Moisture Extraction Concepts, Design and Practices From Soybeans[1]

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Abstract

Expanded markets for soybean products have dictated large increases in processing plant capacities. Larger and more sophisticated oil extraction plants are being put on stream by the industry. Lower moisture beans, and in larger volumes, are necessary for the production of high protein meal. Standard grain drier design criteria no longer suffice, a special Soybean Process Drier-Cooler has evolved. The resulting driers must have a large production capacity while producing bean to bean uniformity with a high degree of reliability and safety. Consideration is given to the physical and chemical characteristics of the bean, to drying concepts and to drier requirements. Rate of moisture migration, allowable air temperatures versus heat tolerance of the bean air flow requirements for moisture removal, and operational as well as safety controls are discussed. Soybean Process Drier-Coolers of today demand a new perspective of the engineer in predicting capacity requirements, in designing adequate feed and take-away equipment, and in the location in the processing plant. Fields are currently being explored to assure the processor of the bigger, better drier that will be required.

Introduction

Drying Needs

The drying of soybeans presents many problems. Some of these are bred into the beans by the plant pathologist. By breeding hybrids for better end results in meal and oil, they also create additional problems in drying. Many problems are grown in the field with the beans and harvested with them, such as trash and weeds. Most of the drying problems are created, however, by the processors in their demands for a particular quality and moisture for their processes. Initial installation at soybean facilities were utilized only to dry the beans to a safe storage level of approximately 12%. Most of the oil at that time was extracted in presses, many of which were converted from cottonseed oil mills. With the advent of more sophisticated methods of solvent extraction and the continued increased demand for high protein meal, moistures entering the processing plant ahead of the cracking rolls had to be dropped to less than 10% and preferably in the 9½% range.

As late as 1957, a Soybean Drier with a capacity of 500 bushels per hour was considered adequate for many plants. However, by 1959, most Soybean Drier sales were in the 1500 to 2000 bushels per hour range of capacity. Due to the increasing demand for the ever expanding line of soybean products, larger and more complex facilities are being designed for construction with production rates up to 2000 tons/day.

With this larger plant capacity, particular attention has to be paid to a balance between storage capacity and drying capacity to insure continuous and uniform output from the mill.

This expansion has also generated tighter competition and the demand for larger, more specialized, and better equipment for these plants. One 1200 ton/day mill requires one 2000 bushels per hour drier operating on a 24 hr basis to handle the input to this single mill.

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Design

Drying takes place when vapor pressure of the bean moisture is greater than the resisting vapor pressure of the surrounding air. The rate of drying increases as the differential of these vapor pressures becomes greater. Drying rate can be changed by increasing drying air temperature or increasing air flow or both. Both of these changes increase the differential vapor pressure as described above.

As there are only three items in a drier that control the final moisture, these are items that must be controlled. They are: temperature, air flow and time.

Early driers were limited in temperature to the same figures used in drying corn. Namely, 140 F bean temperature as an absolute maximum. In order to determine if we were limited to this same figure with soybeans, we began checking with oil chemists and other technical personnel at our customers' plants regarding the effect of bean temperature on the products produced. This investigation showed no change in quality so long as the bean temperature did not exceed 175 F. With this information, a whole new area for expanding temperature upward was made available. This high allowable bean temperature is of particular significance when drying to less than 10% moisture. With the high allowable temperature, high capacity burners with wide turndown ratios and good controls are essential.

Air flow also needed considerable investigation. In corn driers, to remove considerable quantities of moisture from very wet grain, it is necessary to circulate the maximum amount of air through this product. This air carries sufficient heat into the drier to cause the rapid evaporation and removal of large quantities of water. In the drying of soybeans for processing, we not only talk in terms of

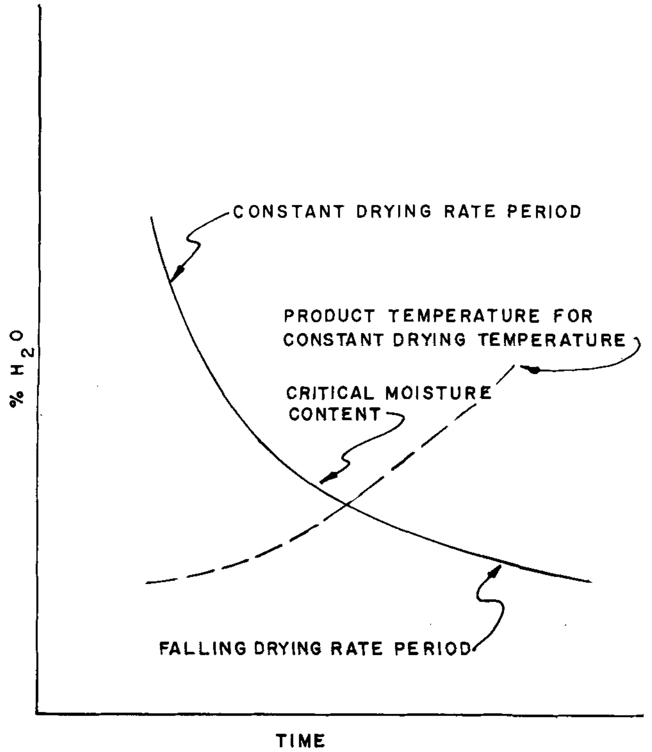

FIG. 1. Typical drying curve.

much smaller differentials of moisture, but are operating in a much lower range where the moisture removal per cent is a much smaller amount in terms of pounds of product through the drier. Here again, we open up a field allowing increased efficiency by lowering the total air flow to that necessary to heat the bean and evaporate the moisture.

Retention time, the last of the three variables is one of the most important. Very high temperature and very rapid drying of beans gives a very dry surface to the bean leaving the center still practically as wet as it was when it entered the drier. There is not enough time allowed for the migration of moisture from the center of the bean to its surface where it can be removed and, consequently, when the bean is put into storage the moisture within the bean equilibrates and generally gives a pick-up moisture in the storage of about ½%. By utilizing a long retention time, medium-high temperature drying, the moisture from the center of the bean has time to migrate toward the surface so that a uniformly dried bean results. When the bean is put into storage, it does not pick up moisture, but generally will lose an excess of ¼% moisture within the first 48 to 72 hr.

Retention time has a great effect on uniformity of the product. The lower the moisture required, the more effect time has on the uniformity of its product. The typical drying curve (Fig. 1) indicates that above the critical moisture point, water is evaporated at a nearly constant rate.

The temperature rise during this rapid rate of evaporation is very slow. Temperature is held down by the evaporation of moisture which tends to cool the product in this range. Below this critical moisture point, or the falling rate period, moisture evaporation is much more difficult and slower. The cooling tendency is greatly reduced causing the temperature of the bean to rise rapidly. Due to this falling rate of drying, slow drying with a long retention time closes the gap between variation in input moisture and a uniform output moisture (Fig. 2).

Time is important in the production of uniform bean to bean moisture, as well as uniform moisture within each bean. Slow drying gives a uniform product which when

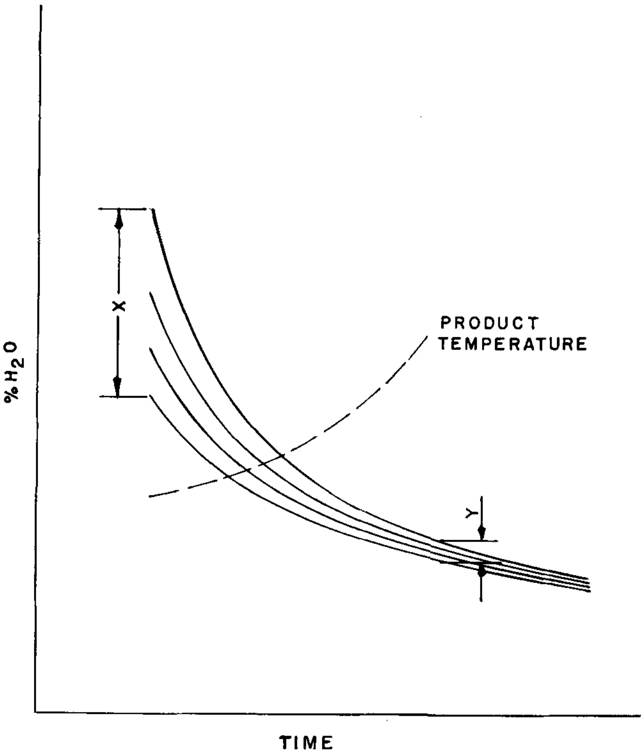

FIG. 2. Constant drying temperature. X, moisture variation into drier; Y, moisture variation out of drier; Y ≅ x/4.

fed to the processing machinery is cracked uniformly and may be handled on a uniform moisture basis through the entire process.

We have now established some definite parameters for the uniform, low moisture drying of soybeans. They are: (a) large capacity to fit in with present receiving and processing needs; (b) large capacity well-controlled burners to assure the drying temperature required; (c) fans selected to circulate the required air uniformly through the product.

Equipment

With these parameters as outlined, we have set out to meet the industry's exacting demands. We have designed and manufactured a line of Soybean Drier models with specified ratings from 1,000 to 6,000 bushels per hour. These driers are structurally designed to be free-standing and weather tight. The internal structural design causes a continuous mixing of the grain as it descends through the drier. The heated air is uniformly distributed through the grain and each bean is exposed to an equal amount of heat and air for the same period of time. The design and operation of the discharge mechanism of the grain drier tower is of great importance. It must assure a uniform flow of beans through the tower while preventing the channeling of beans in one area within the tower and the retardation of the beans in another area. The power discharge unit is readily adapted for use with our simple, but sophisticated, automatic grain moisture controller. This controller adjusts the retention time in the drier to reduce output moisture variations to a minimum while compensating for reasonable variations in soybean feed inlet moisture.

By using the latest design and large heat release burners, we are able to distribute heat from a direct-fired burner uniformly throughout the heated drying air in a manner to assure that all areas of the drier drying zone receive the same amount of heat. By uniformly heating the air, we avoid over-heating and under-heating areas and thereby increase the uniformity of the final product. Wide turn-down ratio and accurate controls of fuel flow to the modulating burners assure the most efficient operation of these burners.

A recent Soybean Drier installation just completed consisted of two 4,000 bushel per hour driers. Present plans are being made for an installation of a 12,000 bushel per hour installation. These figures indicate the growth trend of the soybean industry.

Both the drying air and the cooling air are passed through the drier by means of induced draft design. Using this principle a more uniform air flow through the drier is assured. The induced draft design permits one fan to suck both the heating and cooling air through the soybeans. This design feature also permits the unique use of adjustable drier tower sections which may be used as either drying or cooling sections as the weather may demand. This is accomplished by positioning the cooling air duct with connections to both the heating duct and the outside air. Adjustable dampers permit selection of the type of air desired by the operator. Single fan operation also gives complete control of the air from the time it enters the inlet duct until it is discharged from the fan outlet.

Air Pollution

The fan outlet discharges all of the exhaust air at or near ground level. Therefore, all of the air-borne material is discharged at one point and allows for the adaption of air cleaning devices with the least extra expense.

REFERENCES

1. Christensen, C. M., and H. H. Kaufman, "Grain Storage: The Role of Fungi in Quality Loss," University of Minnesota, Minneapolis, 1969, p. 50–64.
2. Markley, K. S., Editor, "Soybeans and Soybean Products," Vol. 1, Interscience Publishers, Inc., 1950, p. 247–273, 455–487, 503–540.
3. Rush, Raymond, Oil Mill Gazetteer *73*, 24–25 (1968).
4. Sloan, C. E., T. D. Wheelock and G. T. Taso, "Drying Systems tion, New York, 1967, p. 167–214.
5. Sorenson, J. W., Jr., and J. Rice *1967*, 12–15.
6. Kramer, H. A., J. Amer. Soc. Agr. Eng. *28*, 411–414, 417 (1947).