Preliminary Biological Evaluation of the Effect of Microwave Heating on High-Moisture Shelled Corn[1]

G. W. NOFSINGER, J. E. VAN CAUWENBERGE, R. A. ANDERSON, and R. J. BOTHAST, Northern Regional Research Center, Agricultural Research, Science and Education Administration, U.S. Department of Agriculture,[2] Peoria, IL 61604

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ABSTRACT

Total mold counts on ambient-dried shelled corn remoistened to 23.6% moisture content were not affected by microwave heating temperatures of 42 and 51°C but were significantly reduced by microwave heating at 62°C. Total mold counts on freshly harvested shelled corn, although not affected by microwave heating temperatures of 55°C and lower, were significantly reduced by microwave heating at 57°C. In three lots of freshly harvested corn kernels (24.0-26.8% initial moisture content), internal molds were reduced from 100 to less than 20% by microwave heating at temperatures of 54-55°C. Germinability of these same lots of corn was significantly reduced at temperatures above 55°C and approached zero at 70°C.

The drying characteristics (including rates of drying, physical appearance of kernels, and energy consumption) of shelled corn dried by microwave energy have been reported (Boulanger et al 1969, Fanslow and Saul 1971, Hall 1963). The microwave dielectric properties of shelled field corn were also reported (Nelson 1978). A pilot scale microwave-vacuum grain drying system has been developed and is currently being evaluated (Brown 1978).

The objective of our study was to determine the effect of microwave energy on the microbial population and activity and on germinability of high-moisture shelled corn as a function of initial moisture content and temperature of the heated grain mass.

MATERIALS AND METHODS

The microwave oven used in these tests is a Despatch Model SMC-1-33H®, with a 1.8 kW (240 v) heating capacity and an operating frequency of 2.45 GHz. The oven cavity has a rotating reflective device at the waveguide inlet and a revolving turntable on which the grain containers were placed as the grain was being heated.

Although this microwave oven can operate as a conventional air-heated oven, neither forced airflow nor auxillary heat was used; the corn was exposed to microwave energy exclusively. We did not measure the amount of drying that occurred during microwave heating but rather the condensation formed on the turntable beneath the sample containers at all test temperatures.

For each test, 150 g of corn was weighed into each of four paper containers 9.5 cm in diameter to a depth of about 2.5 cm. The four containers were spaced equidistantly on the turntable, and the grain was exposed to microwave energy for a specified time. After being heated, the grain samples (600 g total) were immediately combined and placed into a Dewar flask 6.8 cm in diameter and 30 cm deep, filling the flask. The temperature of the grain mass was determined by inserting a metal-stem thermometer through the cork stopper of the Dewar flask and allowing 2-3 min for the thermometer to equilibrate.

The first set of samples exposed to microwave energy from each lot was used to preheat the Dewar flask and then discarded. Each series of tests for each lot of corn was conducted in order of ascending temperatures.

The heated grain was then spread on plastic trays to cool before microbiological determinations were made. The trays were wiped with a Lysol solution to minimize any recontamination of the grain. The procedures outlined by Bothast et al (1974) were followed to determine: 1) total aerobic bacteria counts and mold counts on finely ground samples, and 2) internal molds (ie, molds growing from surface-sterilized kernels) and germinability in whole kernels.

For the high-moisture respiration/deterioration study, shelled corn that had been dried with ambient air to 16% moisture content was remoistened to 30.5% moisture content in two stages over 8 hr and held overnight before microwave treatment. Samples were then heated in the microwave oven set at 51, 56, 58, and 62°C, following the procedures outlined earlier. From each 600-g sample, 300 g was weighed into a 1-L Erlenmeyer flask fitted with an aeration apparatus (Fig. 1). The aeration apparatus for each flask was connected to an air manifold through 500-ml water-filled gas scrubbing bottles, which supplied humidified air through the corn at a constant rate of 10 cc/min—equivalent to 0.03 m^3/(min/tonne) aeration rate. The test was conducted at 28°C. The production of CO_2 was monitored by determining the volume percent of CO_2 in the headspace of each flask daily for five days by gas chromatography (Ramstack et al 1979).

RESULTS

Preliminary tests were conducted to measure the temperature of grain heated by microwave energy as a function of exposure time and power input. Ambient-dried shelled corn, remoistened to

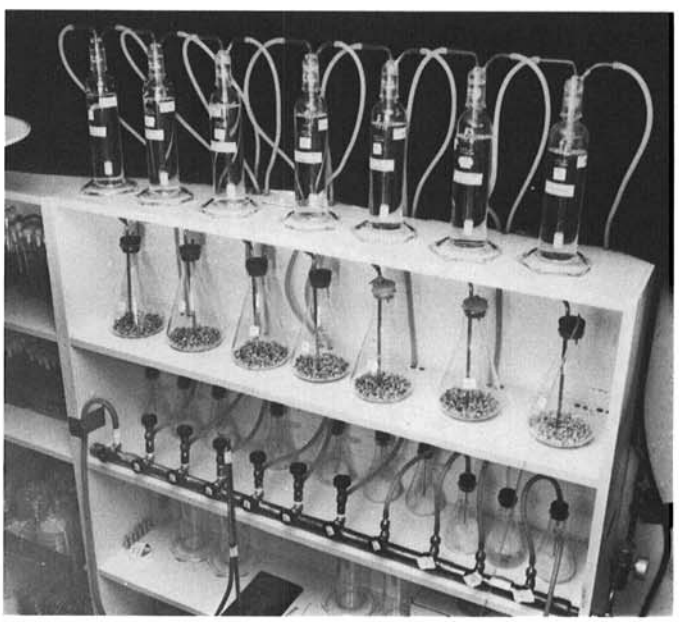

Fig. 1. Laboratory aeration-humidification apparatus.

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[2] Mention of firm names or trade products does not imply endorsement or recommendation by the USDA over other firms or similar products not mentioned.

23.6% moisture content and held overnight, was used for these initial tests. The corn did not heat evenly or consistently at maximum oven amperage—0.66 A (power input). Temperatures were irregular and could not be readily reproduced, and hot spots from nonuniform heating were observed. However, when the power input was reduced to 0.22 A, heating was more uniform and temperatures could be reasonably duplicated. The power setting of 0.22 A was subsequently used for all of the reported tests.

Total mold and aerobic bacteria counts were made on remoistened corn exposed to three temperatures ranging from 42 to 62°C (Table I). At 42 and 51°C, mold counts were not significantly affected. Mold counts in remoistened corn heated to 62°C by microwave energy were significantly reduced, however, from 1.1×10^6/g to 8.9×10^2/g. Aerobic bacteria were not significantly affected at these temperatures (Table I).

The effect of microwave heating on internal molds of three lots of freshly harvested high-moisture shelled corn is summarized in Table II. The freshly harvested corn was stored in plastic-lined bags at 1°C until 12 hr before the tests, at which time they were allowed to reach the ambient temperature of the laboratory. The tests were conducted within 30 days after the corn was harvested.

Internal molds were reduced from 100% to less than 20% at temperatures of 54–55°C in all three lots of freshly harvested corn. Total mold counts in lot 2 (Fig. 2) were significantly reduced from 8.6×10^5/g in the control sample to 1.4×10^2/g at 57°C. Major molds identified in these tests were, in order of predominance, species of *Fusarium, Penicillium,* and *Cephalosporium.* These data agree with Bothast's review (1978), in which he stated that the metabolic and respiratory activity of certain molds ends at about 50–55°C.

In contrast, bacterial counts in lot 2 were not appreciably affected until temperatures in excess of 60°C were reached. At 65°C, bacteria were reduced from 6.2×10^5/g to 8.7×10^3/g.

Within the narrow range studied, the initial moisture content of the corn appeared to have little effect on the extent of reduction of internal molds (Table II). These data indicate that temperature is the critical variable in reducing internal molds.

The effect of microwave heating on the germinability of the three lots of corn is shown in Fig. 3. Germinability of all three lots of corn was substantially reduced at temperatures of about 55°C and higher. At 70°C, germinability was zero in lot 3.

One index of grain deterioration is the respiration of the grain and its microbial population as measured by carbon dioxide

TABLE I
Effect of Microwave Heating on Mold and Bacteria Counts on Ambient-Dried Shelled Corn Remoistened[a] for Laboratory Tests

Microwave Heating Time (min)	Heated Corn Temperature (°C)	Mean Counts per Gram[b]	
		Molds	Aerobic Bacteria
Control	16	1.1×10^6	1.1×10^6
1¼	42	1.0×10^6	1.2×10^6
2	51	1.3×10^5	1.0×10^5
3	62	8.9×10^2	6.2×10^5

[a]Corn dried with ambient air to 16.0% and subsequently remoistened to 23.6% for laboratory studies.
[b]Samples finely ground before microbiological tests.

TABLE II
Effect of Microwave Heating on Internal Molds of Freshly Harvested Shelled Corn

Lot Number	Lot Identity	Moisture Content (% wb)	Microwave Heating Time (min)	Heated Corn Temperature (°C)	Internal Molds,[a]%
1	Dekalb 64	24.0	Control	18	100
			2	48	38
			2¼	54	18
			2½	58	14
			2¾	62	4
			3¼	67	0
2	Dekalb 43	25.0	Control	18	100
			2	48	70
			2¼	51	36
			2½	55	12
			2¾	57	2
			3	61	12
			3¼	65	0
3	Pioneer 3535	26.8	Control	12	100
			2½	51	50
			3	55	6
			3½	61	0
			4	66	0
			4½	72	0

[a]Surface-sterilized kernels from which mold grew.

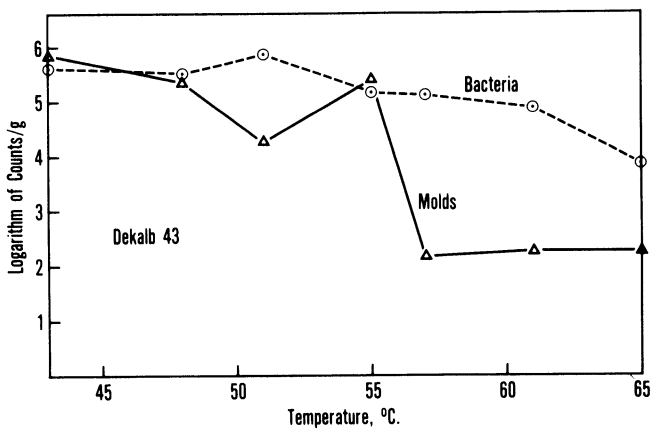

Fig. 2. Effect of microwave heating on mold and aerobic bacteria counts of freshly harvested shelled corn. Initial moisture content, 25.0%.

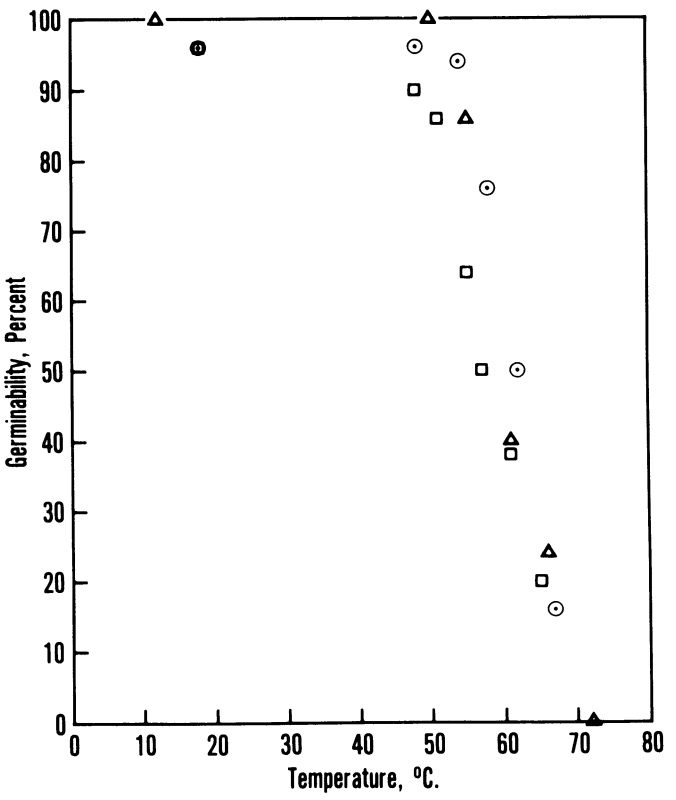

Fig. 3. Effect of microwave heating on germinability of freshly harvested shelled corn. Initial moisture content: lot 1 (⊙), 24.0%; lot 2 (□), 25.0%; lot 3 (△), 26.8%.

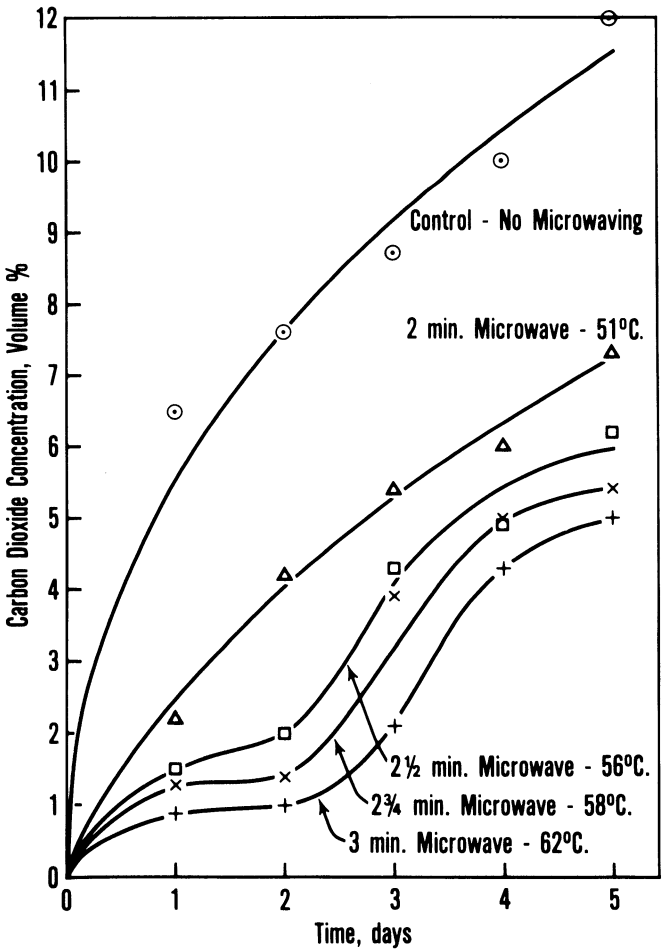

Fig. 4. Effect of microwave heating on remoistened shelled corn (30.5% moisture content) at 28°C in a high-humidity air-fed atmosphere.

production and attendant dry matter loss (Steele et al 1969). We wanted to determine whether microwave heating would slow these respiratory processes in corn at a moisture content above 30% and at varying heating temperatures. The results of this study are shown in Fig. 4. The concentration of CO_2 in the control flask increased to 12 volume percent at the end of five days compared with 5 volume percent in the flask containing corn heated to 62°C in the microwave oven. For room air, our gas chromatography unit under usual operating conditions measured CO_2 concentration at 0.04 volume percent. The data indicate a sigmoidal rate of CO_2 production in flasks containing corn microwave-heated to 56°C or above. At temperatures of 56–62°C, initial CO_2 production increased at a much lower rate than did that of the control, leveled off between the first and second days, then rose, leveling off again at amounts 50% or less than the control.

DISCUSSION

Foster and Peart (1976) suggested that as the demand for grain as food increases, sanitation and quality standards may be raised. Better control of the microbial population in grain utilized in foodstuffs will be increasingly needed. They predicted a need for dryers designed to be self-cleaning and easily sanitized.

Our studies suggest that significant reduction of fungal counts of freshly harvested corn (24–27% moisture content) can be effected at microwave processing temperatures of 55°C and higher. However, at temperatures above 55°C, the germinability is appreciably reduced. Our findings indicate that if internal molds in freshly harvested shelled corn (24–27% moisture content) are reduced to less than 20% of initial count at a microwave heating temperature of 55°C, germinability may range from 64 to 86%. In tests with a small pilot microwave-vacuum unit, corn has been dried at temperatures of 38–43°C with no change in seed germination (Brown 1978).

High temperatures (95–110°C) generated in grain dried with microwave energy can cause the kernels to split and discolor (Hall 1963). Kernels were sound and not discolored in our tests with microwave exposure times ranging up to 4½ min and temperatures up to 72°C.

One potential application of microwave energy in drying corn is its use with ambient temperature grain drying systems. As economics warrant its consideration, we envision conditioning high-moisture corn with microwave energy to initially reduce the fungal population. The corn would then be loaded into a grain bin equipped with a fan for drying with a low air flow unsupplemented by heat, according to a procedure of the Illinois Farm Electrification Council (Anonymous 1978). This procedure might effectively utilize the internal heat generated by microwave treatment to speed the drying rate in the bin. A significant reduction in the fungal population of the corn may lengthen the period of time available for drying to a safe moisture content.

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