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Energy in Agriculture: Performance Evaluation for Natural Air and Low-Temperature Drying Systems

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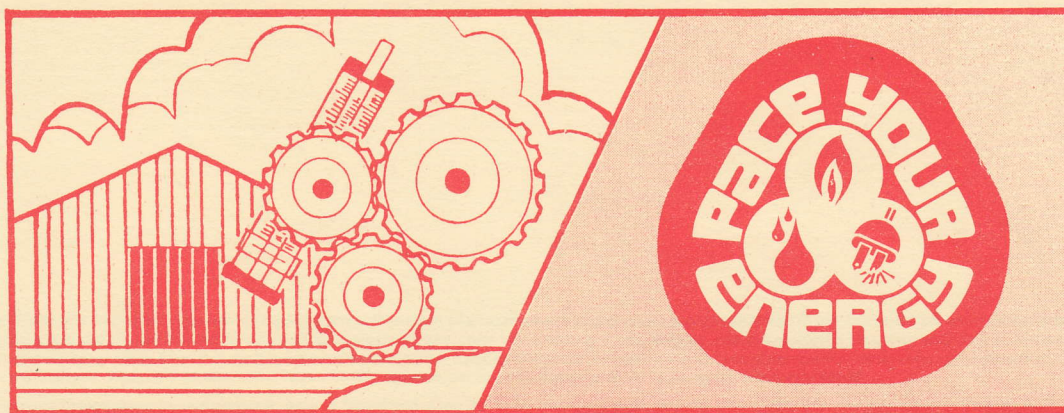
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ENERGY IN AGRICULTURE

PERFORMANCE EVALUATION FOR NATURAL AIR AND LOW-TEMPERATURE DRYING SYSTEMS

O. J. Loewer, T. C. Bridges, G. M. White, R. L. Fehr, and L. W. Turner



UNIVERSITY of KENTUCKY
COLLEGE of AGRICULTURE
DEPT. of AGRIC. ENGINEERING
COOPERATIVE EXTENSION SERVICE

in
cooperation
with

KENTUCKY
DEPARTMENT
of
ENERGY

PERFORMANCE EVALUATION FOR NATURAL AIR AND LOW-TEMPERATURE DRYING SYSTEMS

O. J. Loewer, T. C. Bridges, G. M. White, R. L. Fehr, and L. W. Turner

Natural air and low-temperature drying systems are generally not recommended for Kentucky because of their slow drying rates. In such systems the grain near the top of the drying bin may remain undried for an extended period of time, possibly leading to grain spoilage and/or the production of aflatoxin. An estimate of the period of time which grain at certain moisture contents may be held without significant spoilage is shown in Figure 1:

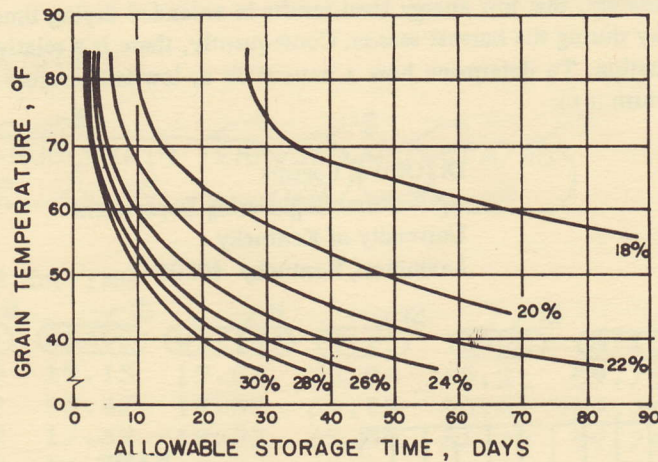


Figure 1. Allowable storage time for shelled corn at various temperatures and moisture contents.

For a complete discussion of low temperature drying, ask your county agent for University of Kentucky Cooperative Extension Publications AEN-22 "Low Temperature Drying—Methods and Management" and AEN-23 "Low Temperature Drying—Use and Limitations."

As shown in Figure 1, the lower the grain temperature and moisture content, the longer the grain will store safely. Increasing airflow will decrease drying time as will an increase in the drying air temperature. Natural air systems use only the drying potential of the outside air to dry the grain, although the force of the fan may increase the air temperature by 2°F. Low temperature systems add heat to the air (5-7°F), reducing its relative humidity and thereby increasing its potential for drying. However, too much heat added to the air will result in overdrying of the bottom layers of grain unless the grain is being mixed within the bin. The relationship between changes in air temperature because of heating and the resulting changes in relative humidity may be found using Figure 2. Temperature changes in the heater always take place along a line parallel to the air temperature axis or scale.

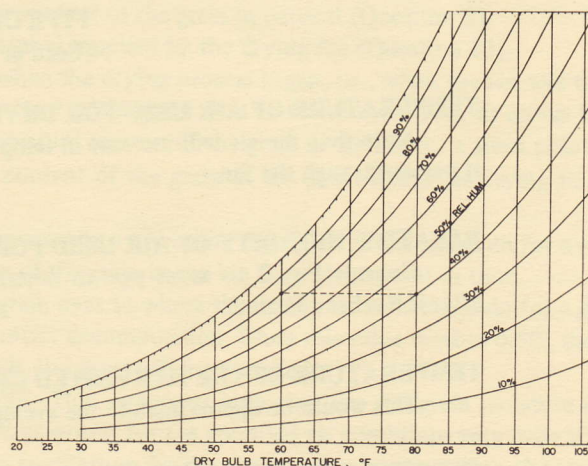


Figure 2. Air temperature and relative humidity relationships.

As an example of how Figure 2 can be used, suppose the outside air temperature was 60°F with a relative humidity of 80 percent. If this air were heated to 80°F, the new relative humidity could be found by extending a line parallel to the bottom of the figure from the original air conditions to a point directly above the new temperature on the bottom scale. The new relative humidity can then be read from Figure 2; the new relative humidity for this example is 40 percent. A "rule of thumb" is that a 20°F increase in air temperature will generally reduce the relative humidity of the air to one-half of its original value.

Another point to consider is that the temperature of the air entering the grain will be two degrees or so higher than the outside air because of the energy added by the fan in moving the air. To better approximate the volume of air per bushel delivered by the fan, the list of other programs available at the end of this text should be consulted.

The natural air and low-temperature drying processes usually require relatively low levels of energy use compared with high-temperature systems. Unfortunately, this low energy level results in extended drying times when air temperatures are similar to those found in Kentucky during the harvest season. Consequently, there is a relatively high probability of grain spoilage and/or aflatoxin contamination. To determine how a natural air or low-temperature drying system will function, complete the following form and return it to:

Dr. Otto J. Loewer
Agricultural Engineering Department
University of Kentucky
Lexington, Kentucky 40506

1.

NAME

2.

ADDRESS

3.

PHONE NUMBER

4.

TYPE OF GRAIN TO BE DRIED
(Corn or Milo)

5.

TEMPERATURE OF AIR USED FOR DRYING, °F

Note that the air will increase in temperature by approximately 2°F when it passes through the fan.

6.

RELATIVE HUMIDITY OF AIR USED FOR DRYING

Consult Fig. 2 to assist you in determining the relative humidity of air after it has been heated.

7.

TEMPERATURE OF THE HARVESTED GRAIN BEFORE DRYING, °F

This would be approximately the average outside temperature.

8.

PERCENT MOISTURE CONTENT OF THE GRAIN BEFORE DRYING.

9.

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DESIRED FINAL PERCENT MOISTURE CONTENT OF THE GRAIN AFTER DRYING.

10.

--	--	--	--	--	--

AIR FLOW RATE IN CUBIC FT. PER MINUTE OF AIR SUPPLIED BY THE FAN FOR EACH BUSHEL OF GRAIN IN THE BIN.

Typical values are: 1-2 CFM/BU for full bins. You may wish to consult other programs to obtain more exact figures for your system.

The computer analysis you will receive will be similar to that shown below. A listing of terms follows the example output.

```

CORN, MILO OR STOP
(CORN)-1
  2      3      4      5      6      7
(AIR TEMP) (REL. HUM) (GRAIN TEMP) (WBO) (WBF) (CFM/BU)
 765      68      65      20      14      2

(CORN)-1
NATURAL AIR DRYING
  8      9      10     11     12     13     14     15
(TIME) (WB(1)) (WBAVE) (WB(10)) (G(1)) (GAVE) (G(10)) (%DM)
47.50  15.40  19.15  19.84  62.96  60.21  59.75  0.0242
95.00  14.19  18.42  19.83  64.93  60.81  59.74  0.0481
142.50 14.19  17.69  19.83  65.00  61.48  59.74  0.0729
190.00 14.19  16.97  19.83  65.00  62.10  59.77  0.0986
237.50 14.19  16.24  19.75  65.00  62.79  59.78  0.1249
285.00 14.19  15.53  19.38  65.00  63.44  59.96  0.1506
332.50 14.19  14.88  18.15  65.00  64.10  60.63  0.1713
380.00 14.19  14.40  16.00  65.00  64.62  62.34  0.1819
408.50 14.19  14.24  14.83  65.00  64.85  63.56  0.1846
(PROGRAM STOPPED BECAUSE WB(10) APPROCHES ME)-16

```

1. CORN—Type of grain to be dried (Question 4).
2. AIR TEMP—Temperature of the drying air (Question 5).
3. REL. HUM—Percentage relative humidity of the drying air (Question 6).
4. GRAIN TEMP—The temperature of the grain to be dried (Question 7).
5. WBO—The initial moisture content of the grain in percent (Question 8).
6. WBF—The desired final moisture content of the grain in percent (Question 9).
7. CFM/BU—The airflow rate per bushel supplied by the drying fan (Question 10).
8. TIME—The time in hours from when the drying process began, i.e., when the fan was turned on.
9. WB(1)—The percent moisture content of the grain next to where the drying air enters the bin for a given time.
10. WBAVE—The average percent moisture content of the grain in the bin for a given point in time.
11. WB(10)—The percent moisture content of the grain at the point where the drying air exits the grain at a given point in time.
12. G(1)—The temperature of the grain next to where the drying air enters the grain for a given point in time.
13. GAVE—The average temperature of the grain in the bin for a given point in time.
14. G(10)—The temperature of the grain next to where the drying air exits the grain for a given point in time.
15. % DM—The percentage of dry matter decomposition. When this value reaches 0.5%, the market grade will be lowered to the next level. When it reaches 1%, the grain will have spoiled.
16. PROGRAM STOPPED BECAUSE—This statement indicates that the grain moisture content has nearly reached equilibrium with the drying air. In other words, for the specified air conditions very little if any additional drying can occur. If the grain temperature reaches equilibrium before the moisture content does, the statement would be, "TOP LAYER COOLED TO WITHIN 10 DEGREES OF AMBIENT."

ENERGY CONSUMPTION:

The energy used in low-temperature or natural air drying systems may be divided into that used by the fan and that used in adding heat to the drying air. Heat may be added by either electricity or gas. In addition, energy may be expended for stirring the grain.

- A. **FAN ENERGY:** The amount of electricity used in fan operation may be determined through the program "Fan Performance on Grain Drying Bins". An estimate of energy consumption may be made from the following equation:

$$\left(\begin{array}{c} \text{KW-hr of} \\ \text{Electrical Energy} \end{array} \right) \cong \left(\begin{array}{c} \text{Horsepower of} \\ \text{fan} \end{array} \right) \times \left(\begin{array}{c} \text{hours of} \\ \text{operation} \end{array} \right)$$

where 1 hp \cong 1000 watts. The hours of operation can be determined from the analysis of your system. For example, 408.5 hours of fan operation were required to dry the grain from the sample analysis. Therefore, if we assume a 10 hp fan was used:

$$\text{KW-hr} = 10 \times 408.5 = 4085$$

If electricity costs \$0.03/KW-hr, the cost for electricity would be \$145.50.

- B. **HEATING AIR ELECTRICALLY:** If low-temperature drying is used with electricity providing the energy for heating the air, the quantity used is:

$$\text{KW-hr} = \left(\begin{array}{c} \text{KW rating of} \\ \text{heater} \end{array} \right) \times \left(\begin{array}{c} \text{hours of} \\ \text{operation} \end{array} \right)$$

The KW rating of the heater may vary because many units are multi-stage; that is, one heating unit may be composed of several stages of heater elements. In this case, use the average rating of the heater. If the rating of the heater was 10 KW and it is operated for 408.5 hours as in the sample analysis, the KW-hr consumption would be 4085. The cost would be \$145.50 based on \$0.03/KW-hr.

- C. **HEATING AIR WITH LP GAS:** The amount of LP gas that is used may be estimated by the following equation:

$$\left(\begin{array}{c} \text{Gal of LP Gas} \end{array} \right) = \frac{110 \times (\text{CFM/BU}) \times (\text{Bu in Bin}) \times (\text{hours of operation}) \times (\text{temperature rise } ^\circ\text{F})}{92,000 \times (\text{efficiency of burning, \%})}$$

From the sample analysis, an airflow rate of 2 CFM/BU is used for 408.5 hours of operation. If we assume that (1) the bin contains 3000 bu (2) we wish to have a 5°F heat rise above that supplied by the fan and (3) the efficiency of the burning process is 80 percent, then the LP gas consumed is:

$$\begin{aligned} \left(\begin{array}{c} \text{Gal of LP Gas} \end{array} \right) &= \frac{110 \times 2 \text{ CFM/BU} \times 3000 \text{ BU} \times 408.5 \text{ hr} \times (5^\circ\text{F})}{92,000 \times 80} \\ &= 183 \end{aligned}$$

If the cost of LP was \$0.45/gal, the cost for drying would be \$82.35 or 2.75¢/bu.

- D. **STIRRING DEVICES:** The computer analysis does not consider stirring devices. However, the effects of these mechanisms may be estimated by using the average moisture content of the grain (item 10) rather than the moisture content of the top layer (item 14). Similarly, use the time required to reach this average moisture content and the associated dry matter decomposition (item 15). The energy used in stirring may be estimated by the following:

$$\text{KW-hr} \cong \left(\begin{array}{c} \text{Average hp} \\ \text{used in stirring} \end{array} \right) \times (\text{hours of operation})$$

SUMMARY:

The natural air or low-temperature drying process is not recommended for Kentucky because of the relatively high risk of grain spoilage and contamination by aflatoxin owing to warm temperatures and high moisture contents usually found during the harvest season. This process does not have much reserve power; that is, the drying front moves relatively slowly through the grain. At any sign of trouble, the grain should be removed from the bin and dried as quickly as possible using other drying techniques such as high-temperature portable batch or continuous flow dryers. Superior management is essential if natural air or low-temperature drying is to be successful each year for Kentucky conditions.

AVAILABLE COMPUTER PROGRAMS:

1. BNDZN: Computer analysis of economics, energy consumption and engineering design of a grain storage system.
2. CHASE: Computer model that evaluates and compares costs of selected methods of harvesting, handling, drying and storage of corn for an individual farmstead. Energy consumption is also estimated.
3. CACHE: Computer model for economic analysis of farm drying and processing systems.
4. SQUASH: Computer simulation of the harvesting-delivery-drying system used to determine bottlenecks in the system.
- *5. ESTIMATING FAN SIZES FOR GRAIN DRYING SYSTEMS
- *6. GRAIN DRYING PERFORMANCE EVALUATION
- *7. DRYERATION PERFORMANCE EVALUATION
- *8. NATURAL AIR-LOW TEMPERATURE DRYING PERFORMANCE EVALUATION
- *9. FAN PERFORMANCE ON GRAIN DRYING BINS

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*These programs were developed by:

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 Agricultural Engineering Department
 University of Nebraska
 Lincoln, Nebraska

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