one of the processes in the chain of operations in the food marketing system. This suggests that it has to be compatible with the operational requirements of the rest of the system. These requirements are for capacity-or volume dried per unit time, product quality assurance, for sanitation, and for dependability. Drying of the commodity in itself is merely in preparation for storage and further processing, and

the value added to the product cannot cover the cost of drying. A system dryer linked or integrated with the rest of the system would allow the cost to be distributed to the various beneficiaries in the system.

The need for, and the advantage of having a system dryer are two sides of the same coin. The traditional practice of sun drying on mats on the highway, if and when the sun is shining, has not resulted in the best product, but people have survived. Inability to dry paddy on time only results in darkened and yellowed kernels, but the milled grain is still eaten by the local people. For maize, groundnut, and copra, inability to dry the grain on time and properly, results in aflatoxin contamination, which may not be physically evident. Aflatoxin is only circumstantially accused of being carcinogenic, but it has stifled free trade in favour of the American aflatoxin-free products. A system dryer can prevent this problem from occurring.

Rice processing and trading is big business. The investment costs and the operating costs to the businessmen are high, but the profits have to be made within narrow margins. The objective, therefore, of grain businessmen is to maximise profits, and a system dryer can allow an increase plant throughput.

Who are the potential users of system grain dryers?

A. The individual farmers

The rice and maize farmers of Southeast Ash cultivate anywhere from a third of a hectare to a few hectares. These are the poorer segments of society and are legitimate targets as beneficiaries of research and development. They may own the land or work as tenants. In most cases, they retain whatever paddy harvest they require for their own family requirements and sell the rest to traders. A three-hectare farmer producing 4 tonnes of paddy per hectare, or 12 tonnes in total, may take 1-2 weeks to harvest his crop. His drying load is anywhere from 1 to 2 tonnes per day for, at most, 2 weeks per season. If the weather is fair, this farmer has no drying problem. If it is rainy, he waits for the silver lining behind the dark clouds. If it is really bad weather, there is always a market for wet grain. How much does he lose for having to wait for the sun to shine, or for having to sell wet grain at a discount? Assuming a high 3% of the value of his crop, that works out to be US$56. These farmers would not even dream of acquiring a dryer.

The farmer may not have a serious drying problem, but somebody down the marketing line inherits the problem.

B. A group of farmers

Several farmers may be serviced by an irrigation system, and out of necessity have to work together. A group of farmers in a research project in the Philippines is reported by Lorenzana et al. (1987) as successfully collaborating in the use of harvesting machines like threshers, and even a small rice mill. The farmers, however, did not make full use of a flat-bed dryer's capacity. They only resorted to it when sun drying was not feasible, and then complained that it did not have the capacity to service the requirements of the group as they had to take turns on a first come first serve basis. The development of the market for their wet grain harvest might be more meaningful for them.

What system dryer would you recommend? Maybe a first-stage dryer, and pass the problem to the next stage.

C. A farmer based marketing cooperative; a family owned milling enterprise; a grain trader; a corporate enterprise

This group of potential users is in the rice processing business for profit. Its operations are centered around milling capability, which would be from 1 tonne of paddy per hour for the smaller plants up to 10 tonnes for the larger. They are motivated first and foremost by anything that can increase financial returns. How well are they doing? Many of the private millers tour the vacation spots abroad once a year. This group

provides a service and I would like to review the opportunities for maximising profits to see how system dryers fit in with them. We need more farmer cooperatives to allow the farmers to participate in the rich proceeds of processing and trading.

Factors that can increase financial returns

High Cost Factors

1. Increase plant throughput.

- **a. Increase operating capital for purchasing paddy.**
- **b. Invest in a grain dryer to allow for purchase of paddy during periods of inclement weather.**
- **c. Increase storage capacity.**

2. Adopt bulk handling and storage and pest control measures.

- **a. Eliminate recurring cost of sacks, and labour cost of stock handling in bags.**
- **b. Eliminate infestation and contamination by insect pests and rodents.**
- **c. Integrate bulk system with an in-store drying system.**

Low Cost Factors

3. Increase milling recovery and improve milling quality.

- **a. Develop paddy grading and price incentive scheme.**
- **b. Improve management of wet paddy receival to prevent mixing.**
- **c. Control drying with a grain dryer to prevent fissuring during the process.**
- **d. Upgrade rice mill design and operation.**
- **e. Produce graded milled rice for different consumer groups.**
- **f. Produce pre-packaged milled rice products for the premium markets.**

4. Establish linkages between farm production, processing, and markets.

- **a. Develop a marketing plan, a variety of products for different consumer groups.**
- **b. Control production, particularly harvesting operations to minimise damage to grain.**
- **c. Develop a first-stage drying process at the farm level to help farmers produce good quality paddy.**

Factors that can decrease financial returns

- **1. Investment in incompatible components or oversized plant machinery that contributes to low utilisation.**
- **2. High energy costs for inefficient process equipment**
- **3. Operating at low throughput or below breakeven point.**
- **4. High dockage paddy procured.**
- **5. Poor quality paddy: meaning high percentage of immature kernels, chalky grain, fissured grains, yellowed kernels, and weed seeds.**
- **6. Obsolete, poorly maintained, or improperly operated milling equipment.**
- **7. Uncontrolled drying of the grain resulting in low head rice recoveries.**
- **8. Delays in handling wet grain resulting in discoloured grain.**
- **9. Insect and rodent infestation.**
- **10. Overall technical incompetence.**

The availability and proper use of a system dryer is heavily implicated in the financial well being of the grain businessman. To give meaning to this listing, a quantified contribution of each factor has to be estimated.

D. Government grain marketing agencies

These are government-subsidised service agencies equipped with dryers. Their problems centre on either lack of capacity or incompatibility of the different components of their systems during peak harvest periods, leading to bottlenecks To the flow of grain. They have, however, been the target of a lot of foreign research aid!

In summary, the problems are:

A. Drying technologies have not been designed as part of the system, resulting in the lack of supportive infrastructure, or incompatibility of capacities with requirements.

B. Farm drying, although the logical place for drying to minimise delays, provides insufficient incentive to farmers.

C. The vertical segmentation of the marketing channels, which are not supportive of each other.

D. The market failure to recognise the benefits of controlled drying and to provide the proper incentives for the production of good quality milled rice.

E. The non-structuring of payment for the cost of drying through a pricing system that distributes the cost among the different beneficiaries of better quality product

produced.

What do we have now?

Every conceivable component drying technology has probably been introduced in the countries of the region. They include natural convection dryers such as the 'improved' African pit dryer, which is a traditional farm dryer for copra, flue curing/drying barns for tobacco adapted for other crops; the forced convection dryers: batch dryers of different configurations, recirculating dryers, continuous flow multistage dryers, in-store or deep-bin dryers; solar dryers galore; infrared radiation dryers; conduction heated dryers. Some of the donor organisations represented here are probably aware of their contribution. For some of the more utilitarian models, manufacturing with about 80% local content has been done.

Aside from the hardware, there is now a high level of native engineering capability for basic design work. Information on the thermophysical properties of local varieties, and constants in drying rate prediction equations have been generated, resistance to airflow for local products are being worked out. The psychrometrics involved in the heat and mass transfer in the drying process are very well understood

There is now a new breed of agricultural engineers that has the facility for analysing

engineering systems using both engineering and economic parameters to determine optimal combinations. With desktop microcomputers, this is now a whiz.

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What has not been done that needs to be done

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We need to get into specifics. In 1986, a drying workshop of research project leaders prepared a checklist of information needed to design a system dryer. The checklist is reproduced here to indicate the coverage as well as details of what is needed for a systems study.

I. Elements of a drying system

A. Technical considerations

- **1. Basic method of drying, or drying combination**
- **2. Pre-drying farm operations (harvesting, threshing, cleaning, transport)**
- **3. Post-drying plant operations (storage, pest control, milling, etc.)**
- **4. Materials handling for pre- and postdrying operations**
- **5. Quality control procedures, e.g. sampling, analysis, grading, stock segregation, monitoring**
- **6. Product volume and characteristics, and scheduling**
- **7. Energy resources**
- **8. Equipment supply and servicing**

B. Socioeconomic factors

- **1. Pricing structure**
- **2. Consumer preference**
- **3. Marketing channels**
- **4. Marketable surplus available**
- **5. Credit/financing scheme**
- **6. Costs and returns**
- **7. Human resources (management, operation, technical supervision, labour)**
- **8. Training and extension program**

- **9. Organisational and management structure**

C. Support infrastructure

- **1. Farm roads**
- **2. Utilities (power, water, etc.)**

D. Environmental and other factors

- **1. Climatic conditions**
- **2. Institutional linkages, and arrangements**
- **3. Government plans, programs, policies**

II. Information necessary for estimating drying load

- **1. Production area and land tenure in service area**
- **2. Number of farmers participating in service area**
- **3. Average yield per hectare**
- **4. Harvesting and threshing schedules, and average output per day per farmer**
- **5. Production management practices (schedules and area planted per**

day)

- **6. Marketable surplus for**
- **- individual farmer**
  - farmer groups
- **7. Marketing practices, commodity flow patterns**
- **8. Physical and varietal properties of product, e.g. IMC, FMC, variety, purity**
- **9. Time delays in product movement**
- **10. Drying schemes**
- **11. Holding storage facilities**
- **12. Effective operation tune per day**
- **13. Drying conditions and rates**
- **14. Types of dryer under consideration**
- **15. Distribution and/or location of drying plants within service area**
- **16. Competition within service area**

III. Information necessary for developing strategies to provide the drying capability of the system

- **1 . Ultimate product use: feed, flour, food, etc.**
- **2. Drying schemes and options or combinations possible, e.g.**

  - two-stage drying (farm and plant drying)
  - sun drying in combination with artificial dryers
  - in-store drying

- **3. Types of dryers options**
- **4. Local manufacturing capability**

  - after-sales service
  - technical support and upgrading program

- **5. Related postharvest practices**

  - harvesting
  - threshing
  - milling
  - storage
  - handling
  - marketing

- **6. Available energy resources**

  - solar
  - crop biomass
  - petroleum-based fuel

- **7. Market demand for different grades of product, local and export**
- **8. Investment capability, availability of credit**
- **9. Organisational structure and management of enterprise**
- **10. Availability of skilled operators**
- **11. Availability of extension services**
- **12. Government policies, re grades and standards, import/export, taxes, price controls**

IV. Parameters for evaluation of dryer performance

A. Financial profitability of investment

Profitability of investment

= F(Q, C) > (e.g. 25%1) where Q = quality of end product.

Technical indicators of quality:

- **1. Total product recovery**
- **2. Head rice recovery (for rice)**
- **3. Moisture content**
- **4. Colour**
- **5. Impurities**
- **6. Aroma and taste**
- **7. Viability (for seeds)**

C = cost

Economic indicators:

- **1. Benefit-cost ratio**
- **2. Internal rate of return**
- **3. Break-even point**
- **4. Net present value**
- **5. Payback period**

I = investment

B. Technical performance

1. Quality of product

- **a. Raw materials**

  moisture content
  impurity
  initial cracked grains ratio
  varietal mixture
  immature grains

- **b. Dried product**

  uniformity of drying
  total and head rice recovery
  viability (for seeds)
  colour, off odours

- **2. Batch loading capacity**
- **3. Drying rate, moisture removed per hour**

- **4. Total operating time, including loading/unloading**
- **5. Heat utilization factor**
- **6. Overall efficiency, use of energy**

C. Information for cost-benefit analysis

- **1. Capital costs (dryer, land, buildings)**
- **2. Fixed costs (depreciation, insurance, rent fees)**
- **3. Variable costs (salaries and wages, repairs and maintenance, fuel and oil)**
- **4. Indirect costs (family labour, downtime, opportunity cost, social cost)**

D. Benefits

- **1. Price differential for wet and dried products**
- **2. Drying fees for custom drying**
- **3. Indirect benefits (time, labour, and losses saved)**
- **4. Overall increase in plant throughput**
- **5. Improvement in product quality and marketing plan**

E. Social benefits

- **1. Labour and employment generated**
- **2. Time generated for other activities**

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Commercial utilisation of research results

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Abstract

Although science and technology is known to be indispensable to sustained growth and development, it is also common knowledge that many useful technologies remain unused by potential beneficiaries. This paper attempts to identify the problems responsible for the slow adoption of research innovations, the steps that could be taken to reduce these problems, and finally a strategy for ensuring that the most promising research results arc used by potential beneficiaries.

Research results that have the best potential for commercial utilisation are those that have a large market, are easy to mass produce, have a wide diversity of uses, have a large edge over existing technologies, can be manufactured cheaply and have a high rate of profitability. For research that is already complete, the results must be evaluated on the basis of the above criteria in order to identify those with the highest potential for commercial use. For research that is yet to be done, an ex-ante analysis focusing on the above criteria must be conducted before any funds are provided to support the research

To hasten commercial utilisation of research results, three immediate tasks are identified. First, fund donors must incorporate utilisation potential as an important criterion for funding research proposals. This should ensure that future applied research will produce results that are easy to commercialise. Second, concerted efforts must be made to evaluate completed research for innovation that has good potential for commercial we. This involves the difficult task of reevaluating past research results against the proposed criteria for research utilisation so that the most promising can be repackaged and reprocessed for possible commercial use commercialisation. Third, the private sector must be encouraged and educated to participate in the actual commercialisation of research results. By showing this sector the potential profitability of some selected innovations, it is expected that promising research results will be their own engine for enhancing commercial utilisation.

Introduction

Science and technology are indispensable instruments for national development. No country in this modern time can prosper without giving due consideration to research and development

Scientific information is the key to sustained economic and social development.

Through research, people and society are continuously provided with numerous alternatives to many technological problems.

However, it is common knowledge that a new technology generated by research is not necessarily adopted and used by the intended beneficiaries. Low productivity, in spite of numerous research breakthroughs, indicates a severe weakness in the overall process linking technology generation and technology utilisation.

The strategic nature of technology has received increasing attention in recent years. One of the earliest and most extensively studied areas is the role of technological change in economic growth. Despite difficulties in measurement and differences among studies, economists generally agree that technological advances have been a significant contributor to the rapid advancement of the industrialised countries.

There is a growing concern for research to produce results that can be applied commercially, especially in the developing countries where meagre resources have to be allocated to pursue modest research activities. It is now clear that the utilisation and application of research results should be treated as an integral part of the research process itself

To be of value, research must contribute to technology that could positively affect the

social and economic lives of people. Thus, the ultimate test of the value of any research activity is the extent to which its results have been utilised on a sustained basis.

In this paper, we define research results as a product that embodies an innovation whose commercialisation is said to have happened when the number of users adopting the innovation is large enough to have a significant impact on the well-being of the target users. We divide the paper into four sections, namely; current experience in commercial utilisation of research; common problems in utilising research; evaluation of research results for commercial utilisation; and a proposed plan of action.

Experiences in research result utilisation

There have been several business ventures designed to commercialise research results. We describe two of these in an attempt to learn from their experiences.

The EVSA Experience

Several years ago, EVSA Corporation-a development management organisation with the cooperation of Filipinas Foundation, a non profit/non- stock organization of the

Ayal a Corporation-set up a company with the sole purpose of commercialising research results or 'new technologies' and inventions. They started with a million pesos initial capital for these activities. What they did first was to make an inventory of research results gathered from institutions are involved in science and technology. From the hundreds of results they were able to gather, they only found less than ten to be more or less marketable (about 7-8 new technologies). Their criterion for short listing was the marketability of the technology. If there was a market for it, then it was counted 'in'. Of this short list of seven, according to a managing associate of EVSA, none was marketed at that time of the company's existence. He cited several reasons for this:

> **1. More capital was needed. After one year of operations, a review was done on the company's performance and the result was that, at that time, prospects of successfully marketing the new technologies were dim so the financiers decided to minimise their losses and did not give the required additional funds for operations.**
>
> **2. Problems with scientist/inventors involved. Some scientists/inventors did not want to modify their products to suit the demands of the marketplace. Compensation problems were also encountered. An agreement on how much these scientists/inventors were to be compensated for their**

discoveries or inventions could not be reached-thus hindering their full utilisation.

3. Secrecy of research results. Scientists tended not to reveal all of their 'secret' formulas to the marketers-a corollary to problem (2).

4. Mass production capability problems. Some technologies though marketable could not be mass produced to meet demand.

5. More time was needed. The timetable of one or two years was too short to fully package and launch an entirely new technology or product on the market.

The company never had a formal systematic evaluation of the research results it gathered. For them, the most critical factor was the market-if there was no demand for the product or technology then they dropped it from the list.

The above problems were not insurmountable: as the managing associate of EVSA said, more time and money were all they needed.

The PABCO Experience

PABCO is the acronym for Philippine Agricultural Biotechnology Company. It is a fairly new company whose sole thrust is to package and market, as the name suggests, agricultural biotechnologies.

While EVSA worked on all types of research results, PABCO is working exclusively on research results on agricultural biotechnology. In all its activities, it works closely with scientists from the BIOTECH Center of the

University of the Philippines at Los Baos. From talks with the officials of both organisations, one can surmise a close cooperative effort between the marketer(PABCO) and the scientists in the packaging of the technology. There seems to be no problem in their relationship.

PABCO does project conceptualisations on selected 'matured' technologies. Again, it stressed the importance of a market study as well as the role of the BIOTECH Center in the perfection of the technical process in the production of the technology. PABCO gets the recommendation from the Institute on whether the technology is ready for packaging or not. How does it arrive at this conclusion? The Center director has three criteria: there is a market for the product; the technological process of production has been perfected; and the technology can be produced economically. Only when these criteria are met will the Center pass on the research result to interested parties such

as PABCO.

A very recent case is that of a product with the brand name Mycogroe. Mycogroe contains ectomycorrhiza, a naturally occurring soil fungus that increases the growth and survival rates of pine and eucalyptus species. It is a natural product beneficial to both plant and soil. The Center developed this technology and the end form is a pella designed for easy application and substantially cheaper than chemical fertiliser.

This technology, according to the Center, was five years in the making before it was picked up by the PABCO group. Intensive pilot testing was done (3 years) for verification of consistent results. As soon as the Center gave the go-ahead for the product to be packaged and marketed, PABCO did an intensive market study and when the study revealed a positive conclusion, the group went on to do market development for the product. Market development entails product packaging, price determination, sales materials, client scanning, product presentation to potential users, and introductory offers. When market feedback was again positive, production contracts were made with users, and the company went into full production. The Philippine Department of Environment and Natural Resources (DENR) has endorsed utilisation of Mycogroe to all implementing agencies of the government's reforestation program as well as timber and logging companies all over the country. These are PABCO's current clients.

PABCO is also actively evaluating the packaging and marketing feasibility for two other biotechnological research results and as a PABCO official said, 'Our activities are systematically done from the product development OR BIOTECH Center's side to the marketing aspect which PABCO does'. He said further that the very open relationship they have with the scientists in the Center has helped them enormously. So far, no major problems have been encountered.

Lessons can indeed be learned from these two experiences. Lessons why EVSA and the Ayala group did not succeed in this venture and why PABCO is doing fine right now and is preparing itself to package more technologies and market them. PABCO's experience gives us confidence that, as in any business venture, packaging and marketing of research results can be successful as well as profitable.

Research result evaluation

After two months of research and interviews, our Research Utilization group at SEARCA identified three major requirements for a new technology to be judged ready for commercial utilization. These are:

- **(a) the technology should be marketable;**

- (b) the technology is technically feasible; and
- (c) the technology can be manufactured or used at a high rate of profitability.

Marketability

The issue of 'is there a demand for this technology' is the heart of market evaluation. There has to be a demand or a market for the technology before it can be utilised. Evaluating all other aspects such as mass production or profitability is meaningless if demand does not exist.

There are three components of marketability, namely:

- (1) substantial demand;
- (2) potential market share (growth); and
- (3) supply situation.

Substantial demand and potential market share are defined by such determinants as population, income, prices, substitution possibilities, changes in user's taste, rate of investments, and government policies and budget. The supply situation, on the other hand, relates to the availability of products that have similar uses and users.

A product or technology is said to have an excellent market potential if its demand and market share is judged to be high while the current supply status is low.

Technical Feasibility

An innovation is said to be technically feasible if it has competitive edge over other technologies, can be readily mass produced, and has diversity of uses. A new process must be technologically perfect so as to guarantee mass production when demands call for it. In addition, the product must be versatile enough to be used and applied in several ways.

Competitive edge means that a new product can be produced at a cost that is lower than that of existing products in the market. Thus, a project can be considered technically feasible if it can be mass produced cheaply to satisfy a wide range of demand.

Profitability

Profitability refers to the comparison of costs with benefits. A technology is said to be profitable if the benefit is much higher than the costs.

There are two main considerations to profitability; financial and economic. Financial profitability is concerned with the income that a business venture could generate from a new technology, while economic profitability refers to the added productivity that is generated for the country and society. We are initially examining the usefulness of income statements, cash flow statements, and balance sheets as potential indices for evaluating profitability.

Our research group is currently working to define a rating system for each of the three requirements for commercial utilization. There are two main tasks required. First, we need to define the relative importance of each of the three requirements and we are initially using the percentages given in Table 1. Second, we need to define a reliable index rating for each component. Here we specify all the factors affecting the component, the data required to quantify each factor and finally the formula for defining the index. This process of developing an objective rating for each component will be done whenever possible. If not, a subjective rating based on expert opinion will be used.

As shown in Table 1, the column specifying the relative importance of each index will be multiplied by the rating to give the overall value accorded to the technology. The technology with the largest overall value is the most attractive for commercial utilization.

Problems in commercialisation

The experiences cited in the previous section identify several key hindrances to the commercial utilisation of research results. These and other problems that we have observed are discussed in this section.

1. Commercial utilisation of research results is not the main criterion for rewarding academic activity. In academe, where a significant amount of research is being conducted, success is measured in terms of such accomplishments as numbers of published papers, numbers of research projects completed, numbers of research grants, etc. Only in very rare instances are research staff rewarded or recognised on the basis of widespread use or adoption of the innovations they have produced. It is probably a consequence of this rarity that some observers claim that research is mainly concerned with collection of sets of data rather than production of viable technologies or contributions to national development goals (Cuyno 1986).

2. The procedure for dividing the financial reward of commercial use is not easy to specify. How does the researcher or the host institution share in the benefits of commercialisation? It is not easy to devise a formal procedure on compensation for the researcher and the host institution. Because of the vagueness of this process, many researchers feel short-changed when their findings are commercialised and in

some instances they tend to withhold information from others, especially those who intend to commercialise their findings.

3. Criteria for granting research support do not highlight potential for commercialization. Many granting agencies follow traditional criteria for evaluating research. In this evaluation process, commercialisation potential is either low on the list of requirements or not required at all. Consequently, the results of research funded by such grants are seldom utilised commercially.

Table 1. Criteria for evaluating the potential of research results.

Criteria	**Weight x rating* = value**
A. Marketing (30%)	
1 . Substantial demand	0.20
2. Supply situation	0.05
3. Potential market share	0.05
B. Technical (30%)	

1. Technical soundness of technology	0.10
2. Mass production capability	0.10
3. Diversity of uses	0.05
4. Competitive edge over alternative technologies	0.05
C. Profitability (40%)	
1. Financial	0.30
2. Economic	0.10
Total	**1.00**

***As described in the text, the rating can be obtained objectively through data or subjectively trough expert opinion.**

4. The poorest sector of society, which stands to benefit most from research, is usually the best attractive target for commercialisation. Most public research institutions focus their activities on technologies that benefit the poorest sector of society, on the premise that this is the sector that usually does not benefit from private investment.

Unfortunately, the same sector usually cannot afford to pay for the cost of new innovations so that commercialisation becomes difficult Because of the low purchasing power of this sector, therefore, it becomes very difficult to produce innovations that can give attractive financial and economic returns.

5. Good researchers are usually poor communicators. Some of the problems in utilisation are caused simply by lack of information about the technology and/or its potential consequences. This may be due to the purposeful isolation of research. Because of this isolation, there is no flow of information from the users to the researchers and vice versa. Researchers are often cloistered in their laboratories, shielded from commercial pressures, and research projects usually produce results that are not directed towards solving problems of commercial significance.

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Proposed plan of action

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We identify three major tasks that can hasten the utilisation of research results: (1) changing the standard of academe so that the utilisation of research results will be recognised as an important criterion of success or failure of applied research; (2) development of an easy to implement procedure for identifying research results that are ready for commercial use; and (3) actual commercial utilisation. In the following sections, we specify the activities that need to be done to make sure that the abovementioned tasks are accomplished.

Changing the Standard of Academe

Although academic institutions are usually conservative and not easily influenced by outsiders, they are most susceptible to the wishes of funding institutions. The criteria that funding institutions use for granting research funds are of major interest to researchers in academe, since they usually depend on financial support from outside donors. Naturally enough, what the donor agencies say is accorded great attention by academe. If the donor agencies specify commercial utilisation of research results as a major consideration for approving research proposals, we have no doubt in our minds that many researchers will listen and quickly mend their ways.

We propose, therefore, that funding agencies, probably starting from those present in this workshop, incorporate potential for commercial use as a main criterion for evaluating research proposals. The evaluation components given in Section 11 can be used as a basis.

Take note that these criteria are in fact most relevant to many researchers in postharvest technology, especially in the area of developing equipment and machinery. Research on the development of a new dryer, for example, must specify beforehand the following:

- **1. Who are the potential users of this dryer and how large is the sector?**
- **2. What are the existing drying methods and what is the potential advantage of the new method to be developed?**
- **3. What is the maximum initial cost of the dryer that the potential market can bear?**

Note that all of the above information should be available to the research proponent even before he starts actual development. Consequently, a fairly accurate ex-ante analysis on the potential for commercialisation can be developed even before any donor funds are a

Procedure for Identifying Utilisable Research Results

We have already discussed in detail the criteria required for identifying research results that are ready for commercial utilisation. How then can these criteria be applied? We plan to do the following at SEARCA:

1. Develop a database describing ongoing and completed research in the region. This database must contain not only the commonly gathered information on author, title, completion date, and money spent but, more importantly, the data that are required for assessing potential for commercialisation.

2. Establish a regional network for gathering the required data so that research being done in all parts of the region can be evaluated.

3. Develop the software for data analysis to quickly identify research results with the best potential for commercialisation.

4. Pilot test prototypes for commercial utilisation.

Actual Utilisation

We foresee two main routes for the actual commercialisation of research results. First is through manufacturing, either by large private corporation or by small-scale village industries, while the second is through direct use by farmers and the rest of the rural sector. For the manufacturing scheme, we expect our present research utilisation group to provide a link between research findings and commercial companies. We shall match technical innovations to entrepreneurs so that utilisable research results will be brought to the attention of the most appropriate private commercial companies.

With respect to the scheme of direct use by farmers, we will institute at SEARCA a regional network of on-farm trials, for both lowlands and hill country. These trials will allow for the direct evaluation, in actual farms, of new technologies and innovations that are ready for large scale adoption by farmers. These trials will, at the same time, determine whether the new technologies will be easy or difficult for farmers to adopt.

References

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