Effect of Drying Temperature and Fruit Moisture on Germination of Sugarbeet Seed[1]

F. W. SNYDER, RICHARD J. PATTERSON, and PAUL BERGDOLT[2]

Received for publication March 17, 1975

Occasionally, sugarbeet seed must be harvested before it is fully mature and made available for immediate use. Thus, one needs to know the approximate stage of maturity, the moisture content, and the temperature at which the seed can be rapidly and safely dried without impairing germination.

Research during the last decade has aided in clarifying the relationships between fruit moisture at harvest, seed maturity, and germination of sugarbeet seed (2, 3, 4).[3] We report the effect on germination of exposing fruits harvested at various moisture contents to different drying temperatures. Also, we suggest drying temperatures that do not affect germination adversely.

Methods and Materials

Fruits of sugarbeet (*Beta vulgaris* L.) were harvested at various stages of maturity from individual plants of cultivars grown in the field or in the greenhouse. Samples of the freshly harvested fruits were dried in a forced-air dryer at temperatures not exceeding 65.6° C. Fruits to be dried were placed as a single layer in wire-mesh baskets (6 × 6 in.). Four baskets were placed vertically a few inches apart. Air at a relative humidity of 6 to 11% and a velocity of 3.7 ft sec^{-1} was used for drying the fruits. Air temperature was measured just before the air passed around the fruits in the first basket. Calculations indicated that the relative humidity of the effluent air was not changed appreciably by the quantity of water removed from the fruits during drying. The forced-air drying temperatures were maintained for 3 hours. Since some samples did not attain air-dry equilibrium in the 3 hours while others were somewhat drier, all samples were returned to the labortory to attain air-dry equilibrium before use in germination tests. Samples of fruits from some plants also were placed directly in the labortory to equilibrate slowly with the air. We oven-dried a small portion of each sample of fruits at 100°C, to obtain dry weights for calculation of

---

[1]Cooperative investigations of the Agricultural Research Service, U.S. Department of Agriculture, and the Michigan Agricultural Experiment Station. Approved for publication as Journal Article 6674, Michigan Agricultural Experiment Station.

[2]Plant Physiologist, Agricultural Research Service, U.S. Department of Agriculture, P.O. Box 1633, East Lansing, Michigan 48823; instructor; and former Graduate Assistant, Agricultural Engineering Department, Michigan State University, East Lansing, Michigan 48824, respectively.

[3]Numbers in parentheses refer to literature cited.

moisture contents. All moisture percentages are expressed on the basis of the oven-dry weight of the fruits. The limited quantity of seeds from an individual plant precluded drying a sample at each temperature.

After fruits attained air-dried equilibrium, the corky material was removed from the fruits by hand rubbing. Seedlots were identified by plant number and drying temperature. At least 90 seeds were germinated for 7 days on blotters in a germinator at about 21° C. Germination percentages of the seeds dried at elevated temperatures were compared with those dried at the lower temperatures for indications of heat injury during drying. Corrections were made for fruits containing no seed and those containing seeds judged not to be developed enough to germinate.

Simple and partial correlations were calculated. The data also were used in two simple regression models in our attempt to confirm the relation between fruit moisture and safe drying temperatures derived by inspection of the germination data.

Results

At a given drying temperature, the degree of heat injury, as measured by germination percentage, generally was inversely related to fruit moisture (Table 1). Simple correlations (r_S) and partial correlations (r_P) were calculated. Germination percentage and fruit

Table 1.—Effect of drying sugarbeet fruits of different moisture contents at given temperatures on blotter germination.

Plant no.	Avg. fruit moisture at harvest[1] (%)	Germination (%) after 3-hour exposure to temperature						
		Air	100 37.8	130 54.4	135 57.2	140 60.0	145 62.8	150° F 65.6° C
1	20				100		100	
2	21				99		99	
3	23				98		98	
4	25		40		96			
5	26	97		95				
6	30							100
7	40	100		99				
8	45		62		97			
9	63						98	
10	140		96	98		96		3
11	160		99			98		43
12	190				73		48	11
13	220	96		96				
14	220	99	99		97			
15	225	99	96	94		51	4	1
16	230		100			99		38
17	250	87		80		62		
18	280		87	65		17	1	
19	290		92	96		78		34
20	330			43	13	7	2	

[1]Moisture percentages on basis of fruit dry weight.

moisture correlated, $r_s = -0.530^{**}$, $r_p = -0.688^{**}$. Germination percentage and drying temperature correlated, $r_s = -0.468^{**}$, $r_p = -0.655^{**}$. A linear and a quadratic regression model failed to relate fruit moisture and drying temperature to the percentage of germination, probably because the percentage decreases precipitously when the drying temperature exceeds the critical threshold.

At fruit moisture contents of 63% or less (dry-weight basis), drying temperatures up to 65.6° C did not depress blotter germination. Between 63 and 230% fruit moisture, drying temperatures of 60° C or lower caused relatively little injury. Fruits harvested with more than 230% moisture were injured at drying temperatures of 54.4° C or higher (Table 1). The data suggest a plant-by-drying-temperature interaction, that seed samples from different plants differed in sensitivity to heat injury, and that this sensitivity does not seem to be related solely to fruit-moisture content. For example, seeds of plant no. 10 (Table 1) at 140% fruit moisture and plant no. 16 at 230% moisture both germinated in excess of 95% when they were dried at 60° C. However, when they were dried at 65.6° C, 3% of the seeds of plant no. 10 and 38% of the seeds of plant no. 16 germinated.

After 3 hours under our forced-air drying condtions, fruits having an initial moisture of 230% or more and dried at 37.8° C did not dry enough for safe storage. In contrast, fruits having an initial moisture of 290% and dried at 48.9° C then had less than 20% moisture. Fruits having an initial moisture of 330% and dried at 60° C then had less than 10% moisture.

Since no temperature guidelines exist for forced-air drying of freshly harvested sugarbeet seeds, the temperatures in Figure 1 are suggested as safe limits. These temperatures are about 2.8° C lower than drying temperatures that appeared to cause no depression in blotter germination.

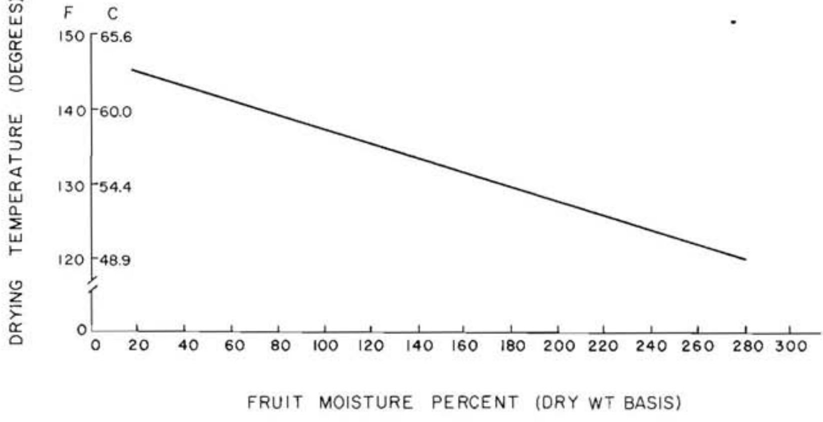

Figure 1.—Suggested safe drying temperature for freshly harvested sugarbeet seeds.

Discussion

If drying equipment similar to that used in this study were available, the approximate fruit moisture of a subsample could be determined in 3 hours. A safe drying temperature could then be selected for drying the seed sample. Without such equipment, a relatively slow drying rate would be preferable to risking injury to the seed.

Evaporative cooling during the drying process can maintain the temperature of the seed below the critical temperature that causes injury. Since 3 hours of drying at 54.4 to 60.0° C reduced fruit moisture content to less than 15%, evaporative cooling during the latter part of drying must have been minimal. Thus, we believe that the temperature of the seed closely approximated the surrounding air temperature and that the indicated drying temperature essentially fully affected later germination. The results of Harrison and Wright (1) in drying ears of seed corn suggest that evaporative cooling during the early part of the drying operation can actually minimize damage, whereas longer drying may markedly depress germination.

Certain guidelines may aid in estimating fruit moisture and sensitivity of the seed to heat when equipment and sufficient time are not available for preliminary drying. Fruits of individual sugarbeet plants harvested 40 days after first bloom ranged in moisture from 145 to 259% (on basis of dry fruit weight) (2). Seeds from these plants, after air drying and hand processing, germinated from 40 to 100% on blotters in 10 days. Since germination percentages are inversely correlated with fruit moisture (2), the germination percentage of a portion of the seeds that are dried at laboratory air temperature or at 37.8° C must be used to determine whether drying at higher temperatures is detrimental.

Seeds of plant no. 4 (25% fruit moisture at harvest) and plant no. 8 (45%) germinated 96 and 97% after 3 hours of drying at 57.2° C, but germinated only 40 and 62% after 3 hours drying at 37.8°C (Table 1). These large differences in germination cannot reasonably be attributed to chance, since the seeds were harvested and tested on an individual-plant basis. In earlier studies, seedlots subjected to moderately elevated temperatures for a period of time also had considerably higher germination than subsamples exposed to temperatures between 0 and 40° C. In contrast, seeds of plant no. 5 with 26% and of plant no. 7 with 40% moisture at harvest did not respond to moderately high drying temperature, but they had equally high germination at air temperature and at 57.2° C (Table 1). We do not know what mechanism stimulates germination of certain freshly harvested seeds after exposure to moderately elevated temperatures for a period of time.

In this study, drying-temperature injury was detected solely by blotter-germination data. In a recent study, the performance of seedlots harvested over a range of maturities was compared by blotter germination and by emergence through 1.5 in. of fine, moist sand (3). These data clearly showed that the blotter-germination test was less able to detect the adverse effects (e.g., lack of vigor) of seed immaturity than the sand-emergence test. Thus, had the sand-emergence test been available for this drying-temperature study, somewhat different injury levels might have been revealed.

Summary

Sugarbeet fruits were harvested over a range of fruit moisture contents and then dried at different temperatures in air of 6 to 11% relative humidity and a velocity of 3.7 ft sec^{-1}. Blotter germination was used to detect injury to the seed.

Seed samples from different plants differed in their sensitivity to heat injury. The sensitivity was not consistently related to the fruit moisture, but heat injury at a given temperature was inversely related to fruit moisture. A safe drying temperature has been suggested for a range of fruit moistures at harvest.

Acknowledgment

We appreciate the aid of Charles Cress, Crop and Soil Sciences Department, Michigan State University, for the statistical analyses and interpretation.

Literature Cited

(1) HARRISON, C. M. and A. H. WRIGHT. 1929. Seed corn drying experiments. J. Am. Soc. Agron. 21: 994-1000.

(2) SNYDER, F. W. 1971. Relation of sugarbeet germination to maturity and fruit moisture at harvest. J. Am. Sugar Beet Technol. 16: 541-551.

(3) SNYDER, F. W. 1974. Maturity effects on fruit characteristics, germination, and emergence of sugarbeet. J. Am. Soc. Sugar Beet Technol. 18: 87-95.

(4) TEKRONY, D. M. 1969. Seed development and germination of monogerm sugar beets (*Beta vulgaris* L.) as affected by maturity. Ph.D. Thesis, Oregon State University. 120 p.