Principles of Rice Drying

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How does rice dry?

Rice gains or loses moisture based on its moisture and the humidity of the air around it. If the humidity is low, high moisture rice will lose moisture until it comes to a constant low moisture content. If the humidity is high, low moisture rice will gain moisture. The relationship between rice moisture and air humidity is described by Fig. 1. The relationship is slightly affected by temperature, as seen by the three lines on the graph.

Another way to describe this relationship is that if rice is placed in a constant temperature and constant humidity air stream it will attain an equilibrium moisture content (EMC) corresponding to the air humidity and temperature (Fig. 1). Or, if rice is placed in a sealed container, the air in the container will gain or lose moisture until it attains an equilibrium relative humidity (ERH) corresponding to the rice moisture and temperature.

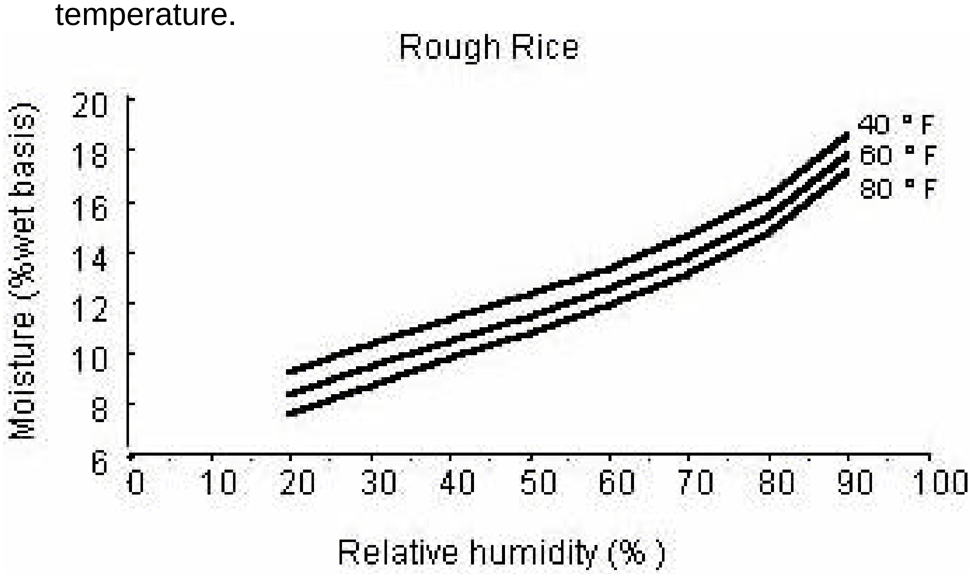

Figure 1. Equilibrium moisture for rough rice.

Rough rice is generally stored at 12.5 to 14% moisture. According to the equilibrium moisture data, rice at moistures above 14% will be exposed to drying conditions when air humidity is less than 64% RH at 40° F or less than 75% RH at 80° F. If 14% moisture rice is exposed to humidities above these conditions it will gain moisture.

In an individual kernel, moisture is lost first from the hull, the part of the kernel most exposed to the drying air. The inner kernel then loses moisture to the hull. In high temperature drying the grain is exposed to drying conditions for about half an hour. During this short time the hull may lose four to six percentage points of moisture, but the inner kernel loses only about one point, see figure 2. During tempering (holding the grain in a bin for at least two hours with no drying air flowing through the bin) the inner kernel continues to lose moisture and the hull gains moisture. This causes a rather continuous loss of moisture from the inner kernel during the repeated drying and tempering cycles. The hull goes through cycles of moisture loss and gain.

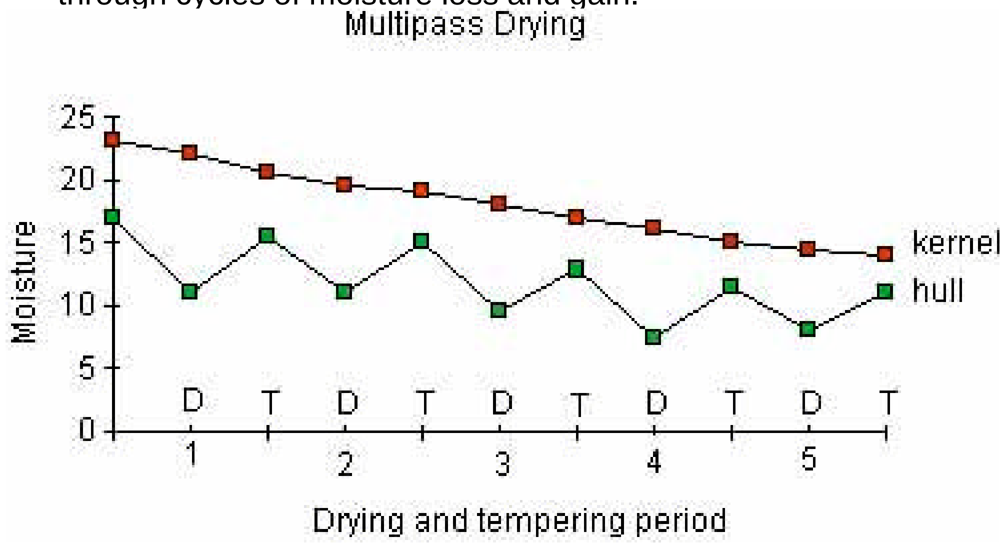

Figure 2. Moisture content of kernel and hull after each drying pass and tempering period in five passes drying of rough rice. Data from Nagato, et al., in Mossman, 1986.

In a bin, rice dries in a layer, called the drying zone, which slowly moves from the floor to the top of the batch (Fig. 3). As drying air moves up through the rice it gains moisture from the wet rice and it cools. This causes the drying air relative humidity to increase. When the air reaches a certain relative humidity (specific humidity depends on rice moisture and temperature), it reaches an equilibrium relative humidity with the rice and drying stops.

If the rice above the drying layer is at the same temperature as the air flowing through it, it stays at its original moisture. If the rice is colder than the drying air, it will cool the air and the rice will be exposed to high relative humidity, sometimes moisture even condenses on rice above the drying layer. If this condition lasts long enough, it may cause fissuring. This is the reason why heaters for bin dryers should add no more than 10° to 15° F to the drying air.

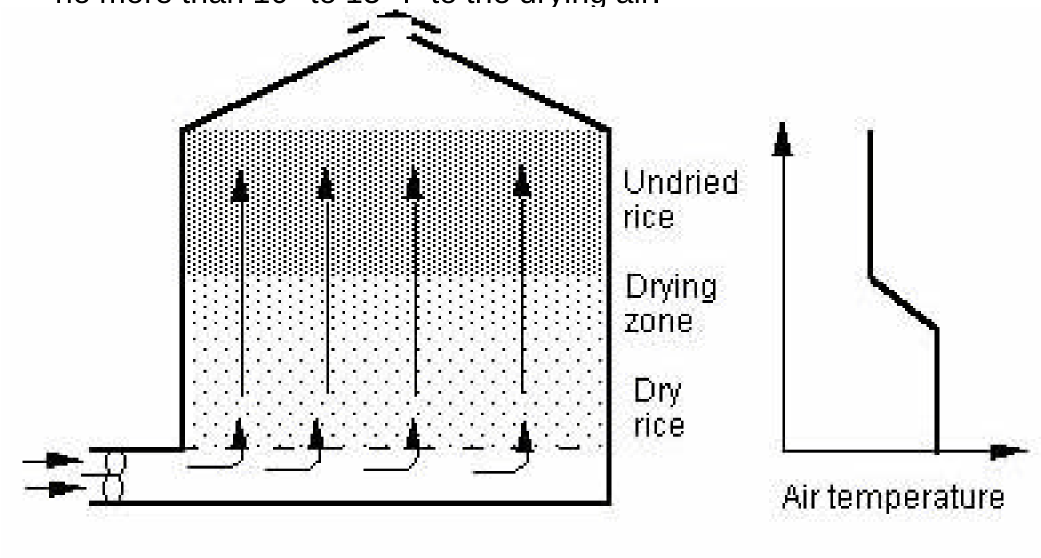

Figure 3. Air passing through a bed of rice produces a distinct drying zone.

Combinations of air temperature and relative humidity that cause drying

Table 2 in the Bin Drying chapter shows the combinations of temperature and relative humidity that will cause drying or moisture absorption for rice at a range of moistures.

Factors that control drying rate in a bin dryer

Rice dries faster if it is exposed to:

1) higher air flow rates
2) higher air temperature
3) lower relative humidity.

Air flow for dryers is best described in terms of cubic feet per minute per hundred weight of product (cfm/cwt). Figure 4 is a plot of drying time versus air flow for a bin of rice. It shows that small increases in air flow greatly decrease drying time at low air flow rates, but at high air flow rates, increases in air flow cause small decreases in drying time. Air flow rates over 50 cfm/cwt are commonly used in column dryers where air travels only through 6" to 12" of rice. In bins, high air flow rates are not feasible because of the great amounts of fan horsepower required to push high air flow rates through a deep bed of rice. Air flow in a filled bin of rice is often in the range of 2 to 5 cfm/cwt. A 3 ft to 6 ft layer in a bin may allow air flow rates over 20 cfm/cwt.

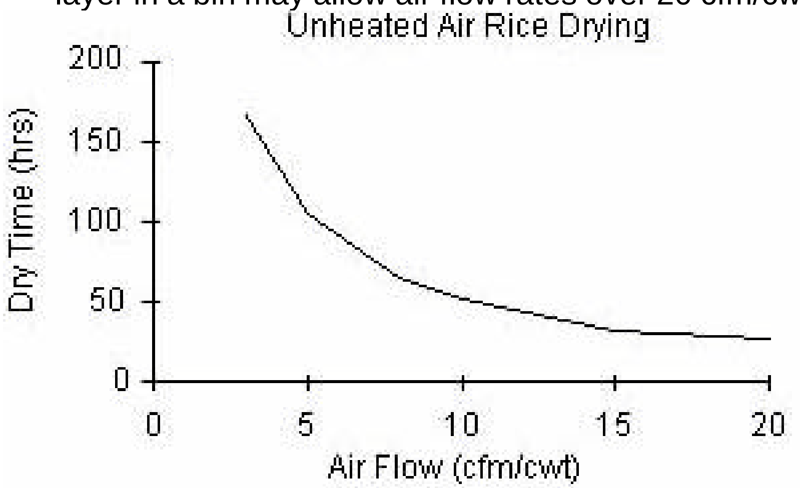

Figure 4. Effect of air flow rate on drying time for rice dried from 24% to 18% moisture with air temperature equal to September average for Red Bluff, CA.

In bin dryers or flat storage, air temperature and humidity is controlled by starting drying as early in the season as possible to take advantage of higher air temperatures and lower relative humidity. Figure 5 shows the monthly average air temperature for the warmest and coolest parts of the Sacramento Valley. In September average air temperature ranges from 72° to 76°F. At the end of the drying season in November air temperature has dropped to less than 55°F. Bin drying in November takes 2.5 to 3 times more time than it does in September.

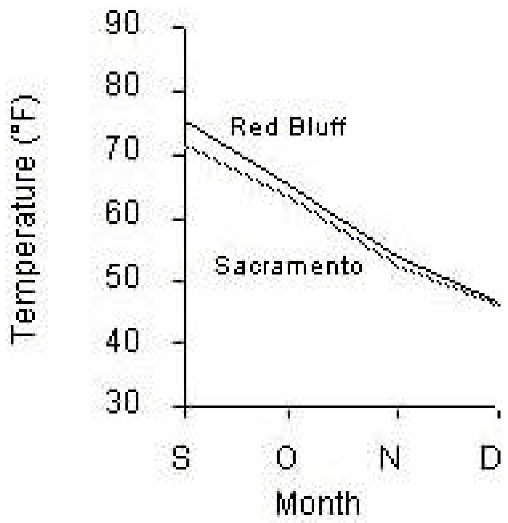

Figure 5. Average air temperatures for Red Bluff and Sacramento, California.

Gas burners can be used to add heat to the air and increase drying rates. However in bin dryers, adding more than 10° to 15° F to outside air will usually reduce head rice quality because top rice may be exposed to high humidity or even condensed moisture.

Air humidity is sometimes controlled separately from air temperature by using special dehumidification systems. Some of these units supply air at a specified humidity and temperature and are useful for providing very controlled conditions for rice in storage. They are expensive to purchase and operate.

Increasing air flow through rice

Air flow (measured in cfm/cwt) can be increased by:

1) decreasing rice depth
2) installing a second fan
3) using stirrers.

Decreasing rice depth increases cfm/cwt directly because rice depth is reduced (cwt is reduced) and fans produce more air when operating against lower pressure drops. Fig. 6 is an example of how air flow rate increases rapidly as rice depth decreases. The data in the figure are based on a specific size bin and fan performance data for two commercially available fans.

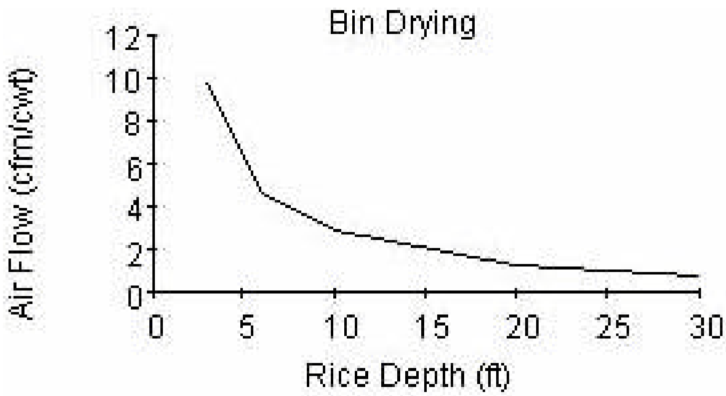

Figure 6. Effect of rice depth on air flow rate through rough rice in a grain bin. Relationship is based on a typical centrifugal fan.

There is one disadvantage with shallow rice depths. After the drying front reaches the top of the rice, the drying air is not completely saturated as it leaves the rice. This air could have been used for additional drying if it could be passed through rice. Maximum amounts of rice are dried when there is always a layer of undried rice on the top of the bin. Some drier operators achieve this by filling bins fairly deep, at least 10 feet, and dry until the top most rice just begins to lose moisture. Then they transfer a center cone of dried rice and the top layer to another bin, where they add more undried rice. The rest of the bin is transferred to a bin with dried rice.

It is possible to add an additional fan and increase air flow. For a well designed system a second fan, which doubles fan horsepower, can increase bin drying capacity by 25% to 35%. The additional fan is usually placed in parallel with the existing fan (both fans feed directly into the bin). Carefully consult manufacturer's performance data to determine the combined performance of the fans. The fans should have similar performance characteristics, otherwise it is possible for the air to be pushed out the original fan!

Stirrers

Stirrers increase air flow by about 10% compared with a well settled batch of rice. The value of this extra drying capacity is offset by the purchase and operating cost of the stirrers and they reduce storage capacity in a bin. Stirrers can also be used to level rice and mix pockets of high moisture rice.

Drying rate in a column dryer

Column dryers have very shallow bed depth and very high air flow rates per hundred weight of rice. Adding additional fan capacity rarely increases drying rate.

Increasing air temperature greatly decreases drying times, see Table 1 for an example of this effect. But short drying times cause fissuring and loss of head rice. Acceptable head rice quality can be maintained while using high air temperature by increasing the number of passes through the dryer.

Table 1. Effect of drying air temperature and number of passes on total drying time and head rice quality. Data based on drying Colusa 1600 rice from 23.6% to 13.0% moisture in a 2 inch deep laboratory dryer, adapted from Thompson et al., 1955.

	3 pass drying		5 pass drying	
Air temp. (deg F)	Hours in Dryer	Head Rice (%)	Hours in Dryer	Head Rice (%)
100	4.0	62	2.7	65
120	1.8	50	1.3	58
140	1.0	<50	0.7	<50

* total time rice is in the dryer for all passes.

Reducing the amount of moisture removed per pass reduces time in the dryer, independent of temperature effects. Moisture loss is rapid in the first few minutes rice is exposed to drying air because moisture is easily removed from the hull. Moisture deeper in the grain takes time to migrate to the surface. Column dryers have more capacity, produce higher head rice quality and have lower energy use when they are operated with as many passes as possible.

Reference

Mossman, A. P. 1986. A review of basic concepts in Rice-drying research. Critical Rev. in Food Sci and Nutr. 25(1):49-70.