Low-Energy Drying of Pine Cones

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A prototype microwave unit dries pine cones effectively, using only 10 to 33 percent as much energy as a conventional dryer. The results suggest further research to determine if practical use of the technique can cut the high cost of drying cones.

Drying pine cones to obtain the seed they hold is a very expensive operation. Unpublished nursery data on energy consumption indicate that between 90,000 and 200,000 British thermal units (Btu) per bushel of pine cones are required. The actual amount depends on the species and the age of the kiln.

A recent spinoff from space technology allows for drying agricultural products at lower temperatures with far less energy than conventional agricultural drying-systems (*2*). A new microwave vacuum system called MIVAC was developed by McDonnell Douglas Corporation in St. Louis, Mo.; and a small-scale facility was built at Tifton, Ga., (*2*) to experiment with low-energy drying of agricultural crops. In fall 1979, preliminary trials were undertaken to evaluate the effect of MIVAC drying on loblolly pine cones and seeds.

Method and Materials

In October 1979, the Arkansas Forestry Commission provided a bushel of loblolly pine cones from their seed orchard. The cones were mature, but still green. The base of each cone was trimmed to expose fresh, woody cells. The trimmed cones were then placed upright in plastic containers holding 1 to 2 inches of water to minimize further drying of the cones. They were kept this way for 1 week while being transported to St. Louis. The cones had begun to develop a little reddish-brown color by the time they arrived in St. Louis.

The cones were randomly divided into three piles. The first batch served as the control. These were placed in a cabinet with circulating, dry air at 80 °F. The second batch was used for preliminary microwave trials, and the third batch served as the evaluated treatment for optimum microwave drying. Each batch consisted of about 47 cones.

A mixed lot of loblolly pine seed was taken from storage at the National Tree Seed Laboratory and adjusted to 15-percent moisture content. The seed lot was then sealed in a polyethylene bag and transported to St. Louis with the cones. Upon arrival at St. Louis, the bag of seed was opened and divided in half. One-half was placed in the circulating dry-air cabinet with the cones, while the other portion was subjected to microwave treatment.

Treatments were conducted in a sealed chamber, which looked much like an autoclave. The cones or seeds were placed on a revolving.plastic tray. A vacuum of 1 atmosphere was drawn in the chamber, and then the microwave treatment was set. Treatment control was by input microwave power and exposure time. The treatments, applied at 43 °C, are shown in table 1.

Following treatment, both the seeds and cones were sealed in polyethylene bags and transported to the National Tree Seed Laboratory for evaluation. Seeds were shaken from both the microwave-treated cones and the control cones. They were dewinged and a random selection of 4 x 100 seed was prepared for germination tests on crepe cellulose paper in plastic boxes at 22 °C exposed to 16 hours light. A second set was stratified for 30 days before testing to overcome any seed dormancy. The remaining seeds were sealed in polythelene bags and stored 6 months at 2 °C. Following storage they were tested as described above.

Although microwave radiation is nonionizing, it was not known whether the molecular excitation would alter the DNA content, so an evaluation was included. Ten root tip samples were collected at germination from each treatment. They were fixed in Farmer's fluid (*1*) for 2 days and then passed through an increasing alcohol series in 2 days. The root tips were sent to North Carolina State University for evaluation of DNA changes.[1]

Results and Discussion

The cones had a moisture content above 70 percent when drying began. The preliminary trials (first drying) were rather lengthy and at low microwave levels (table 1). Following these trials, a treatment (second drying) was designed that would minimize time. The seed samples were dried with a low-level treatment based on the knowledge derived from the cone drying.

Table 1.—*Summary of microwave treatments on loblolly pine cones and preconditioned seeds*

Treatment	Watts	Minutes	Total exposure	Energy	Moisture content
			Megahertz	British thermal units	Percent
Cones:					
Control	—[1]		—	—	72
First drying	200	60	575	1,681	15 (not completely open)
	500	45			
Second drying	1,000	30	875	2,559	10
	500	45			
Seeds:					
Control	—	—	—	—	15
Drying	100	15	46	134	10
	50	25			

[1] — = not applicable.

Following treatment, germination of unstratified seed decreased with increasing radiation exposure; however, these effects were overcome by stratification. The microwave treatment apparently created a secondary dormancy. The higher the microwave treatment, the faster the water was removed from the seed. Microwave operates in seed drying by exciting the water molecules to the boiling state. In this state, water is removed by vaporization. When the vaporization takes place at the surface faster than internal vapors can reach the surface a differential or vapor lock is created. This vapor lock inhibits the germination of the embryo until it is removed. This condition was not removed during 6 months of storage, but was removed by stratification. It did not seem to be detrimental to seed viability as evidenced by the stratified results after storage. It may even be beneficial to seed storage. Placing the seed in a nongerminating condition may delay deterioriation due to aging. An analysis of all of the data showed no significant effects on total germination (table 2), nor on the rate of germination with these microwave treatments.

Evaluation of the root tips showed no differences in the relative DNA value due to microwave treatment (table 3). It may be concluded that microwave radiation will not be detrimental in short-term storage of germ plasm.

Loblolly pine seeds reach maturity when cone moisture contents are about 140 percent. The moisture content decreases to about 70 percent at cone maturity with a specific gravity of 0.88. At collection time, cones are usually air dried for a week and then dried by forced hot air

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[1] The author wishes to express appreciation to Dr. J. P. Miksche for this evaluation.

Table 2.—*Summary of germination*

	Immediate germination		Germination after storage	
Treatment	Unstratified	Stratified	Unstratified	Stratified
Cones:	— — — — — — — *Percent* — — — — — — —			
Control	96a[1]	88ab	88ab	95a
First drying	85ab	91ab	81b	98a
Second drying	66c	94a	70c	90ab
Seeds:				
Control	80a	68a	75a	73a
Drying	76a	83a	69a	76a

[1] All figures in a treatment followed by the same letter are not significantly different at the 1-percent level of probability.

Table 3.—*Relative DNA value determined from root tips of germinating seedlings*[1]

Treatment	DNA Value (± 1 standard deviation)
Cones:	
Control	409.39 ± 148.21
Second drying	392.52 ± 148.14
Seeds:	
Control	386.23 ± 145.36
Drying	351.59 ± 118.41

[1] Date provided by Dr. J. P. Miksche, Head, Botany Department, North Carolina State University.

for about 48 hours to open the cones. This treatment consumes 100,000 Btu or more of energy per bushel of cones or about 6,500 Btu per pound of water removed.

The microwave dryer treatments required about 1,280 Btu to evaporate a pound of water. At an average weight of 35 pounds per bushel, green cones at a specific gravity of about 0.90 could be opened in 75 to 125 minutes by a microwave dryer using about 26,800 Btu. This microwave treatment reduced the moisture content of the cones from 70 percent to 10 percent. If the cones are air dried for a week, the moisture could be reduced to 30 percent or less. After 1 week of air drying, the cones could be opened in less than 1 hour by a microwave dryer using about 8,900 Btu. This would be a tenfold reduction in energy needs.

One caution: no comparison of equipment cost is available. The MIVAC technique is so new that a commercial kiln has not yet been built. It is likely that further study in this area will be forthcoming.

Literature Cited

1. Sass, J.E. Botanical Microtechnique. Ames, IA: The Iowa State University Press; 1964. 228 p.
2. Singer, Dale. Microwave being tested to dry crops. The Mail Tribune. Medford, OR: 29 November 1978.