18. TECHNICAL PROBLEMS IN DRYING AND PROCESSING

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In Japan the government purchases all the rice produced except the rice for farmer's family consumption. The government purchase price of rice is determined by a certain standard of the quality of the husked rice, so that farmers are requested to make paddy rice into husked rice according to this standard. Reaped paddy rice is dried, threshed, dried again, husked, sorted and finally packed. Although the operation is variously arranged according to the local climate and practices, it might be outlined as shown in Fig. 1. The arrangement of operation can be simplified by using the binder and the combine which have recently spread rapidly and widely. Drying operation has been greatly influenced by the simplification in harvesting. The main subject to discuss in this paper will be on the drying methods and their comparison.

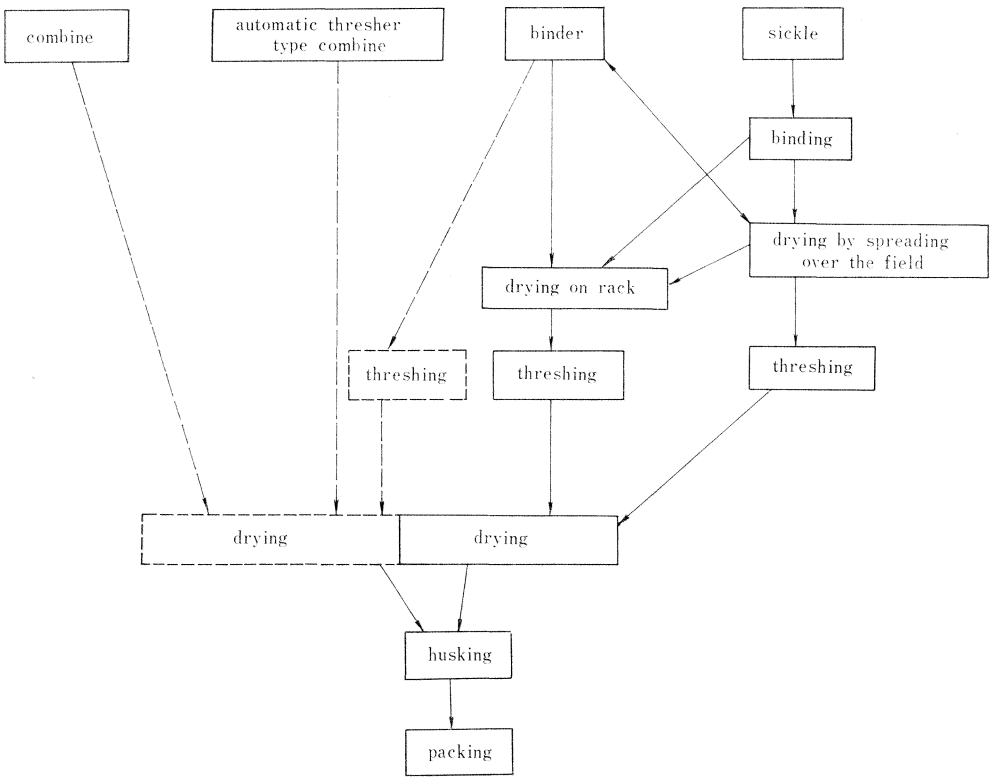

Fig. 1. Various arrangements of farm jobs needed before packing.

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Drying of cut plants

The drying method depends on the local and climatic conditions. So long as the paddy field is well-drained, cut plants to dry are usually spread on the field in small bundles or as they are. This method tends to cause the deterioration of the paddy quality even if the weather is fine. In order to avoid this, after cut plants are dried on the field for a half to 1 day, they are hung on the rack, or arranged in bundles with ears up, or piled up until they are dried up enough to be threshed. There are several kinds of the rack, and cut plants are dried on a single, double, or sometimes multiple racks not to cause the crack damage under strong sunlight.

Cut plants are threshed on the Pacific side of this country mostly after they are dried up on racks for 3 to 7 days down to 17 to 18 percent of the moisture content of paddy, and on the side of the Japan Sea for 15 to 20 days down to 14 to 15 percent.

Rack drying has some following merits; cut plants can be left on the racks without the increase of damages while the farmer is busy at other farm jobs; the paddy dried on the racks is easy to thresh; and so few haulms and leaves are mixed with paddy so that the paddy can move fluently and cause no troubles in handling and drying later. On the other hand the demerits are as follows: many timbers and the barn to store them are needed for using only once a year and besides rack making and removing, and hanging paddy require much labor at the busy time of harvesting.

Threshing

When dried enough, dried paddy is threshed in the field or at home. In the case of threshing at home paddy is often received once at the barn and threshed later when the weather and the farming works are convenient. A 2 wheel tracter with trailer can carry dried cut plants of 3 a (0.03 ha) in amount once. The special carriage with a large ground contact area is sometimes used on wet and soft paddy field.

Threshing operation was mechanized earliest of all. Over 3 million power threshers are in use at present and over 300 thousand threshers are newly produced every year, most of which are automatic. There are almost no problems in threshing of paddy dried on ground or rack. In some districts threshing is tried immediately after reaping so as to rationalize operation. In this case, the high moisture content of haulms, leaves and paddy often causes difficulty of shattering, damage of grain, clogging of grain sieve, low movability of grain, and decreases the operating efficiency. These problems, however, have been almost solved along with the development of the combine of a Japanese type.

Drying of paddy

Most of threshed paddy needs to be dried as they contain over 18 to 19 percent of moisture. They have been spread thinly on the straw mat under the sunlight for drying. It takes much labour to take in the spread grains when rainy or at night, or to turn them over when fine in order to avoid the deterioration of paddy quality by the crack damage, so that the dryer came to use: The ventilation dryer by forced unheated air, which began to be used since about 1955, was improved on, and the vertical type and the circulation type dryers were produced: farmers use over 1 million and 500 thousand dryers at present.

Husking operation was also mechanized as early as threshing operation, and over 1 million machines are now in use. The paddy is divided into husk and husked rice by making use of the difference of peripheral speed when they pass through the two husking rubber rolls, and the husk is blown off by winnower.

Then the husked rice is separated from broken rice, non-ripened grains and alien

substance contained by grain sorter, that is, the husked rice of poor ripening, falls down through the clearance of slanting steel wires stretched in parallel with each other, while fully ripened grain runs over the wires.

The husked rice, packed in a bag, every 60 kg before, and every 30 kg recently, is sold to the government by the agricultural cooperative after inspection of the government.

Quite different farming operation is conducted at the growing stages of rice plant. They are so closely related to one another, that it is necessary to improve one of them together with the preceding one that often influences it. As recently devised combines of a Japanese type spread rapidly the drying operation became very much difficult.

Paddy harvested by the combine contains far more moisture than the paddy threshed after drying on racks. Paddy at a harvesting period contains about 22 percent of moisture and sometimes it is harvested at as high as 30 percent of moisture along with the progress of the harvesting machine, while moisture content of paddy dried on racks is about 18 percent. The farmer sells rice to the government at about 14 percent of moisture. When the combine is used, the drier must remove over two times moisture as much. Paddy of high moisture content does not move fluently, and cannot be stored safely for a long time, so that the paddy harvested by combines is difficult to thresh and needs to be dried immediately after harvesting. Dryers already in use are roughly classified into a ventilation type, a vertical type and a circulation type dryers. The mechanism, characteristic and problem of each will be given as follows.

Ventilation dryer

The test and research on drying by forced unheated air began at agricultural experiment stations about 1950, and the ventilation dryer was used in 1955. The method is to dry paddy by ventilatin unheated air through thinly piled paddy on the flat flood. At the harvesting period the weather is fine more often and the relative humidity of atomosphere is under 50 percent in the daytime. The equilibrium

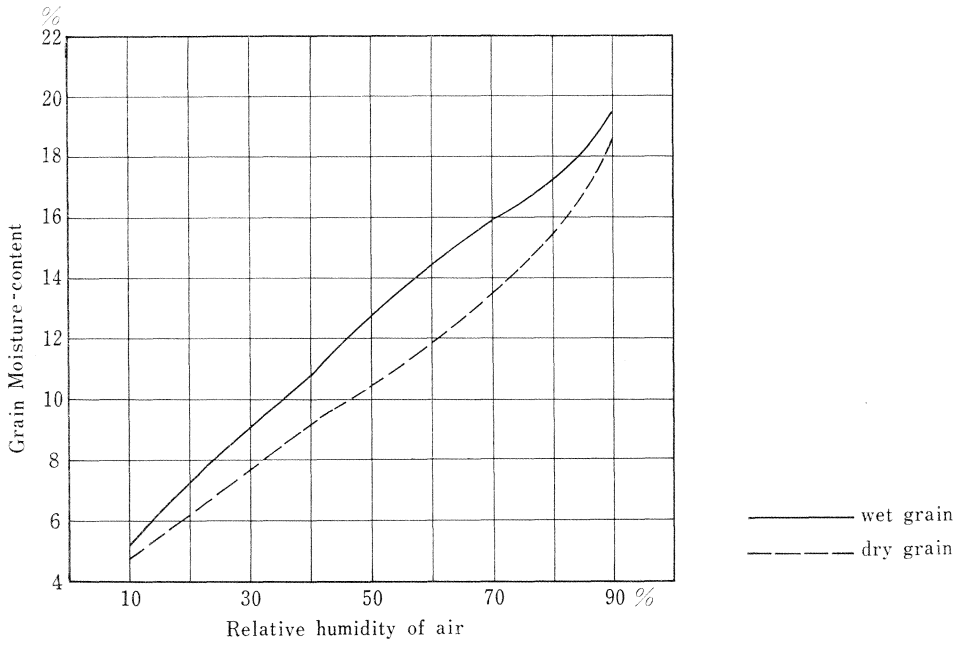

Fig. 2. Equiliblium moisture content of paddy.

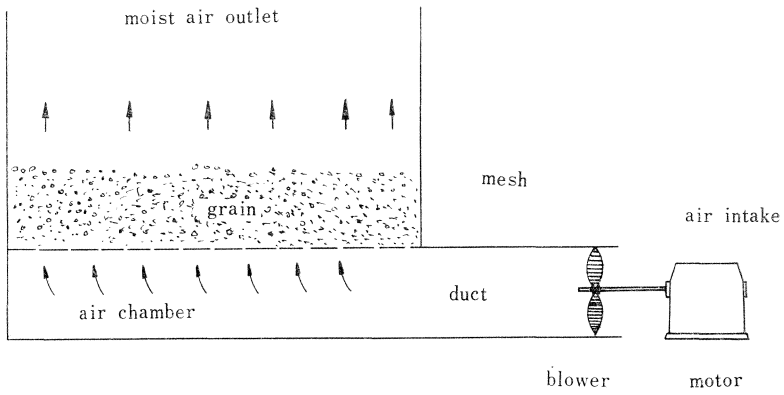

Fig. 3. Cross sectional view of batch dryers with a flat floor.

moisture content is below 14 percent at 50 percent of relative humidity as shown in Fig. 2. Drying of this type is to dry paddy to the required moisture content, making use of these conditions. The mechanism is very simple as shown in Fig. 3. The dryer consists of the box to charge paddy with mesh stretched at its bottom to ventilate air, air duct, a fan and an electric motor. Fresh paddy is piled flatly as high as 30 cm on the mesh and dried by sending about $5\times10^{-2}m^3$/sec air per 100 kg of fresh paddy.

This dryer was devised at first only for forced unheated air, but it took much time, and therefore the barner was equipped to ventilate heated air. The condition for use is roughly as follows: the temperature of air should be below 35°C, and the relative humidity should be over 30 percent. Drying speed of more than 1 percent an hour causes the deterioration of paddy quality by the crack damage. The merits of this dryer are as follows: 1) Simple mechanism accounts for its low price and enables farmers to fix the dryer to the barn. 2) The dryer, which is devised to pile paddy about 30 cm high, can pile up paddy of large quantity as high as about 60 cm. 3) As grains do not need to be moved during drying, it does not cause the damages such as husked grain and broken rice. 4) Paddy, although it contains high moisture or is mixed with straw, can be dried as they are. 5) Grasses to feed animals can be dried as well as grain. 6) The material can be dried by using unheated air without deterioration of its quality. 7) The dryer is easy to be cleaned, disassembled and assembled again. It can be disassembled and tucked away when it is not needed.

On the other hand the demerits are as follows: 1) As paddy is dried from the bottom layer to the top along the drift of air and therefore it is apt to be dried unevenly, it needs to be stirred up during drying to avoid the unevenness. 2) The heated air passes at so high a drying speed at the bottom layer that the cracked grain occurs often. 3) This dryer presents a difficulty in charging and discharging paddy* and above all much dust raised during discharging is unwholesome. 4) The barn is narrow to install the dryer of large bulk in, especially, at the harvesting period when many things have to be stored there. 5) The dryer must be operated according to the weather conditions, and the temperature of heated air is difficult to adjust. 6) It is difficult to know when to stop drying.

The fresh paddy of high moisture content is dried particularly unevenly in the different layers. The precaution is to ventilate extremely large quantity of air or to dry paddy gradually for a long time by unheated air.

Vertical dryer

Vertical dryers have the improvement over the ventilation dryer because it was improved in the size to occupy the space and in the charge and discharge of paddy. The dryer is equipped with a grain hopper to charge grain easily, a bucket elevator, a screw conveyer to discharge paddy by motor as shown in Fig. 5. Paddy is dried by ventilating heated air sent by fan through compiled paddy. The theory of drying is the same with that of the ventilation dryer. And in the case of this dryer the box to contain paddy parts right and left, and the air passes through the central air duct into both sides.

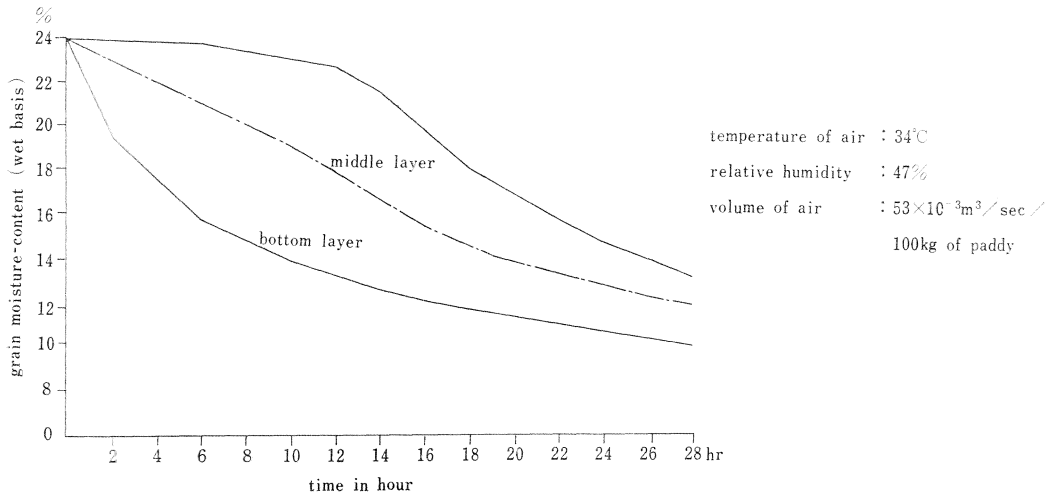

Fig. 4. Moisture content of paddy during drying.

The merits of this dryer are as follows: 1) Paddy is charged and piled up high between meshes stretched at regular intervals, and the machine does not occupy much space for installation. 2) It can be easily conveyed, equipped with wheels. 3) Paddy can be charged and discharged automatically and easily by motor. 4) Paddy, which is still dried unevenly in the different layers, can be stirred up easily by making use of the machanism of grain charger and discharger. 5) In discharging paddy, the thrower or bucket elevator which is equipped with the dryer can carry it high enough to feed the husker. So the dried paddy elevated, for example, in the second floor of barn, can easily fall to be supplied for husking, so that husking operation becomes efficient.

The demerits are as follows: 1) Paddy can not be dried unless a certain quantity is supplied. Paddy of less quantity is short of height and makes a space left at the top layer as shown in Fig. 5. The heated air sent passes through not paddy but this space. So paddy should be harvested within a certain area so as to reach the required height, otherwise a supplementary dryer is needed. 2) When paddy is piled up in the vertically high box, the high density of the lower layer affects the quantity of air flow through the grain. In spite of a slight difference in density between layers, the quantity of air flow at the same static pressure greatly differs and causes the unevenness of drying. Paddy should be stirred during drying and there appears much quantity of dust. 3) The dryer should be operated according to weather conditions and it is difficult to decide when to stop drying, which is also the case with the ventilation dryer. But as this is

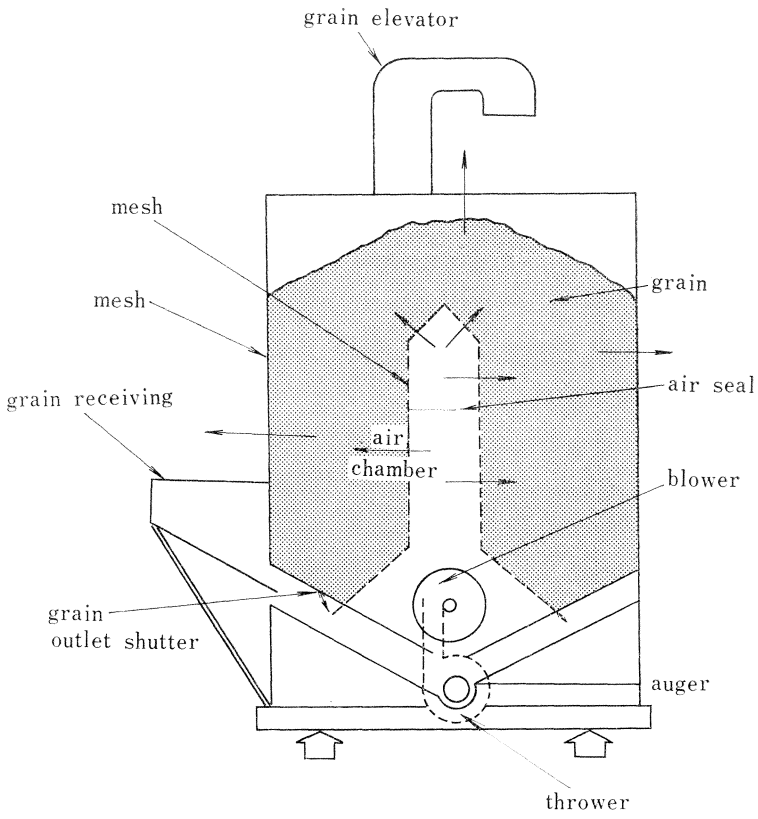

Fig. 5. Cross sectional view of the vertical dryer.

more complicated, the cleaning is more difficult and the price is higher.

The paddy of high moisture content is neither charged fluently through the hopper nor easily moved when stirred, so that the paddy gets the dryer clogged and is attached to its wall, which causes the unevenness of drying or sometimes the deterioration of grain quality.

Circulation dryer

The vertical dryer was improved into this type of the dryer in order to be available for various quantity of fresh paddy. The vertical dryer, as was mentioned above, cannot dry paddy when it does not fill the dryer and a space is left at the top. So a tank of large capacity is equipped at the upper of the ventilation area as shown in Fig. 6, for the normal circulation, regardless of quantity of paddy. Most of charged paddy is sent out successively and little by little from the bottom layer through ventilation area by rotary valves. Paddy is sent back to the tank again, so all the paddy circulates in order through ventilation area. Paddy in ventilation area is usually about one-third as much as all the charged paddy and it takes about 70 minutes to circulate the paddy once. That is; paddy is dried up about 20 minutes in ventilation area and stored in the paddy tank about 50 minutes. Consequently, even though the drying is made at a higher temperature of air and at a higher drying speed it causes less cracks than in case of constant ventilation. This is because the moisture content of paddy is averaged

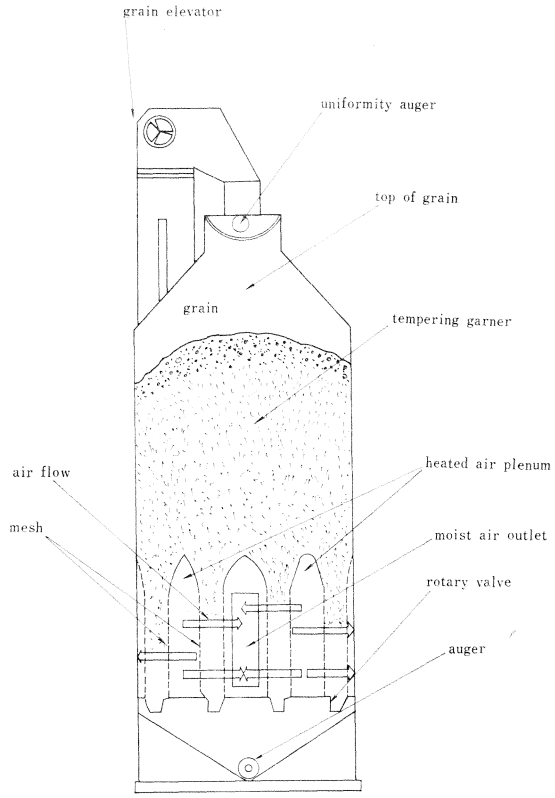

Fig. 6. Cross sectional view of the circulation dryer.

while the paddy is stored in a tank, and the drying speed counting in the time of storage, is the same as that at the constant ventilation. In the case of small amount of paddy, the paddy is stored in the tank for a short time, so that it should be dried at the lower drying speed and the lower temperature of air.

The merits of this machine are as follows: 1) The dryer can be available for any quantity of paddy. 2) Paddy can be dried evenly because all the paddy circulates constantly. 3) The dryer can be used without an operator during night, with equipments to control the temperature of air and to stop automatically. 4) Not influenced by weather conditions, the dryer can dry paddy at a constant standard by sending the heated air of high temperature.

On the other hand the demerits are as follows: 1) The dryer is expensive because it has highly mechanized automatic equipments. 2) Usual farmer's barns are not high enough to install this high dryer without some partial improvements of it. Once installed, it cannot be moved to other places nor disassembled easily. 3) Automatic stopping equipment dries paddy too much unless accurate measurement of moisture content of paddy is made before charging. 4) Constant circulation raises much dust.

Paddy of high moisture content tends to increase husked grain during the circulation and to be stored in a tank at a considerable high temperature longer than a certain period allowed for safety. The dryer gets clogged with paddy wet with dewing which is caused by the difference of temperature inside and outside the tank, and this causes the irregular

circulation and drying. The dryer with highly efficient automatic equipments is complicated to set to work and in addition some kinds of dryers cannot be left about during operation. At present no dryer is completely effective for the fresh paddy of high moisture content harvested by the combine.

Public facilities for drying on a large scale

In the whole country there are 800 co-operative drying facilities on a large scale called rice centers and 24 country-elevators.

In order to dry the fresh paddy harvested by the combine, the dryer must remove over twice as much moisture as in case of the paddy dried on racks. Consequently the cost of drying increases. In addition, the conveyance equipment and dryer often get clogged with fresh paddy which does not move fluently. In some facilities they refuse to dry the paddy harvested by combines. The low liquidity is attributed not only to the high moisture content of paddy but also to the mixture of straw and grains with rachis-branch in paddy, which is caused by low threshability due to the high moisture content of paddy. In order to avoid clogging during drying, the paddy cleaner must clean admixture of straw and others. At the harvesting period the facilities are flooded with the harvested paddy beyond their capacity at a time. Some installations need to be equipped for storing paddy safely for a while. The drastic remedy to make effective use of facilities is cooperative farming and planned harvesting operation taking their drying capacity into consideration.

So far the outline of drying operation has been given. There are some problems left: that is, 1) to diminish the defects such as the noise of fans at night operation and the rise of dust, 2) to develop the cheap meter to measure moisture content accurately, the automatic equipment to stop drying when the moisture content of paddy attains to a certain amount, and the highly efficient cleaner to remove admixture in fresh paddy.

Recently it is demanded to make clear the inter-relation between the taste of rice and the drying and storing methods. The other problems to be discussed in the future are as follows: 1) the influence of the heating temperature of forced air, ventilation hours and tempering hours in use of tempering dryers on paddy quality, and 2) the arrangement of harvesting and carrying operation in relation to drying.