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Paper presented at 1960 Short Course for Seedsmen
Mississippi Seed Technology Laboratory
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GRAIN AND SEED DRYING FUNDAMENTALS

It is indeed an honor and a pleasure for me to have this opportunity of being present for this part of your program. For a number of years the boys of the North Carolina Crop Improvement Association have hinted that I should enroll in one of your short courses. I still hope that at some future date I can arrange my spring schedule so that I can participate as you are participating in a full week's course to learn the many facets involved in the production and marketing of high quality seeds. We in North Carolina recognize the tremendous influence that the Mississippi Seed Technology Laboratory and your annual Seedsmen's Short Course have on the progress made by our seed producers.

In the beginning, let me state that I do not pose to be an expert in the field of seed drying. However, my eleven years' experience with the Agricultural Extension Service in promoting more and better grain storage and handling facilities has afforded me the opportunity of working with the fundamentals involved in grain and seed drying.

Of course, we recognize that there are certain factors that influence the design of a seed drying installation that are not of prime importance when we consider the needs of a general grain or crop drying facility.

The principal objective that points up the difference between the two systems is, of course, a definite desire for high germination and viability of the kernel of grain dried for use as seed. This objective is influenced principally by two factors: drying temperature and initial moisture content. Before we look at the data now available concerning these two influencing factors, let us back up and think for a few minutes about the fundamentals involved in drying a crop for seed or for any other purpose.

The term "drying" is so widely misapplied that its significance is oftentimes confused. Almost without exception, in the case of hygroscopic materials with which we are concerned here, the process ordinarily and loosely referred to as "drying" involves much more than the mere removal of moisture or other volatile constituents. Even when the product of evaporation is water alone, the drying process must be so devised that it conforms to the physical, and often chemical, characteristics of the given material.

Drying, as meaning the removal of moisture, is practical for a number of distinctly different reasons. In the case of drying seed and grain, the reasons are simply: (1) to preserve the material from physical or chemical changes induced or supported by the presence of excess moisture; (2) to bring the product to the standard commercial regain or moisture content; and (3) in some cases to remove the crop from exposure to field conditions that might damage the quality (loss in heat weight, shattering, insect infestation, etc.)

As you know, drying may be accomplished in a number of entirely different ways, as by draining, absorption, mechanical separation, or evaporation. (And in some cases by simply voting "it" out.) Evaporation, the most important and widely used method of drying, is the process with which we are concerned today. Evaporation, in the simplest aspect, is the conversion of liquid water into gaseous water-vapor.

Water, like all other matter, is conceived to be composed of a number of molecules. The molecules are in a state of rapid motion, the speed and extent of that motion depending upon the temperature of the matter - temperature of course, being merely a measure of heat energy.

Of, by any external means, we increase the heat energy of matter, we affect both the rate of vibration of its molecules and the position of its molecules with respect to each other.

By use of heat we can cause the change of the state of a liquid into a vapor. This is evaporation. The heat causes the molecules of the liquid to vibrate faster and separate further, until the cohesive force or mutual attraction is so weakened that they separate widely and become almost perfectly fluid and infinitely expandible, so that the vapor will expand and uniformly fill any space that it occupies.

At this point let us apply this information in a practical manner. We know that the heat of evaporation or amount of heat required to evaporate one pound of free water at 76° F. is 1051 BTU. As a result of studies made by Dale and Johnson of Purdue University, the following information is available:

1. The heat required for evaporation of moisture in wheat and shelled corn may be greater than the heat required for evaporation of free water, depending on the magnitude of the hygroscopic effect at lower moisture contents.
2. Over the range of moistures encountered in most actual drying systems for wheat and shelled corn, above 14% dry basis, the heat required for vaporization is between 1.00 and 1.06 times that for vaporization of free water.
3. If drying is carried to moisture contents below 14% dry basis, the heat requirement is further increased; at a moisture content of 10% dry basis, it is about 1.15 to 1.20 times that for free water.
4. For calculations dealing with the moisture-time relation in most drying systems, the variation of heat requirement with moisture content is not sufficient to preclude the assumption of a constant value for this quantity. Generally this value is set at 1100 BTU's for the evaporation of one pound of water.

Now may we take a look at vapor pressure as it is related to our drying problems. A liquid upon changing its state into a gaseous form, as we have said, expands. Gas or vapor enclosed within a container will expand, filling uniformly all available space within the container. Its tendency further to expand which we have shown to vary in intensity with its temperature sets up a definite, uniform pressure upon the walls of the container. This is vapor pressure. Whenever the vapor pressure within a given product such as grain is greater than the vapor pressure of the atmosphere surrounding it, then molecular action will be such that vapor will move from the grain. If the vapor pressures were reversed, the action or movement of vapor would also reverse or move into the product. If the vapor pressures were equal, there would be no movement of vapor in either direction. At this point, the moisture content of the product would be in a state of equilibrium with the atmospheric conditions.

Again, looking at the critical factors influencing the proper design of a seed drier, we are aware of the importance of holding the maximum drying temperature at a safe level. Considerable work has been done at several institutions to determine the effect of temperature on the quality of seed. In one study, ears of corn intended for seed use were harvested at different stages of maturity and either artificially dried at $108 \pm 1.5^{\circ}$ F. or air dried. Immaturity had definite effects upon the appearance of the seed. The kernels were small, shrunken, dull, opaque, and the pericarp often blistered. Artificial drying had no further effects upon such seed other than to cause some additional blistering of the pericarp and a rather bleached appearance.

Kernel weight, volume, and specific gravity decreased with immaturity. Artificial drying brought about no appreciable change in these physical characters.

Seedling emergence was most rapid in the mature seed. Immaturity retarded emergence while artificial drying caused slight retardation of emergence in mature seed and a greatly retarded and reduced total emergence of the immature seed.

Mature seed containing 25.2% and 35.1% moisture, and immature seed containing 44.6% moisture, artificially dried for 32 days at $108 \pm 1.5^{\circ}$ F. was reduced to 2% of moisture. The mature seed suffered no injury to the percentage germination, but seedling emergence was increasingly retarded as the drying time extended beyond four days, and the kernel moisture was reduced to below 4%. The percentage germination of the immature seed decreased as the drying period increased, and seedling emergence was greatly retarded even after two days of drying in comparison with the more mature seed.

Well matured corn, containing 22.5% and 26.0% of moisture at harvest, was dried at 110° F., 120° F., 130° F., 140° F., and 150° F., for periods up to 24 hours. The germination and seedling emergence was seriously affected at all temperatures above 120° F.

As the result of investigations, reported by Dimmock of the Canadian Department of Agriculture, the drying of seed corn by heated air under forced draft at a temperature of $108 \pm 1.5^{\circ}$ F., can be recommended as a safe procedure for corn that has reached normal maturity, containing up to 35% of moisture in the kernels at harvest. Such seed when dried on the ear to 14% or slightly lower suffers no injury to its germination, vitality, or productivity, and may be shelled and stored safely.

In tests by Wileman and Ullstrup (Purdue University), designed to determine whether some inbred lines are inherently tolerant to high drying temperatures and transmit such heat tolerance to their single and double cross combinations, demonstrated that if such differences in heat tolerances do exist in the material used, they are small and of no practical consequence within the range of air temperatures used to dry seed corn.